SESAR 2020 PJ.14-W2-77 TRL6 Overall Concept of Operation FCI Services

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Authoring & Approval

Authors of the document

Beneficiary	Date
EUROCONTROL	30/09/2022
Frequentis	30/09/2022
ENAIRE	30/09/2022
TAS-I	30/09/2022
Indra	30/09/2022

Reviewers internal to the project

Beneficiary	Date
Frequentis	30/09/2022
Indra	30/09/2022
Leonardo	30/09/2022
Honeywell	30/09/2022
Airbus	30/09/2022
Airtel ATN	30/09/2022
EUROCONTROL	30/09/2022
ENAIRE	30/09/2022
Inmarsat	30/09/2022

Reviewers external to the project

Beneficiary	Date

Approved for submission to the S3JU By – Representatives of all beneficiaries involved in the project

Beneficiary	Date
Frequentis	30/09/2022
Indra	30/09/2022
Leonardo	30/09/2022
Honeywell	30/09/2022
Airbus	30/09/2022

Airtel ATN	30/09/2022
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ENAIRE	30/09/2022
Inmrsat	30/09/2022

Rejected By – Representatives of beneficiaries involved in the project

Beneficiary	Date

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Copyright Statement

PJ.14-W2 I-CNSS

INTEGRATED COMMUNICATION, NAVIGATION AND SURVEILLANCE SYSTEM

This Concept of Operations is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 874478 under European Union's Horizon 2020 research and innovation programme.

Abstract

This Concept of Operations document describes how to the Future Communications Infrastructure should be used to support the future communication services for safety and regularity of flight as from the 2028 – 2035 time horizon within the Single European Airspace System. This document is intended to become the reference material describing the end state of how the Future Communications Infrastructure operates in the long term, including the operational environment, supported services, target levels of performance, safety and security, and operational requirements.

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1 Introduction[1]

1.1 Purpose of the document

This Concept of Operations (ConOps) document describes how to the Future Communications Infrastructure (FCI) should be used to support the future communication services for safety and regularity of flight as from the 2028 (Initial Operating Capability) – 2035 (Final Operating Capability) time horizon within the Single European Airspace System. This document is intended to become the reference material describing the end state of how the FCI operates in the long term. For transition aspects, reader should refer to the material generated in Task 2 "D5.1.800 - PJ.14-W2-77 TRL6 Deployment and Transition Strategy FCI Services"[2].

The objectives of this ConOps are to:

- Describe the users and entities operating the FCI, their roles and responsibilities.
- Describe the new operating method and the difference with the previous situation (reference scenario), defined as operational use cases. This new operational environment is provided as input to PJ.14-W2-77 Task 2 to define the transition roadmap between the reference and the new operating method, and also to PJ.14-W2-76 CNS roadmap.
- Outline assumptions applicable to the operating environment, communication services, traffic load, and safety/performance targets.
- Identify the operational procedures and capabilities defining operational requirements which drive the FCI technical specification (PJ.14-W2-77 Task 3) and safety/performance targets. These requirements will be used to confirm the operational feasibility of the SESAR Solution in the TRL6 validation (PJ.14-W2-77 Task 4).

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[2] The deliverable D5.1.800 is not yet available and will be submitted by March 2022

Figure 1 depicts the Task 1 results that are provided as input to other tasks within PJ.14-W2-77.

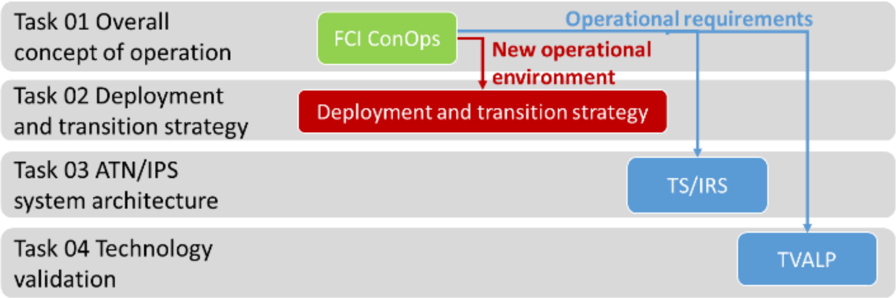


Figure 1 Scope of FCI ConOps within PJ.14-W2-77

1.2 Intended readership

The intended audience for this document is SESAR Joint Undertaking, other PJ.14-W2-77 team members and related Solutions: PJ.14-W2-60, PJ.14-W2-61, PJ.14-W2-107, PJ.01-W2-08, PJ.02-W2-21, PJ.18-W2-56, PJ.18-W2-57, PJ.10-W2-73.

External to the SESAR project, other stakeholders are to be found among:

- Standardization Bodies (EUROCAE ED 108);
- Air Navigation Service Providers (ANSP);
- AOC service providers;
- Airport owners/providers;
- Airspace users;
- Industry.

1.3 Structure of the document

The ConOps is composed of different parts:

- Section 1 introduces the FCI concept, logical architecture and topology.
- Section 2 describes the operational environment, definition of FCI actors, roles and responsibilities, and operational scenarios.
- Section 3 defines the ATM services supported by the FCI.
- Section 4 defines the target levels of performance, safety and security for the ATM services supported by the FCI.
- Section 5 defines the FCI network services provided to support ATM/ services.

1.4 Glossary of terms

Term	Definition	Source
4D Trajectory	The 4D trajectory is: • the lateral path consisting of route waypoints, and • the vertical path consisting of the predicted altitude and vertical constraints, if any, at each of the waypoints forming the lateral path, and • the predicted speed and speed constraints, if any, at each of the waypoints forming the lateral path, and • the predicted time and time constraints, if any, at each of the waypoints forming the lateral path. NOTE: The aircraft 4D trajectory includes any FMS computed and/or flight crew inserted waypoints.	ICAO WG-I
ACARS	A digital datalink network providing connectivity between aircraft and ground end systems (command and control, air traffic control).	ICAO WG-I
Access network	A network that is characterized by a specific access technology	ICAO WG-I
Airborne IPS system	The collection of airborne components and functions that provide ATN/IPS services	ICAO WG-I
Application	The ultimate use of an information system, as distinguished from the system itself	ICAO WG-I
Aeronautical Telecommunication Network	A global internetwork architecture that allows ground, air-ground and avionic data subnetworks to exchange digital data for the safety of air navigation and for the regular, efficient and economic operation of air traffic services.	ICAO WG-I
Aeronautical Telecommunication Network / Internet Protocol Suite	The set of technical provisions and standards that define the architecture and operation of Internet Protocol-based networking services on the Aeronautical Telecommunication Network. Note: It is also referred as IPS in the documents	ICAO WG-I
Availability	The probability that an operational communication transaction can be initiated when needed.	ICAO WG-I
Communication, Navigation,	System based on digital technologies, satellite systems, and enhanced automation to achieve a seamless global Air Traffic Management.	ICAO WG-I

Term	Definition	Source
Surveillance / Air Traffic Management		
Continuity	The probability that a transaction completes within the expiration time.	ICAO WG-I
FANS 1/A	Implementation of Air Traffic Service applications using ARINC 622 data communication.	ICAO WG-I
Ground IPS System	The collection of ground components and functions that provide ATN/IPS services.	ICAO WG-I
Handover	Process where an aircraft is moving across heterogeneous access networks, and is able to switch between the different air/ground datalinks and access the access networks with minimum impact for transactions in transit (e.g. delayed or even loss of transaction).	ICAO WG-I
IPS Host	Originator or terminator of IP packets in the IPS System. The IPS Host ignores IP packets that are not addressed to it. IPS Host is a node that is not an IPS Router.	ICAO WG-I
IPS Node	A device that implements IPv6. There are two types: IPS Host and IPS Router. Note: IPS Gateway could be considered as an IPS Node.	ICAO WG-I
IPS Router	A node that forwards IP packets not explicitly addressed to itself. A router manages the relaying and routing of data while in transit from an originating IPS Host to a destination IPS Host.	ICAO WG-I
IPS System	The all-encompassing Aviation Internet that provides data transport, networking, routing, addressing, naming, mobility, multilink and information security functions to the aviation services. The IPS System includes the Layer 3 and Layer 4 functions of the ISO/IEC 7498-1 OSI 7-layer Reference Model. The IPS System does not include the underlying subnetwork functions that provide connectivity or the Applications.	ICAO WG-I
Mobile subnetwork	A subnetwork connecting a mobile system with another system not resident in the same mobile platform. These subnetworks tend to use free-radiating media rather than contained media (e.g. wire or coaxial cable); thus they exhibit broadcast capabilities in the truest sense.	ICAO WG-I
Mobility	The ability of an IPS Node to move between or make concurrent use of two or more networks without changing its global IP address (macro-mobility) or local IP address (micro-mobility).	ICAO WG-I

Term	Definition	Source
Multilink	Ability to use all available air/ground access networks in order to provide the specified performance	ICAO WG-I
Subnetwork	An actual implementation of a data network that employs a homogeneous protocol and addressing plan and is under control of a single authority.	ICAO WG-I

1.5 List of acronyms

Term	Definition
4D	Four Dimensional
A/C	Aircraft
ACARS	Aircraft Communications Addressing and Reporting System
AD	Air Defence
ADS-C	Automatic Dependent Surveillance – Contract
AeroMACS	Aeronautical Mobile Airport Communication System
ADSP	ATM Data Service Provider
AIS	Aeronautical Information Services
AMHS	Aeronautical Message Handling System
AMQP	Advanced Messaging Queuing Protocol
AMSRS	Aeronautical Mobile Satellite (Route) Service
ANSP	Air Navigation Service Provider
AOC	Airlines Operational Communications
APT	Airport
ASE	Application Service Element
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network

ATNPKT	Aeronautical Telecommunication Network Packet
ATN/IPS	Aeronautical Telecommunication Network (based on) Internet Protocol Suite
ATS	Air Traffic Service
ATSP	Air Traffic Services Provider
ATSU	Air Traffic Service Unit
AU	Airspace Users
CM	Context Management
ConOps	Concept of Operations
CoS	Class of Service
CPDLC	Controller – Pilot Data Link Communications
CSP	Communications Service Provider
DMM	Distributed Mobility Management
DNS	Domain Name Service
DS	Dialogue Service
DSCP	Differentiated Service Code Point
EATMA	European ATM Architecture
E-ATMS	European Air Traffic Management System
ENR	En-Route
EPP	Extended Projected Profile
FANS	Future Air Navigation System
FCI	Future Communications Infrastructure
FIS	Flight Information Service
FMS	Flight Management System
FOC	Flight Operations Center
GANP	Global Air Navigation Plan

HF	High Frequency
HMI	Human Machine Interface
HO	Handover
HTTPS	HyperText Transfer Protocol Secure
ICAO	International Civil Aviation Organization
IEG	Information Exchange Gateway
IER	Information Exchange Requirement
IP	Internet Protocol
IPS	Internet Protocol Suite
IPSEC	Internet Protocol Security
LDACS	L-Band Digital Aeronautical Communication System
LLA	Link Local Address
MET	Meteorological
METAR	Meteorological Aerodrome Report
MIL	Military
MMF	Multilink Management Function
MNP	Mobile Network Prefix
NAT	North ATlantic
OSI	Open Systems Interconnection
PBCS	Performance Based Communications and Surveillance
PKI	Public Key Infrastructure
QoS	Quality of Service
RAT	Radio Access Technology
RBT	Reference Business Trajectory
RCP	Required Communication Performance
RPAS	Remotely Piloted Aircraft Systems

SATCOM	Satellite Communications
SBT	Shared Business Trajectory
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SNMP	Simple Network Management Protocol
SWIM	System Wide Information Management
TBO	Trajectory Based Operations
TCP	Transmission Control Protocol
TMA	Terminal Manoeuvring Area
TRL	Technology Readiness Level
UDP	User Datagram Protocol
VDL(M)2	VHF Data Link Mode 2
VoIP	Voice over IP
WOC	Wing Operations Centre

1.6 Background

ICAO has designed a Global Air Navigation Plan (GANP) and the Global Air Traffic Management (ATM) Concept that should achieve the performance levels required by society and airspace users. For communication performance, this is reflected in the Performance-Based Communication and Surveillance (PBCS) framework.

Different regional or national ATM modernisation Programmes are concretizing the global ATM concept. In Europe, this is outlined in the European ATM Master Plan, Edition 2020 and the SESAR Concept of Operations – Edition 2019. Together, these describe the future SESAR vision for the Single European Sky performance objectives in line with the global plan, and the essential operational and technological changes necessary to achieve that vision.

In the SESAR Concept of Operations, the sharing of 4D business/mission trajectories by means of CPDLC and ADS-C applications is the cornerstone for trajectory-based operations on the aerodrome surface, within en-route and TMA airspace. Sharing of relevant ATM data (aeronautical, flight and weather) provides a consistent view of the flight across multiple air and ground stakeholders, and supports route planning and in-flight operations (e.g. Continuous Descent Arrival). The exchange of AOC data between the flight crew and the airline Operational Control Centre also plays an important role during the execution of the flight.

In order to achieve full 4D Trajectory-Based Operations (TBO), the need for higher data link communication capacity and performance is identified. Current systems providing aeronautical communications are capacity-limited, rely on a myriad of non-interoperable technologies, and lack integration. This leads to an inefficient usage of resources including radio spectrum. To overcome this, the ATM Master Plan envisions the deployment of the next generation of aeronautical communication infrastructure to be service-oriented and performance-based, in order to support rationalisation, reliability and efficiency of the communication capabilities.

The Future Communications Infrastructure (FCI) is a new Internet Protocol Suite (IPS) System providing the digital and secure communication capabilities supporting integrated Communication, Navigation and Surveillance (CNS). It provides the network functionality necessary to interconnect air and ground end-systems via multiple IP broadband air/ground datalink (multilink) subnetworks and core networks (NewPENS) to support aeronautical data and voice applications for safety and regularity of flight operations. The FCI is based on communication standards including Aeronautical Telecommunications Network over IPS (ATN/IPS) and System-Wide Information Management (SWIM) to define the interoperability features needed for data exchange and network management functionality. The FCI is also expected to interface with external networks for legacy ATN/OSI system accommodation, civil-military coordination and information exchanges with commercial IP networks.

An initial study of the FCI Concept of Operations was performed in SESAR1/P15.2.4. Under SESAR2020 Wave 1/PJ.14 EECNS (Enhanced and Efficient CNS), Solution 14.2.4 advanced research and development of the FCI concept to TRL4. This activity defined the operational and technical use of the FCI, as described in the following deliverables:

- D5.1.020.1 FCI Initial Concept Description [1]. This document defines the communication services supported by FCI, transition roadmap, multilink operational concept, OSI/IPS interoperability aspects, operational requirements and open issues.
- D5.2.010 FCI Functional Requirements Document [2]. This document details the functions of the system architecture regarding IP mobility, multilink strategies, interface between the FCI constituents, and security.
- D5.3.060 Transversal and Complementary Studies [3]. This document outlines FCI performance requirements for the short and long term, and results of the safety and security analysis.

In SESAR2020 Wave 2, PJ.14-W2-77 Task 1 has the objective to update the initial concept description with the results of Wave 1 and the new requirements of Wave 2 including:

- Updates of the SESAR operational environment reflected in the SESAR proposal for the future architecture of the European airspace (2019) [4], the European ATM Master Plan (2020 edition) [6] and the SESAR2020 Concept of Operations Edition 2019 [7].
- Support of SESAR2020 Wave 2 Operational Solutions supported by FCI such as PJ.01-W2-08 "Dynamic E-TMA for advanced continuous climb and descent operations and improved arrival and departure operations", PJ.02-W2-21 "Digital evolution of integrated surface management", PJ.18-W2-56 "Improved vertical profiles through enhanced vertical clearances", PJ.18-W2-57 "RBT revision supported by datalink and increased automation" and PJ.10-W2-73 "Flight-centric ATC and Improved Distribution of Separation Responsibility in ATC".

- Support of the development of a Digital Voice ConOps.
- Updates in datalink subnetworks targeting TRL6 maturity[3]: PJ.14-W2-107 “Future Satellite Communications Data Link” and PJ.14-W2-60 “FCI Terrestrial Data Link and A-PNT enabler (L-DACS)”.
- Link with PJ.14-W2-61 “Hyper Connected ATM” and open network services (e.g. 4G/LTE, 5G, new satellite services).

1.7 Overview of the Future Communications Infrastructure

The FCI is an integrated system providing secure digital IP communications (data and voice) for future aeronautical telecommunication services supporting safety of life and regularity of flight, such as 4D trajectory sharing, net-centric ATM-related data exchange via SWIM, and increased levels of automation. It specifies an architecture encompassing multiple connected networks which include high-performance air/ground data link technologies.

1.7.1 Logical architecture

Figure 2 depicts a logical architecture of the FCI, which delineates the logical functions provided by the FCI to support the required communication capabilities.

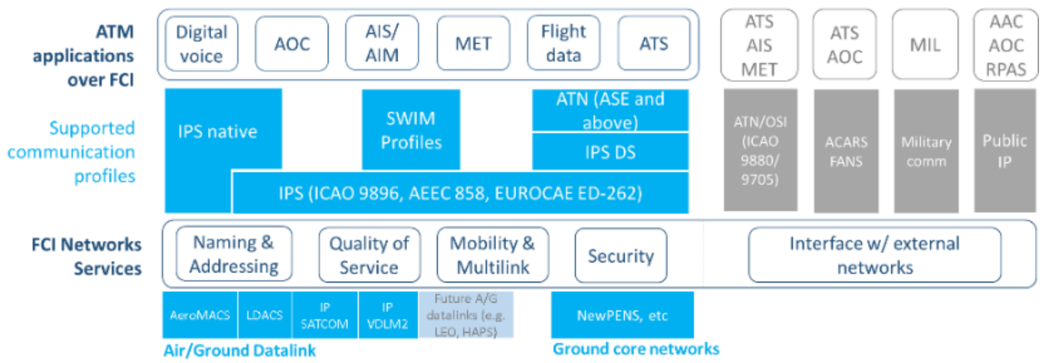


Figure 2 Logical view of the FCI

The FCI ConOps describes the following aspects in the operation of the aeronautical communications network:

ATM applications. This ConOps characterises the categories of ATM applications for safety of life and regularity of flight – data and digital voice – which are provisioned by the FCI (Section 3), and defines the security, safety and performance targets for these services (Section 4). These targets impose more demanding requirements compared to current networks and data links.

[3] PJ.14-W2-107 is expected to achieve TRL5 with initial steps towards TRL6 within SESAR 2020 Wave 2

ATM applications over the FCI are required to support one of the following **communication profiles or protocol stacks**:

- ATN Application Service Elements (ASE) and Dialogue Service (DS) as defined by ICAO 9880/9705 over IPS as defined by ICAO 9896, AEEC 858, and EUROCAE WG-108 IPS Profiles.
- SWIM Profiles over IPS (as defined by ICAO 9896, AEEC 858, and EUROCAE WG-108 IPS Profiles).
- Another upper layer protocol stack, defined at ICAO or EUROCAE level, which includes provisions for end-to-end service performance requirements for IPS native applications, over IPS (as defined by ICAO 9896, AEEC 858, and EUROCAE WG-108 IPS Profiles). This may be the case e.g., for newly defined safety and regularity of flight data services.
- Another upper layer protocol stack, defined at ICAO or EUROCAE level, which includes provisions for end-to-end service performance requirements for IPS native applications, over another IP transport/network protocol stack, and which includes provisions for communications performance requirements. This may be the case e.g. for Digital Voice.

FCI provides **network functions**, common to all services, which implement instances of the supported communication profiles in a deployment within the SESAR Airspace Architecture. These FCI network functions are described in Section 5.

FCI is a communication system supported by **IP network infrastructures**. The ground core networks can be operated by ANSPs or airspace users, and interconnected via NewPENS. Air/ground datalink networks provide connectivity to the aircraft, and implement radio technology standards (AeroMACS, LDACS and IP SATCOM).

The FCI ConOps is focused in the long term and thus assumes legacy communication technologies (e.g. ACARS, FANS1/A and ATN/OSI) are not part of the FCI. However, the long term FCI is expected to **interoperate with other co-existing networks** under certain conditions. Provisions are supported for the following interfaces:

- An OSI/IPS gateway function allows ground accommodation of 1) OSI or FANS1/A equipped aircraft communicating ATS with IPS aircraft or ground end systems in the FCI, 2) ground end systems in the OSI or FANS1/A networks with IPS ground end systems, 3) IPS equipped aircraft communicating ATS with OSI or FANS1/A equipped aircraft or ground systems outside the FCI.
- Civil-military communications interoperability will be based on interfacing between military systems and ATM-related IP structures and exchange of aeronautical information. This will be based on the specific needs of the military regarding confidentiality, interoperability, system resilience, data access and ATM security.
- Commercial IP technologies using cellular and satellite networks are currently emerging and are starting to provide high-capacity aviation services for passenger and cabin communications. Although currently not suitable for safety applications due to operational, interoperability and safety reasons (ATS communications are very much integrated within aircraft and ground systems, and users must be able to use radio spectrum that is always accessible and free from interference), they are feasible candidates to share the provision of

certain services with FCI, e.g. external sources of MET data or ATS relay with RPAS users in the U-space network.

Note: SESAR 2020 PJ14-W2-61 is studying the use of such communication technologies for ATM

The FCI is a critical part of the Integrated CNS concept being developed by PJ.14-W2-76. Following the CNS as a Service approach, there is potential to improve CNS efficiency as a whole, by optimization of capabilities and spectrum usage (An example is use of LDACS as alternative technology for the DME navigation ranging capability).

1.7.2 Geographical coverage

The geographical scope of the FCI is expected to be similar to the area of applicability of the EC REG 716/2014 mandate for the first wave of mature operational and technical changes from the SESAR 1 package (Figure 3a). In addition, as defined in PJ14.2.2 SPR, the service coverage area shall include the FIR/UIRs under the control of ECAC Member States as well as States involved in FAB development as for the red areas in figures reported in Extended Service Coverage Area # 1 (Figure 3b) and Extended Service Coverage Area # 2 (Figure 3c). At a minimum, the FCI should span the same geographical area with connections to adjacent regional networks (e.g. North African States)

Figure 3 Geographical scope

a) Service coverage area, b) Extended Service Coverage Area #1, c) Extended Service Coverage Area #2

It should be noted that potential exceptions for implementation are excluded from this document and it is assumed they will be coordinated with the SESAR Deployment Manager, when it comes to regulated implementations. For example, currently, EC Regulation no 29/2009 (Data Link Implementation Rule) excludes the implementation and use of ATSB1 of Sweden and Finland UIR north of 61°30´, while in EC Regulation 716/2014, the exception is no longer mentioned.

The FCI is also an essential enabler of U.S. NextGen and the Global ICAO ATM Plan, and therefore will also impact the communications infra-structure in Oceanic/Remote airspace. The ICAO North Atlantic Systems Planning Group (NAT SPG) is tasked with implementing the NAT 2030 Vision. This strategy pursues the improvement of NAT communications infrastructure performance as part of PBCS, and the enhancement of the role of Regional Monitoring Agencies, including EUROCONTROL, in monitoring performance-based service provision. A major priority of the group is improving inter-regional co-ordination (seamless at the boundaries) with all adjacent Regions and avoiding duplicated requirements for equipment (e.g. ATN and FANS). This vision is aligned with the FCI ConOps, and therefore, the NAT airspace is also considered as FCI area of coverage.

1.7.3 Network topology

Figure 4 presents a high-level representation of the topology implemented by communication networks within the FCI.

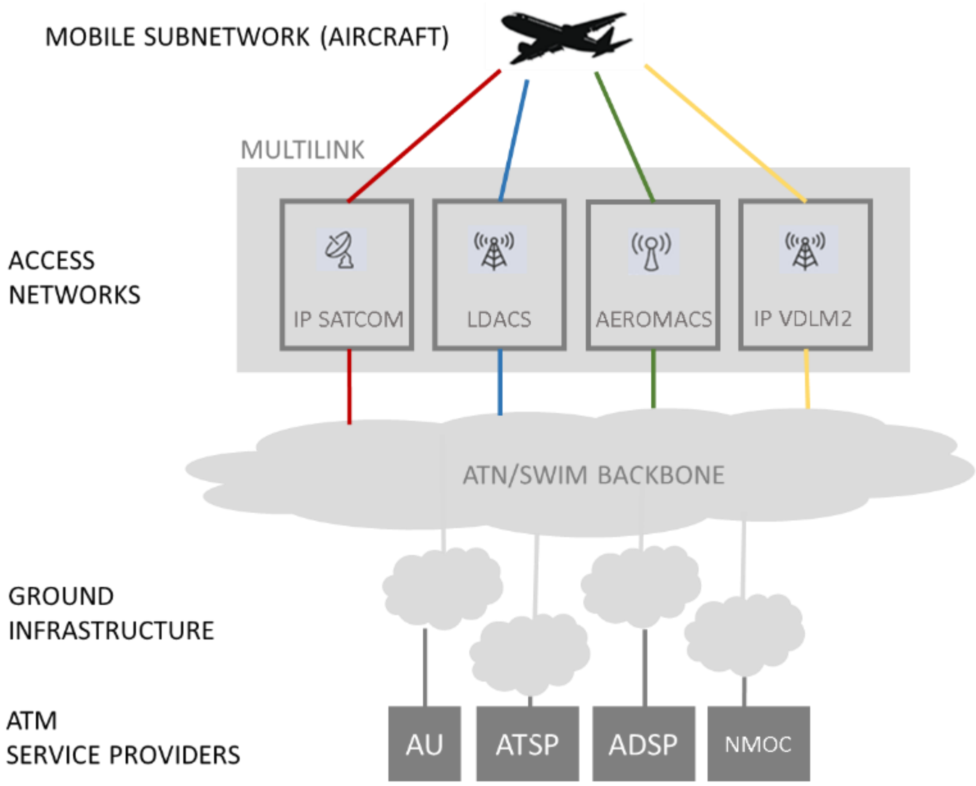


Figure 4 Network topology of the FCI

ATM Service Provider

ATM Service Provider is the independent entity providing services to entities located on the mobile subnetwork. Examples of an ATM Service Provider is an Air Traffic Service Provider (ATSP) providing ATS services (B2/B3 or voice), an Airline's Flight Operations Center (FOC) for the exchange of AOC information, and an ATM Data Service Provider (ADSP) like MET service. The ATM Service Provider network is composed of IPS Hosts and applications that interact with applications on IPS Hosts located on the mobile subnetwork.

Ground Infrastructure

The ground infrastructure is the internetwork responsible for providing links between the ATM Service Providers on one side and the access networks on the other side. This component is divided into Administrative Domains, each of which instantiates a Mobility Service Provider (MSP) and is normally under responsibility of a Communication Service Provider (CSP). A CSP may operate its own network infrastructure, a state's owned network, a common services network such as NewPENS, or a combination. The ground infrastructure composed by interconnected and mutually routable Administrative Domains allows a given ATM Service Provider to seamlessly provide its services to other entities in the ground infrastructure (ground/ground communications) and also entities on the mobile subnetwork of an aircraft (air/ground communications) independently of the access technology used to convey this information to the mobile subnetwork. The multilink functionality monitors and selects the best route, including the radio link selection, for packet transmission.

A specific function allocated to the ground infrastructure will be interfacing with external networks to ensure end-to-end interoperability between different aircraft and ground implementations, e.g. by means of ground-based gateways. This is the case of OSI/IPS gateways which will support accommodation of the OSI equipped aircraft and ground systems.

Access networks

Access networks are logical entities responsible for establishing and maintaining the datalink between the mobile subnetwork and the ground infrastructure for air/ground communications. This entity could be under administrative responsibility of a CSP or an Access Service Provider (ASP, as defined in ICAO Doc 9896). An access network is specific to one Radio Access Technology (RAT) through which it connects with the mobile subnetwork. RATs supported by the FCI are: AeroMACS, LDACS, IP-based SATCOM and IP-based VDLM2. Logically speaking, the airborne routers of all the aircraft connected to a given access network can be reached through the access network. The FCI comprises multiple Access Networks (at least one for each of the available data link technologies).

Mobile subnetwork

The mobile subnetwork is one end of the FCI. All air/ground communications that are handled by the FCI either start or end in the mobile subnetwork which hosts the airborne end systems. The airborne router, edge point of the mobile subnetwork, handles communications between airborne end systems and ground end systems through the use of one or more access networks through which it has access by the use of one or more radios. A multilink functionality monitors and selects the radio link for packet transmission.

2 Operational environment

2.1 Operational context

This section sets the contextual framework in which the FCI operates. The context is defined by:

- The SESAR Airspace Architecture Study (AAS) [4] defines a service-oriented framework for the future provision of CNS capabilities, and the role of service providers and consumers.
- The European ATM Master Plan, 2020 Edition [6] lays out the implementation strategy of CNS as a service, and how it is driven by operational changes.
- The SESAR Concept of Operations, Edition 2019 [7] indicates the envisioned European ATM operation of the future, with a focus on the operational improvements developed under the SESAR 2020 programme to be supported by the FCI as a technical enabler.

2.1.1 The SESAR Airspace Architecture Study

In April 2019, the Report of the Wise Persons Group on the Future of the Single European Sky [8] published a set of recommendations to implement "a customer-focused Single European Sky that meets future needs for aviation services and environmental goals. A safe, seamless, scalable and resilient aviation network will be delivered through digital air traffic management services for all airspace users (civil and military) and passengers." One of these recommendations is to "Implement a Digital European Sky based on an agreed roadmap building on the recommendations described in the Airspace Architecture Study, managed by the Infrastructure Manager, ensuring resilience of the system."

The AAS identified factors limiting overall capacity, scalability and resilience of the current aviation architecture. These include sub-optimisation of interoperability and data sharing, geographical constraints in the provision of air traffic control services, and limited automation support. The target architecture aims at solving these issues by implementing a service-oriented approach based on the decoupling of the data service provision from the physical CNS infrastructure.

The decoupling of integration services and the underlying CNS infrastructure services allows for a performance-based approach to CNS as defined in the European ATM Master Plan. In this context, providers and consumers agree contractually on the delivery of clearly defined and harmonised services compliant with quality of service aspects like reliability, availability and security by means of Service Level Agreements.

The performance-based service delivery is managed at the level of the integration services, allowing technology-specific implementations to develop independently. This way, an ANSP could, for example, contract a service based on operational needs (e.g. RCP levels defined by ICAO GOLD); the service provider could then integrate seamlessly available CNS technologies with different quality of service characteristics, and provide the necessary service meeting the requirements. The technical implementation is transparent to the end user, as the provider will organise the necessary service delivery management capabilities to ensure the service is available as agreed.

The main elements of CNS services and infrastructure identified in the AAS include datalink with high capacity and reliable response times to enable sophisticated interactions between controllers and pilots for time and safety-critical separation purposes, and a strong IP backbone to support connectivity. PJ14.W2.77 Solution is defining the Future Communications Infrastructure, including IPS Multilink, to support the Communications needs identified in AAS.

2.1.2 The SESAR ATM Master Plan

The SESAR ATM Master Plan, Edition 2020, describes the SESAR vision for future CNS infrastructure and services as following a rationalisation and integrated approach driven by the move from physical assets to services and standardisation between systems. This will result in integrated combinations of air and ground services, increased civil-military synergies, and a more efficient use and long-term availability of spectrum. Consecution of this vision will require interconnection to high-bandwidth, low-latency IP network infrastructure, adequate protection of ATM information against security threats, and infrastructure rationalisation driven by virtualisation, automation, digitalisation and Artificial Intelligence.

CNS as a service

The historical national ownership of CNS infrastructure, as well as the need to support a variety of heterogeneously equipped airspace users (civil and military), has led to an inefficient distribution of equipment when taking performance needs in relation to air traffic into consideration. In addition, some technologies still in operation have overlapping capabilities and, in a context of steady growth, may not be able to provide the required performance to deliver the SESAR vision. Therefore, the main challenge is to optimise the infrastructure and rationalize it both on the ground and in the air.

Changes in the area of CNS driven by a performance based service provision approach will provide the incentives for service providers to optimize the use of technologies and geographical distribution of equipment in a rationalized CNS infrastructure, and create a competitive environment to enable ANSPs for more flexible implementation choices.

The future CNS infrastructure will be based on an integrated CNS backbone comprising datalink with multilink capabilities, Pan-European Network Service (NewPENS), a global navigation satellite system (GNSS) and ADS-B. The introduction of new integrated capabilities will continue to follow the performance and service-based CNS approaches. These will be added in a way that guarantees availability, integrity, safety, security and performance requirements as mandated by relevant authorities, which can be expressed differently per airspace user and environment, thus avoiding compromise of overall performance due to the least capable users.

Future Communication Infrastructure

Within the CNS infrastructure, the SESAR Master Plan defines the role of the FCI as “provision of digital communication services (IP-based data and digital voice). It supports future ATS and airline operations centre (AOC) services with demanding high air-ground communication capacity and high performance. It will allow the real time sharing of 4D trajectories and timely access to ATM data and information services and will enable network-centric SWIM architectures. It manages, in a secure way, different subnetworks. It also integrates the services provided by open networks needed for “hyper-connected ATM.” The latter is defined as a deployment scenario supporting broadband applications providing services to the FCI for ATM, U-space operations and other uses (e.g. engine maintenance).

The SESAR Master Plan also indicates that mitigating cybersecurity risks in CNS systems requires implementing high-level security requirements in each of the technological solutions and in the CNS system as a whole, leading to an evolution of the architecture to enable resilience against cyberattacks.

Levels of Automation

The SESAR Master Plan introduces a phased approach of implementation of the SESAR vision, which includes a model of increased Levels of Automation for connectivity and data sharing. The introduction of these Levels of Automation is necessary to support future SESAR vision implementation Phases B ("Efficient services and infrastructure delivery") and C ("Defragmentation of European skies through virtualisation").

The FCI concept advances communication capabilities including cockpit connectivity evolution (multilink management, broadband datalink communications), and data sharing (digital aeronautical information, Flight Object sharing and Yellow/Blue/Purple SWIM Profiles). These capabilities support the Full support of Level of Automation 2 ("Task Execution Support") for ATC operations. This level provides the human operator with automation functions for information acquisition and exchange, information analysis, action selection and action implementation for some tasks/functions. Actions are always initiated by Human Operator. Adaptable/adaptive automation concepts support optimal socio-technical system performance.

2.1.3 The SESAR Concept of Operations

The SESAR ConOps describes areas identified by the SESAR Vision documented in the European ATM Master Plan where Operational Improvements (OI) are supported by technical enablers to bring performance gains and yield the overall performance expected in SES High-Level Goals. Three operational Key Features are identified:

- Optimised ATM Network Management

- Advanced ATS

- High Performing Airport Operations

The enhancements described in the three Key Features will be underpinned by an integrated and rationalised aviation infrastructure providing the required technical capabilities in a resource-efficient manner. This feature will rely on enhanced integration and interfacing between aircraft and ground systems, including ATC and other stakeholder systems, such as flight operations centres and military wing operations centres. CNS systems, SWIM, trajectory management, Common Support Services and the evolving role of the human will be considered in a coordinated way for application across the ATM system in a globally interoperable and harmonised manner.

The development and deployment of new communication technologies should converge towards a service and performance-based integration approach. The introduction of U-space services to support access to airspace for a large number of unmanned vehicles (RPAS) requires ATM capabilities to be interoperable with manned aviation capabilities and compliant with local air/ground communication procedures.

Trajectory Based Operations (TBO)

A significant and fundamental shift takes place with the adoption of 4D Trajectory Management Principles to manage flights, which facilitates the performance-friendly transition from tactical intervention towards a more strategic focus on planning and intervention by exception. TBO enables effective dynamic adjustment of airspace characteristics to meet predicted demand and makes full use of developed civil/military collaboration whilst aiming to keep any distortions to the Business/Mission Trajectories to the absolute minimum without compromising the flexibility required for optimisation purposes.

In TBO, enhanced knowledge of the predicted vertical profile of the aircraft is available (e.g. through the eFPL or ADS-C data, such as EPP). This allows automation to be developed which supports ATCOs in issuing enhanced vertical clearances to facilitate continuous climb and descent, while ensuring separation from other traffic.

The implementation in the FMS of the above-mentioned lateral and vertical clearances is done by the flight crew, as much as possible through the usage of loadable CPDLC messages, which allows them to be aware of the ATC intent while minimising the risk of errors. ADS-C EPP and additional Aircraft Derived Data are used by the ground for consistency check and conformance monitoring. Any discrepancies are automatically identified by the system and highlighted to the ATCO, to take appropriate action.

Via CPDLC, flight crews may also be able to request revised routing directly to ATC, which the latter will aim to accommodate, after appropriate ground coordination processes have taken place. Controllers will be assisted in both their planning and tactical separation tasks by Data Link as the predominant means of communication between airborne and ground side, except for time critical messages.

With the integration of RPAS into non-segregated controlled airspace with ICAO classification A, B and C, and between dedicated airfields, they are managed alongside all other trajectories to meet the required safety and performance objectives. RPAS trajectory planning captures any specific performance/communication/coordination needs that are of relevance to a planned and optimised network. Their subsequent execution is enabled by technical capabilities and procedures to enable compliance with ATC instructions. For the Military, RPAS Integration is of upmost importance.

Integrated Surface Management

Surface movement management solutions are being developed within SESAR into an integrated environment dedicated to maintaining or improving current safety levels together with increased reliability and improved predictability of the planning milestones associated with aircraft taxi times. This includes the integration of RPAS into surface operations. The new processes and technologies focus on the surface movement management in the two ground segments of the trajectory of the aircraft - taxi-in and taxi-out.

Enhanced Guidance Assistance to Aircraft and Vehicles on the Airport Surface Combined with Routing provides enhanced guidance to ATCOs, Flight Crews and vehicle drivers based on holistic surface traffic planning. The holistic plan is broken down to individual, optimised route instructions reducing conflicting situations and being transmitted to Flight Crews or vehicle drivers via data link or radio telecommunication.

MET Aspects

As described by the SESAR ConOps, MET information distribution and consistency between all ATM actors are enhanced thanks to a unified access to MET Information Services for ATM called the 4DWxCube. The implementation of enhanced meteorological services allows improving predictability, flight efficiency and network performance by supporting the design of optimum trajectories.

The 4DWxCube and the new MET Information Services it supports, is the major source of MET information for all applications within ATM, ensuring a common situational awareness among all ATM actors. It ensures that the planned trajectory and the agreed trajectory are based on the best available MET information and consistent with what is available to all other actors. MET information is used for various applications during both the planning and execution phases. The planned trajectory can be initiated much earlier with MET forecasts available many days in advance.

Flight Crew continuously receives the following MET information via data link and/or air-ground SWIM, which allows for visualisation by on-board systems:

- Latest airport information, including runway in use and MET information.
- Relevant and reliable MET observations and updates relevant for each trajectory (e.g. wind, temperature, icing, convection, turbulence and when required, satellite/radar imagery showing how hazardous clouds evolved).

4DWxCube information sources are enriched by MET data from on-board sensors (e.g. icing, hail, turbulence, wind/temperature) provided to ground systems via air-ground SWIM and/or data link.

Military specific aspects

For military AUs, trajectory management, together with performance-based navigation (PBN) and advanced surveillance, will be fundamental features of future TBO. A key enabler of trajectory management will be high capacity air-ground data link communications and the ability of military airborne functionalities to rely on flight guidance to process trajectory parameters at the level of flight management systems/military mission systems (FMS/MMS). The compliance approach will vary with aircraft types and mission.

2.2 Related SESAR operational Solutions

The following operational Solutions are identified as potentially relevant to PJ.14-W2-77, as they may provide requirements or assumptions for the FCI at the operational level. At this moment, this is a list of placeholders while the coordination with the mentioned solutions continues. The list will be updated during the final update of the ConOps (2022) and will include a full description of inputs and impact analysis per operational Solution.

2.2.1 PJ.01-W2-08A — Digital synchronization of arrivals and departures, PJ.01-W2-08B — Dynamic E-TMA for advanced continuous climb and descent operations

The objective of this key R&D activity is to improve descent and climb profiles in busy airspace, as well as the horizontal flight efficiency of arrivals and departures, while at the same time ensuring traffic synchronization, short-term DCB and separation. This requires a very broad scope, which includes advances in airspace design, development of ground tools, and development of ATC and airborne procedures. ATS Baseline 2 standard has been identified as relevant for the support of new request, instruction and clearance messages to manage RTA and CTA between Approach & En-Route ATC centre and aircraft.

2.2.2 PJ.02-W2-21.1 – Extended Airport Safety Nets for Controllers at A-SMGCS Airports, PJ.02-W2-21.2 – Enhanced Guidance Assistance to Airport Vehicle Driver Combined with Routing, PJ.02-W2-21.3 – Airport ATC provision of ground-related clearances and information to vehicle drivers via datalink, PJ.02-W2-21.4 – Full Guidance Assistance to mobiles using 'Follow the Greens' procedures based on Airfield Ground Lighting (aprons/taxiways/runways), PJ.02-W2-21.5 – Enhanced Safety in LVP through use of Dynamic Virtual Block Control, PJ.02-W2-21.6 – Advanced Automated Assistance to Controller for Surface Movement Planning and Routing

The R&D activity covers the development (e.g. using new algorithms, artificial intelligence / expert systems) of procedures and required system support for an improved surface traffic management, including the extension of the A-SMGCS routing and the integration of inputs from airport DCB processes. This also covers as well the guidance assistance to both pilots and vehicle drivers using Airfield Ground Lighting (AGL), the consolidation of the ¿Follow-The-Greens¿ procedures, the exchange of information between ATC and vehicles/aircrafts using airport data link and other guidance means, and the development of enhanced airport safety nets for controllers beyond those delivered in SESAR 1.

2.2.3 PJ.18-W2-56 — Improved vertical profiles through enhanced vertical clearances

The objective of this key R&D activity is to develop an automation support for ATCOs to issue vertical constraints that support more efficient flight profiles while ensuring separation provision. In a first step, for a certain flight still in climb, enhanced prediction of vertical profile data are presented to ATCOs to facilitate their decision making on whether using constraints in the vertical dimension is appropriate and sufficient to achieve separation (using eFPL 4D trajectory or performance data, but ideally using downlinked EPP data). In a second more advanced step, in the same situation the ATC system would generate proposals for conflict-free clearances that take anticipated aircraft performance into account, and those proposals are then presented to the ATCO for uplink to the flight crew.

2.2.4 PJ.18-W2-57 — RBT revision supported by datalink and increased automation

The key R&D activity aims at supporting a continuous increase in the amount and the usefulness of information shared between air and ground and of the level of automation support to controllers and pilots, e.g. towards the automatic uplink of clearances with or without previous controller validation and towards increased use of the auto-load to FMS of uplinked clearances and of managed/automatic mode by the flight crew. The R&D activity addresses the medium-term evolution in airborne systems e.g. FMS, FCU/MCP and flight crew operating procedures synchronized with the medium-term evolution of ground systems and associated procedures for the G/G coordination between NM, ACCs and FOCs to address the DCB, Airspace User operations, traffic synchronisation and separation needs.

2.2.5 PJ.10-W2-73 CC – Collaborative Control, PJ.10-W2-73 FCA – Flight Centric ATC, PJ.10-W2-73 NGCV – Non-geographical Controller Validations

The key R&D activity covers a concept that consists of assigning aircraft to ATCOs without references to geographical sectors, and have the aircraft controlled by that same ATCO across two or more geographical sectors. This requires flight-centric specific allocation, visualization (traffic filtering), coordination tools (e.g. in the event of a conflict, establish which controller is responsible for its resolution) and, for high traffic densities advanced CD&R tools (that are not flight-centric specific). The R&D activity also covers the concept of collaborative control with planned boundaries in which sectors are retained as they are today, with aircraft being assigned to a sector according to its geographic location. The boundaries between sectors have planned coordination conditions like in current operations, but with some additional flexibility by allowing controllers to issue clearances without prior coordination to aircraft in a different sector.

2.2.6 Other relevant operational Solutions

In addition to the operational Solutions listed above, there is potential for relevance in coordination with Solutions PJ.18-W2-53 and PJ.13-W2-117 (TBC, as neither EPP nor RPAS are considered in the scope of FCI).

2.3 Actors, roles and responsibilities

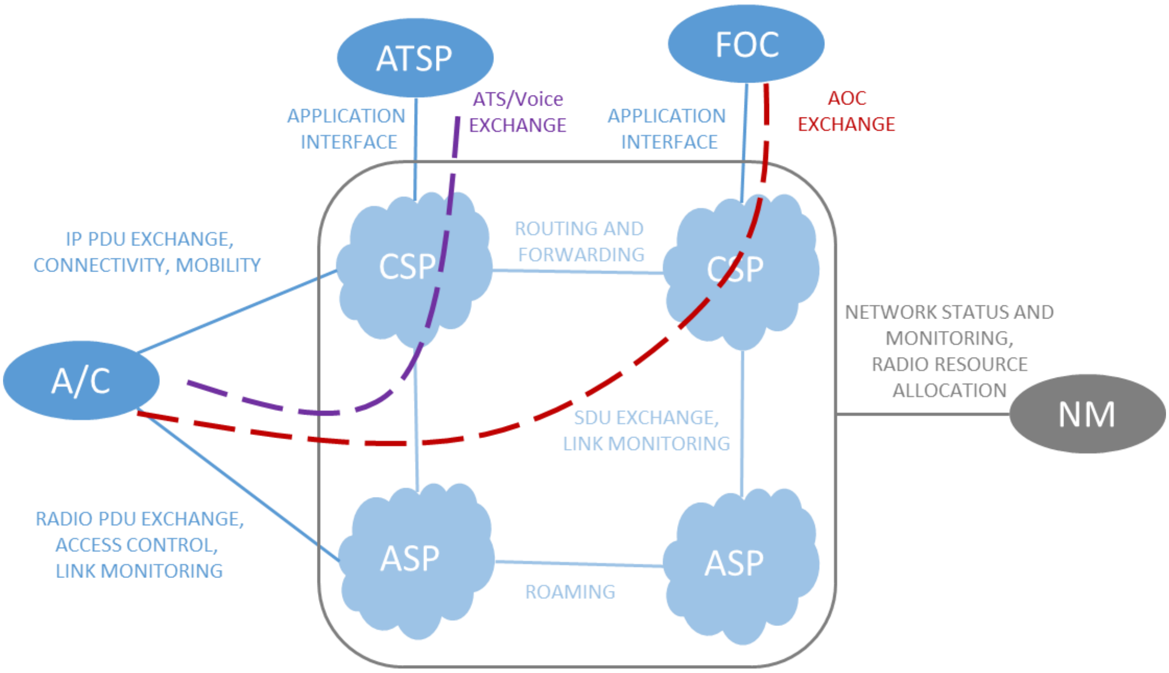
This section identifies the actors involved in the provision of communication service in the FCI, together with their associated functionalities (roles and responsibilities) within the operational environment.

- **Air Traffic Service Provider (ATSP).** Integrated national ATS provider responsible for producing part of the data required for ATS, processing and combining this data to make it available to their controllers and using that data to provide ATS to aircraft via datalink. ATSP are usually part of the Air Navigation Service Provider domain.
- **ATM Data Service Provider (ADSP).** Provider of data and applications supporting the provision of ATS and aircraft operation. The ADSP can be part of the Air Navigation Service Provider domain or be an entity independent to the ATSP. ATM data relies on underlying integration services for weather, surveillance and aeronautical information. Data services include flight data processing functions like flight correlation, trajectory prediction, conflict detection and conflict resolution, arrival management planning, and AIM/MET.
- **Communications Service Provider (CSP).** The CSP provides communication services for air navigation and operation. This involves providing the network connectivity between ground and/or aircraft located IPS hosts, the role of Mobility Service Provider (MSP), and security related features. The CSP may also be an Access Service Provider (ASP) to provide access to aircraft, in which case it is called an A/G Communications Service Provider (ACSP). Otherwise, CSPs establish and manage relationships with ASPs for this purpose. In the future it is foreseen

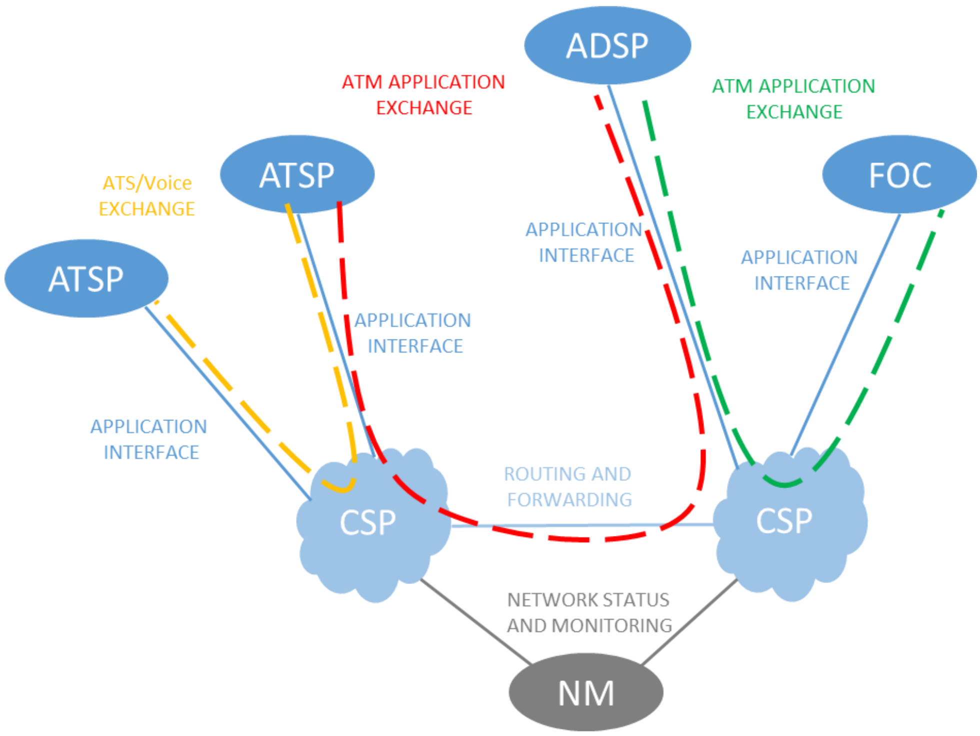
that the CSP role is to be managed at a common European service provision level, at a minimum for ATN datalink backbone services.

- **Access Service Provider (ASP).** The ASP is the operator of Radio Access Technology (RAT) providing A/G datalink communications with aircraft accessing the network. This role is dependent on the functions (medium access, link control, handover, roaming, and Layer 2 security) supported by the specific radio communication infrastructure technology (e.g. LDACS, AeroMACS, IP SATCOM or IP VDLM2).
- **Network manager (NM).** The Network Manager manages regional air traffic management network functions as well as scarce resources (e.g., radio frequencies), in Europe. It monitors the performance of ATC datalink and reports appropriate statistics for the network datalink to allow stakeholders to understand how well the system is performing on a regional (Europe-wide) basis. The NM will also provide insight as to why the system is performing the way it is and recommendations on how to tackle system-wide issues.
- **Aircraft (A/C).** This actor involves the ensemble of human (flight crew) and automated systems on-board an aircraft operated by an airspace user, communication functions (including radio) and managing applications on IPS hosts within the aircraft mobile subnetwork.
- **Flight Operations Centre (FOC).** This actor represents an airspace user coordination hub centralising the tasks of flight planning and monitoring. The FOC manages the AOC communication with its operated A/C, and shares ATM information for coordination and situational awareness with ADSP.

Figure 5 depicts the role and responsibility of FCI actors in relation with other actors they interact with, in the two possible use cases of operation: G/G and A/G communication. Note that the CSP interface to specific ATSP, ADSP and FOC is illustrative as an example topology.



a) **Air-ground exchange**



b) **Ground-ground exchange**

Figure 5 Interactions between FCI actors

Table 1 summarises the responsibilities for each FCI actor as depicted in Figure 5 above.

FCI Actor	Associated Responsibilities
Air Traffic Service Provider (ATSP)	Provide ATS and Digital Voice services to A/C and other ATSPs Ensure end-to-end datalink service performance, security and safety levels Manage service contract with CSPs providing connectivity to FCI Establish and manage ATS and Digital Voice applications
ATM Data Service Provider (ADSP)	Provide ATSP with integrated ATM data required to provide ATS Perform flight data processing functions (potential future evolution) Ensure end-to-end ATM data service performance, security and safety levels Manage service contract with CSPs providing connectivity to FCI Establish and manage ATM data applications (weather/aeronautical information including AIS/MET, flight information for TBO)
Communications Service Provider (CSP)	Provide end-to-end connectivity, mobility and communications services to air and ground IPS hosts running ATM applications Provide access to ground network infrastructure (e.g. IP BB, NEW PENS…). Optionally, provide access to air/ground datalink infrastructure (if also an ASP) Manage service contract with ATSP, ADSP and airspace users (FOC and A/C). Ensure levels of security, safety and performance as compliant with service level agreements in service contract Monitor network performance and events, and share with NM for system-wide monitoring Apply NM directives to improve network performance

FCI Actor	Associated Responsibilities
Access Service Provider (ASP)	Provide accessibility to access network via air/ground datalink infrastructure Provide status of radio link with aircraft in the access network Manage service contract with CSP and airspace users (A/C). Ensure levels of security, safety and performance as compliant with service level agreements in service contract Monitor access network performance and events, and share with NM for system-wide monitoring Apply NM directives to improve access network performance (e.g. radio resource allocation)
Network manager (NM)	Monitor system-wide performance of ground network and access radio networks in FCI. Publish appropriate performance statistics and reports Provide recommendations for corrective action on network-wide issues to appropriate stakeholders (CSP and ASP)
Aircraft (A/C)	Ensure the correct operation of on-board A/G datalink capability, and ATM applications (ATS, Digital Voice, AOC, AIS/MET) Monitor datalink avionics status and record logs for performance monitoring
Flight Operations Centre (FOC)	Provide AOC services to A/C operated by the airspace user Ensure end-to-end AOC service performance, security and safety levels Manage service contract with CSPs providing connectivity to FCI Establish and manage ground AOC applications

Table 1 FCI Actor Responsibilities

2.4 Operational scenarios

This section describes representative scenarios of FCI usage, which illustrate the new operating method provided by FCI capabilities. For reference, the baseline scenario before FCI deployment is also described. Each operational scenario is defined by its involved actors, operational context, and the sequence of events involving interaction between actors and the IPS System.

2.4.1 Reference scenario

The reference scenario represents the operational environment before FCI is implemented (Figure 6). The main limitation of this scenario is the high fragmentation of the communications infrastructure. This leads to low flexibility of datalink usage, high costs for equipage and maintenance, and lack of infrastructure rationalisation.

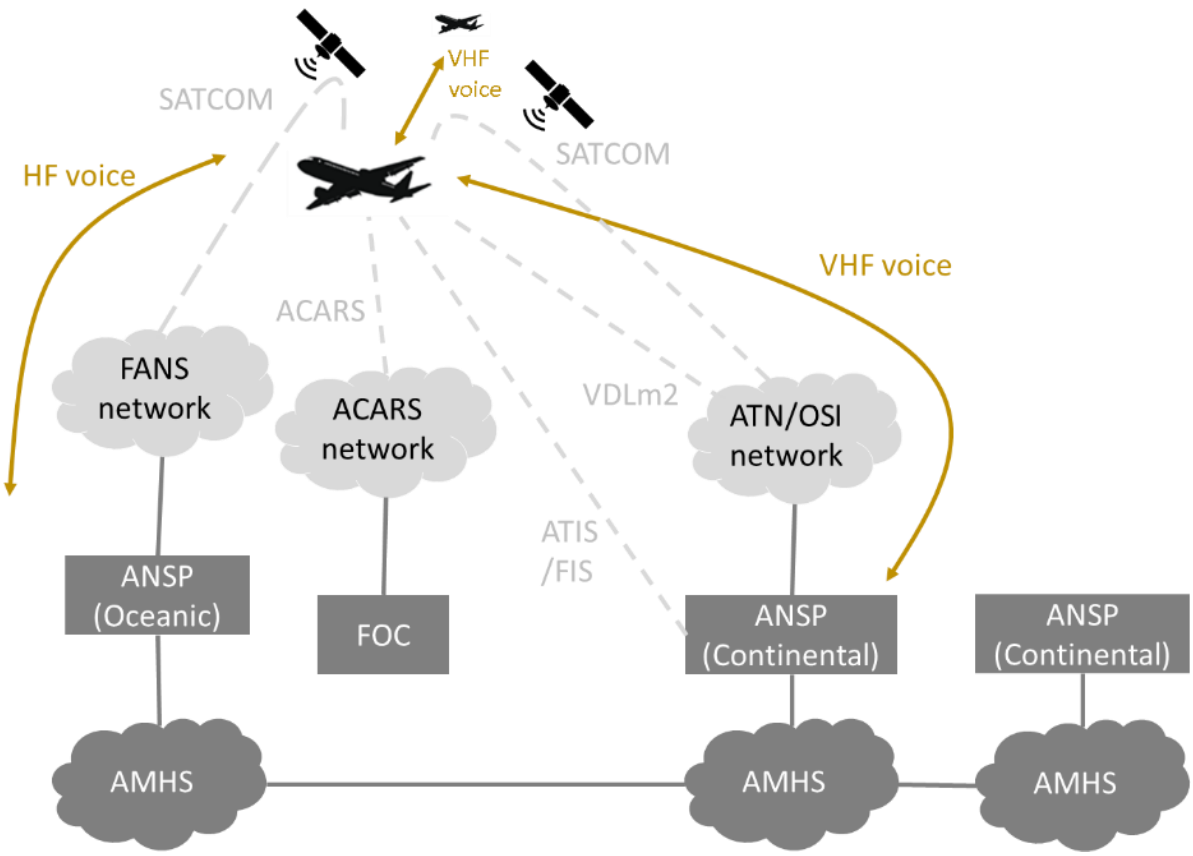


Figure 6 Reference operational scenario

The actors present in the reference scenario are:

- ANSP, providing ATS datalink services and analog voice. There is a differentiation between oceanic ANSP, which communicate through HF voice and FANS 1/A over SATCOM, and continental ANSP, which in Europe communicate through VHF voice, ATN/OSI over VDLM2 and SATCOM (for ATS Baseline 1), and ATIS/FIS (for AIS/MET). ANSPs communicate using ground voice or interconnected AMHSATS Message Handling Service (AMHS) networks.

- FOC, providing AOC services via ACARS.
- A/C, required to be equipped with all the systems above to support the range of applications. Due to the broadcast nature of analog voice, voice communications are in the form of party-line dialogues where conversations involving aircraft in the same frequency channel can be listened. This characteristic makes direct Air-Air voice communication technically possible.

For the execution of a flight in this operational scenario, the only information available by ANSPs is the approved flight plan. Flights are transferred directly between ANSPs handling the flight and, in the case of a change in required equipage (e.g. flying from oceanic FANS to continental ATN region), a handover procedure needs to be executed. If one datalink shows degraded performance, the decision to fall back to HF/VHF voice is made by the pilot based on human perception (possibly supported by flight instruments). Dual link ATN/OSI (VDLM2 – SATCOM) is supported by the reference scenario as described in the SESAR Deployment Manager FCI Multilink Concept of Operations [5]. This initial link selection mechanism is based on relative VDLM2 - SATCOM link preferences configured statically in the aircraft and signalled through the SATCOM network.

The situational awareness is limited, since information managed by ANSP, FOC and A/C is not necessarily fully consistent, and incomplete since it does not necessarily have full visibility on surrounding traffic other than limited FIS data. If a flight rerouting is required due to e.g. weather, the pilot will make the decision considering information available on-board, supported by limited exchanges by NOTAM and weather reports transmitted via AOC and ATIS/FIS, and requiring previous ATC clearance. The current procedure to decide the new route, request permission and receive clearance is slow and sub-optimal.

2.4.2 Target scenarios

The target scenarios illustrate operational uses of the FCI. Each scenario represents a typical sequence of utilisation of FCI services by actors in the provision of ATM applications. Scenarios are not mutually exclusive, i.e. more than one may be happening simultaneously involving the same aircraft and ground infrastructure systems.

2.4.2.1 Multilink – administrative policy

This scenario represents the selection of alternative datalinks among available radio access technologies for an IPS equipped aircraft, following the preferences and constraints defined by administrative policies. Figure 7 illustrates this scenario depicting an aircraft flying on different flight domains with different associated multilink policies. This scenario is complementary with performance-based multilink.

The actors present in the scenario are:

- ATSP, providing datalink services (ATS B2/B3, AIS/MET, Flight information) and digital voice to A/C, and end to end service monitoring. ATSP may be associated to a specific airspace volume (oceanic or continental) or according to other operational scope.
- FOC, providing AOC services to A/C and end to end service monitoring.
- CSP(s), providing end-to-end network connectivity and monitoring between ATSPs, or between ATSP or FOC and A/C. The radio access segment of the air/ground communications

is supported by an ASP specific for a datalink technology. CSP either operates one or more access networks, or establishes agreements with ASP to support its communication services.

- A/C equipped with an IPS mobile subnetwork and IPS datalink radio systems.

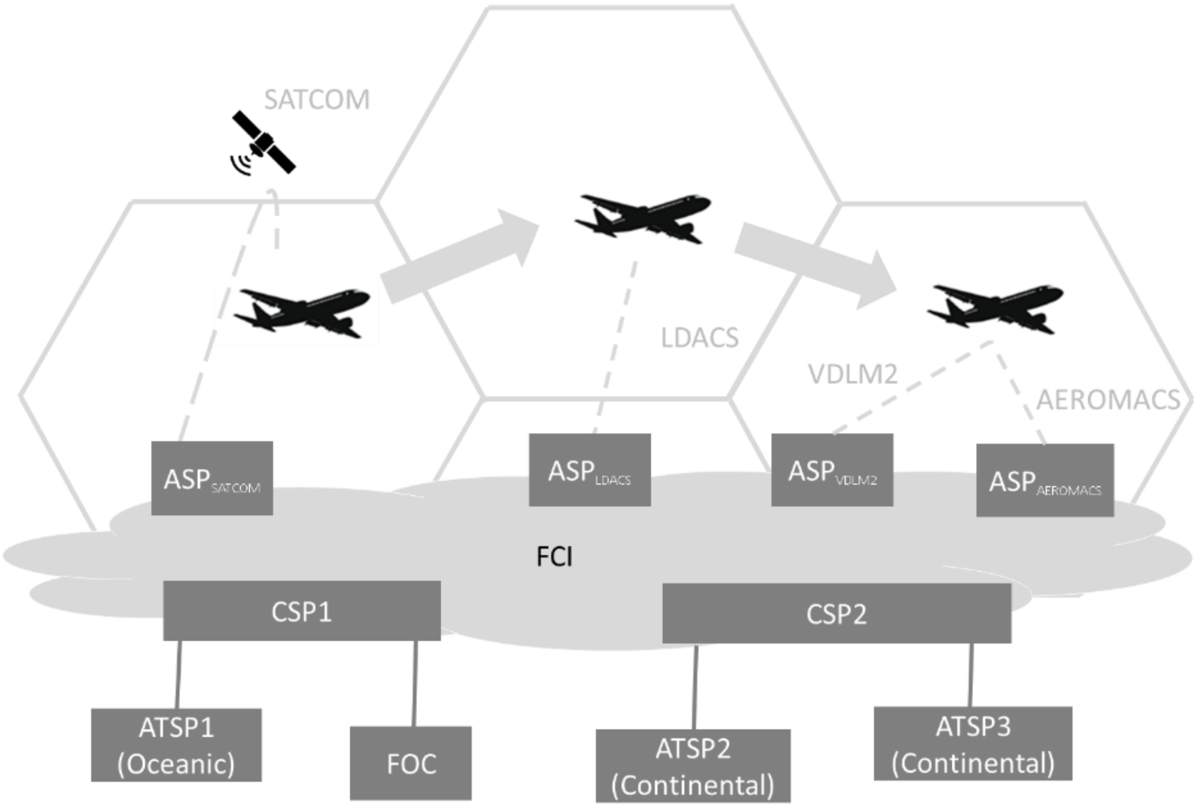


Figure 7 Administrative multilink policy (example)

The selection of datalink(s) to be used depends on pre-defined policy or preferences. Policies set by national regulators can be mandatory (e.g. datalink not certified for use) or recommended, and must be endorsed by AUs and ATSPs in the applicable region. Link preferences respond to preferences or constraints from the current ATSP or the airspace user, and criteria such as geographical location, altitude, airspace region, or phase of flight. This can obey to commercial, regulatory, or other reasons. This results in ATM service providers making use of the datalinks that are preferred, or authorized, among the available datalinks. CSPs maintain the connectivity and network routes to accommodate end-to-end communication over the selected access network. Note that datalink selection for downlink and uplink directions may be different, as asymmetric routing is expected to work properly as it currently does within the public Internet.

Note: It is assumed the datalinks remain within acceptable performance. Performance-based datalink selection is described in the next operational scenario.

Link selection policy may be defined per application, e.g. ATS and AOC may be configured to follow different paths. This is implemented via defined Classes of Service (CoS) which drive the routing policies associated to the configured administrative policies. Following the preferences defined per CoS, different applications can be transmitted over different datalinks, or over the same datalink (for which different priorities and QoS parameters may be applied).

Since it is a digital communication, it does not broadcast voice conversations to other A/C in the vicinity as VHF voice. Aircraft exchanging information with each other need to rely on an IP host on the ground to provide this service. In order to implement party-line communications, the ground infrastructure needs to manage voice call groups and maintain call sessions.

A change in the link preferences and constraints may occur, either as an administrative procedure for long-term modifications, or quickly due to unplanned circumstances. In either case, the FCI is expected to allow the user to reconfigure these values, and subsequently propagate changes in the routing policy through the network for affected applications transparently to the user. In addition, if a new ground ATM service provider or a new aircraft address is added to the FCI, it should be authorised as a source and destination of ATM traffic and associated routes propagated through the network.

2.4.2.2 Multilink – performance-based policy

This scenario represents the selection of alternative datalinks among available radio access technologies for an IPS equipped aircraft, according to the acceptability of the performance level achieved. Figure 8 illustrates the scenario depicting different overall levels of performance (GREEN for high, YELLOW for medium, RED for low)[4] for different datalinks which are simultaneously available to an aircraft. This scenario is complementary with administrative multilink policies.

The actors present in the scenario are:

- ATSP, providing datalink services (ATS B2/B3, AIS/MET, Flight information) and digital voice to A/C, and end to end service monitoring. ATSP may be associated to a specific airspace volume (oceanic or continental) or according to other operational scope.
- FOC, providing AOC services to A/C, and end to end service monitoring.
- CSP(s), providing network connectivity and monitoring between ATSP or FOC and A/C. The radio access segment of the air/ground communications is supported by an ASP specific for a datalink technology. CSP either operates one or more access networks, or establishes agreements with ASP to support its communication services.
- A/C equipped with an IPS mobile subnetwork and IPS datalink radio systems.
- Under performance-based multilink, link selection is based on the acceptability of a datalink quality to guarantee the performance levels for a particular application. A datalink will not be authorised for the provision of an ATM service whose required performance is above that considered to be guaranteed by the access network. As a result, different services (e.g. ATS, AOC, digital voice) may use different datalink depending on whether they are considered by the system to comply with the QoS parameters configured for the CoS assigned to the service. When two different services are transmitted over the same datalink, QoS configuration allows

[4] Colour codes do not have an intrinsic significance in FCI. They are just to illustrate datalinks can offer different levels of performance. Note that the assignment to a colour to a specific datalink is an arbitrary example and does not intent to convey the capacity or limitations of a particular technology.

for prioritization. More sophisticated techniques such as load balancing are also possible with performance-based multilink policy.

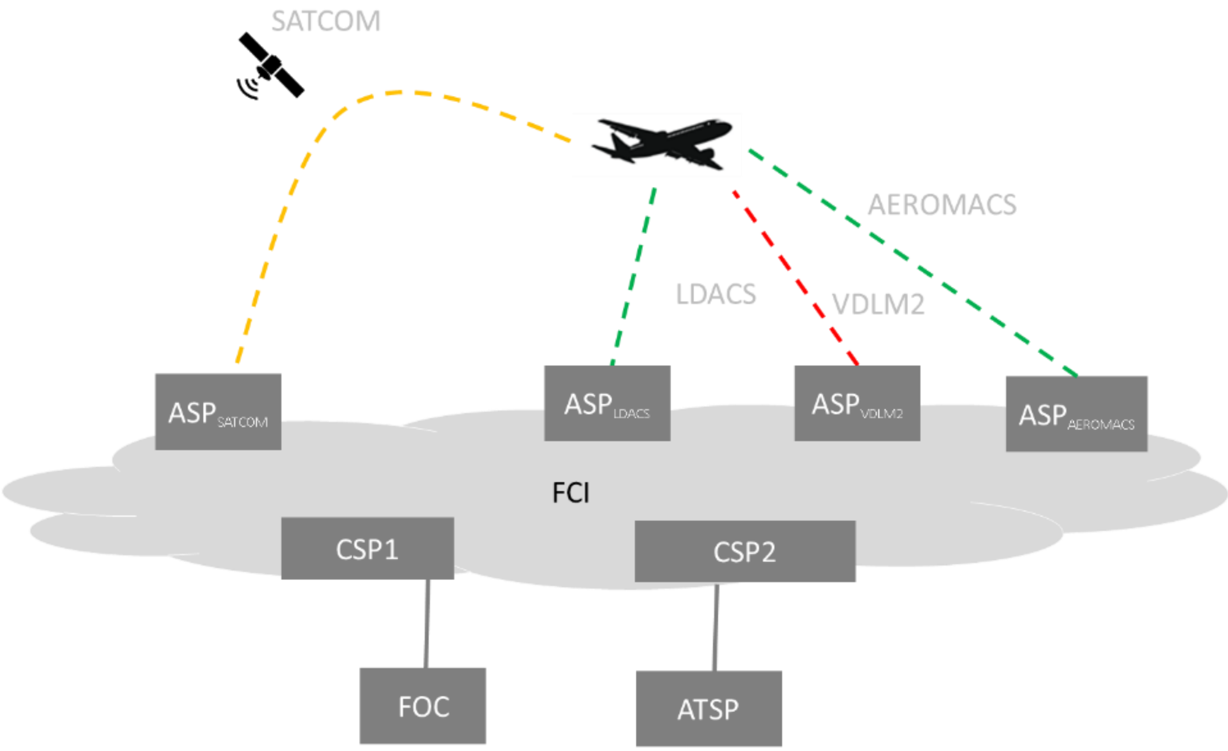


Figure 8 Performance-based multilink policy (example)

In the absence of an administrative policy, performance-based multilink considers all the active links usable as long as they guarantee the performance levels for a service. However, performance-based multilink can be combined with an administrative policy. As a result, among the acceptable datalinks in terms of performance, the user or service provider may still select a preferred link among the available options.

In some cases, the nominal performance guaranteed by a radio technology is sufficient to reject provision of more stringent services. In other cases, the technology is capable but due to coverage problems, there is a degradation or outage in the datalink quality which drops the datalink performance to levels of non-acceptability for the service. Performance-based multilink has the goal to maximise not only performance but also availability of the service. As a result, the performance-based policy executes mechanisms of traffic rerouting to other acceptable links, and/or pre-emption of low priority traffic to reserve limited resources to high priority traffic. The following failure levels can be defined for communication with an A/C:

- The FCI has capacity to provide all ATM services at their required performance levels in any of the active datalinks.
- Some datalinks do not support required performance levels for some ATM services, but FCI still has sufficient capacity to support all ATM services at their required performance. Link re-selection is applied.

- Some datalinks do not support required performance levels for some ATM services, and FCI has not sufficient capacity to support all ATM services at their required performance. Link re-selection and pre-emption is applied.
- No datalinks support required performance levels for any ATM services. Fall-back and mitigation are applied, in addition to mechanisms to resume traffic upon link recovery.

In order to detect timely changes in the performance level supported by a datalink (degradations, outages, and recoveries), a link monitoring function is provided by the access network (air radio, ground radio, or both). This function also involves capability to inform other entities of link quality changes (e.g. air notification to ground, or propagation of routing preference through the network). This has the goal to achieve common awareness throughout the network of the acceptability of an end-to-end path for specific traffic.

2.4.2.3 ATM data dissemination, and interoperability with non-FCI airspace users

This scenario illustrates the dissemination of updated aeronautical, weather and flight information to achieve common situational awareness of ATM information among FCI users and also with other airspace users located in non-FCI networks. These exchanges are expected to be executed over SWIM Technical Infrastructure using the appropriate profiles (note the particular case of accommodation for users in ATN/OSI or FANS 1/A networks is described in 2.4.2.4). Figure 9 depicts the information exchanges in this scenario.

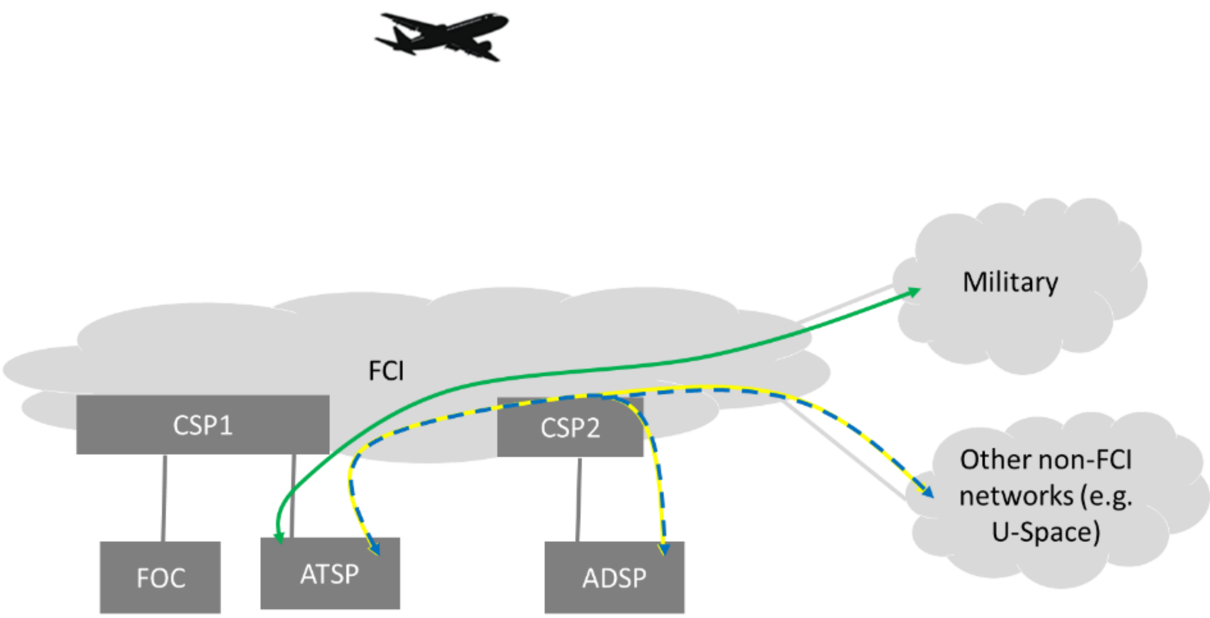


Figure 9 Information exchanges supporting TBO (example)

The actors present in the scenario are:

- ATSP, providing ATS services (AIS/MET, flight information) and end to end monitoring.
- ADSP, consolidating, disseminating and processing ATM information.
- FOC, providing AOC services to A/C and end to end monitoring.

- CSP(s), providing network connectivity and monitoring between ATSPs and ADSPs, or between ATSP or FOC, or between these and other entities located in non-FCI networks.

The support of new ATM concepts like TBO requires collaborative sharing of updates in ATM data including Shared/Reference Business Trajectory (SBT/RBT) flight plans, FF-ICE elements such as Globally Unique Flight Identifier (GUFI), Controlled Time of Arrival (CTA) updates, Extended Projected Profile (EPP), traffic flow and Demand Capacity Balance (DCB), and strategic/tactical conflict management. This information is processed, negotiated and disseminated among ADSP, ATSP and FOC involved in a flight planning and execution. In addition, aeronautical and weather information supporting TBO negotiation and selection needs to be updated and disseminated.

To support new airspace users such as RPAS, these information exchanges also involve the users of the appropriate networks such as U-Space. Exchanges between FCI users and other airspace users can involve ATM information disseminated by ADSP or ATSP, and external information (UTM/UTC) shared by the external airspace user which may affect ATM operations in the FCI airspace. In addition, civil/military coordination is achieved by supporting ATM information exchanges between ATSP and military users. For exchanges with external users, appropriate interfaces are in place.

Information exchanges with external networks also enable communication of A/C between FCI and non-FCI airspaces for air traffic handover situations (note that the particular case of handover between FCI and ATN/OSI or FANS1/A networks is part of 2.4.2.4):

- A/C entering the FCI airspace is handed over by entities providing ATS and/or FOC in non-FCI airspace. Appropriate exchange procedures with the interfaced networks facilitate the A/C handover.

- A/C leaving the FCI airspace needs information to communicate with entities providing ATS and/or FOC in a non-FCI network. Appropriate exchange procedures with the interfaced networks facilitate the A/C handover.

- A/C leaving the FCI airspace needs to communicate with a FOC in the non-FCI network. Traffic for relevant ATM services can be relayed over the interfaced network to maintain reachability with the A/C.

2.4.2.4 Ground accommodation of ATN/OSI and FANS1/A

This scenario represents the need to accommodate A/C equipped with ATN/OSI or FANS 1/A and communicate ATS services (B1/B2 or FANS) with ATC units which are ATSPs in the FCI. It also involves accommodation of IPS-equipped A/C in the FCI which need to communicate with ATSP using the ATN/OSI or FANS 1/A networks.

Figure 10 illustrates the two separate cases for ATN/OSI and FANS 1/A accommodation.

The actors present in the scenario are:

- ATSP, providing ATS services in the FCI backward compatible with ATN/OSI and FANS networks.

- CSP(s), providing network connectivity and monitoring between ATSP and A/C. Different CSPs may be responsible of the FCI and external networks. The ground accommodation is provided by at least one of the CSPs involved.

Note: When the ANSP provides ground accommodation directly, it is acting as a CSP in this scenario.

- Either IPS-equipped A/C over FCI-capable datalink, or A/C equipped with ATN/OSI stack over VDLM2 radio, or FANS 1/A stack over ACARS radio.

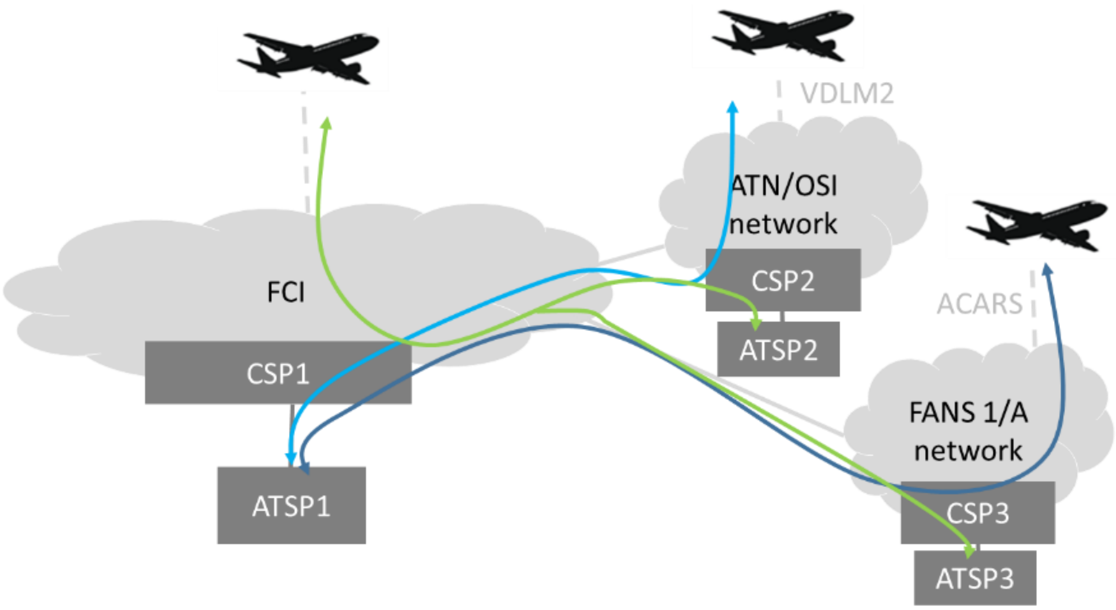


Figure 10 Ground accommodation of ATN/OSI and FANS 1/A (example)

During the transition to FCI, A/C fleets not yet equipped with IPS capability and IPS enabled datalink may need access to ATS services provided by ATSPs which are connected to the FCI and acting as ATSPs. This will ensure service is continued to legacy A/C if ground infrastructure transitions to ATN/IPS stack before avionics do. In an analogous way, ATSPs may be relying on ATN/OSI or FANS1/A networks during the transition phase.

Ground accommodation is expected to be provided by an application gateway located at the border between the FCI and legacy networks. This gateway acts as the IPS host for ATM services in the FCI, and as the ATN or FANS end system in the legacy network. More details about the gateway capability are given in 5.5.1.

2.4.2.5 Communication with commercial IP networks

In the future, fast and exponentially capable broadband air/ground datalink are expected to be available for supporting future ATM operations and air/ground data exchanges. These technologies are likely to rely on commercially available technologies such as 5G. FCI users may have the need to interoperate with these networks for the provision of ATM applications, considering proper security and safety restrictions. This area of research is being addressed by PJ.14-W2-61 “Hyper-connected ATM”.

3 ATM Applications over FCI

As outlined by the ICAO GANP, ATM Masterplan 2020 [6], and Airspace Architecture Study [4], the implementation of new operational concepts, such as Trajectory Based Operations, Flight Centric Operations and Dynamic Use of Airspace, relies significantly on the timely exchange of information between all participating actors, and especially on the exchange of information between air and ground. The use ATM Applications over datalink will therefore increase both in volume and scope. New ATM applications such as digital voice and future ATS Baseline 3 with potentially very stringent performance requirements will also require the support of datalink infrastructure. This section describes the support of these ATM applications by the FCI.

REQ-14-W2-77-OP-001	**The FCI shall support the communication of ATM applications between IPS hosts located in the ground infrastructure (G/G communications)**
REQ-14-W2-77-OP-002	**The FCI shall support the communication of ATM applications between IPS hosts located in the ground infrastructure and IPS equipped airborne systems located in aircraft mobile subnetworks (A/G communications) at all phases of flight while aircraft is located over the geographical coverage area**

The Future Communication Infrastructure supports ATM Applications with the necessary performance levels in order to ensure safety, security as well as flexibility and scalability in the provision of Air Traffic Control in particular, and Air Traffic Management as a whole. As a conclusion of Chapter 3, section 3.7 provides an initial proposal of categorisation of user applications/services based on their safety criticality and time-sensitiveness which drives the security, safety and performance requirements for the ATM applications.

3.1 FCI Upper Layers

The FCI is designed to provide connectivity to IPS hosts which implement the higher layer protocol stacks and ATM applications depicted in the logical architecture of Figure 2. Such protocol stacks are defined for specific applications with associated levels of safety and performance, and standardized to guarantee interoperability.

REQ-14-W2-77-OP-003	**The FCI shall interface with the following IP stacks:** **- ATN/IPS as per ICAO Doc 9896** **- SWIM Technical Infrastructure using Yellow, Blue, Purple-Advisory, Purple-Safety and Green Profile specifications** **- Native IP stack based on IETF RFC for ATM applications**

At this moment, the only defined protocol stack is specified for ATN/IPS and SWIM applications by ICAO Doc 9896 [9] and EUROCAE ED-262 Technical Standard of Aviation Profiles for ATN/IPS [10]. This stack supports two transport layer options for ATM applications:

- **Connection-oriented Applications.** Under this option, applications bind the end-to-end relationship (e.g. between a controller and pilot) to the transport connection, using the TCP protocol. The advantage is reliable delivery of packets to destination. The disadvantages are apparent when the communication link is degraded, which leads to session reestablishment and chain loss or delay of packets. Connection-oriented is usually more appropriate for transmission of heavier messages over stable connectivity (e.g. G/G communications) or which are not time-critical.
- **Connectionless Applications.** Under this option, applications operate UDP protocol or an enhancement of it. While the end users may be aware of an agreed relationship or context for the communications, the underlying communications services have no such awareness and each message is thus a separate and unique event. The advantage is that each message is delivered separately, making recovery faster in cases of degraded connectivity. The disadvantage is that delivery is not guaranteed, and thus application-layer mechanisms for message sequencing, acknowledgment and retransmission are needed. Connectionless is usually more appropriate for short, time-sensitive applications over dynamic communication links, e.g. ATS applications over A/G datalink.

The ATN/IPS network protocols defined by ICAO Doc 9896 and EUROCAE ED-262 specify the interface to higher layers of ATN/IPS for support of ATS services. In addition, they provide the network capabilities to support the SWIM technical infrastructure, and could eventually support other higher layer protocol stacks.

3.1.1 ATN/IPS

The ICAO Doc 9896 contains the minimum communication protocols and services that enable implementation of ATN based on IPv6. The Manual includes provisions for protocol interoperability, network administration, and instantiation of network functions such as security and mobility. In addition, it defines the ATN/IPS Dialogue Service (DS), which interfaces to upper ATN layers via the control function, and is a replacement of the ATN/OSI DS documented in ICAO Doc 9880. This approach minimizes the impact on the ATN applications, which are maintained from ICAO Doc 9880. The IPS DS maps TCP/UDP primitives to the ATN application DS interface as depicted in Figure 11.

In order to retain commonality with the ULCS dialogue service primitives described in Doc 9880, the IPS DS uses the same primitive names. These primitives allow peer communicating IPS nodes that support the DS functionality to:

a) establish a dialogue;
b) exchange user data;
c) terminate a dialogue in an orderly or abnormal fashion;
d) be informed of DS abnormal dialogue termination due to the underlying communication failure; and
e) be consistent with the appropriate use of the corresponding service primitives.

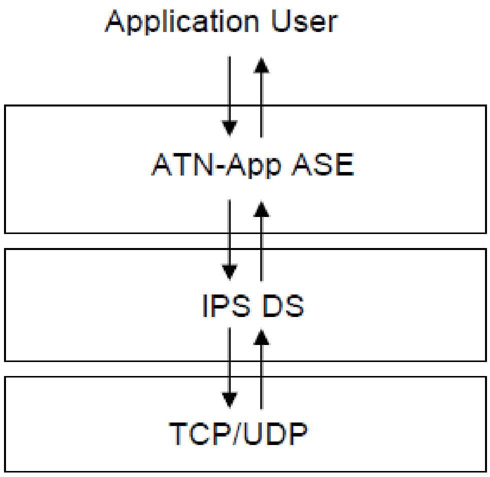


Figure 11 ATN/IPS Upper layers diagram

The ATN packet (ATNPKT) is defined with the purpose to convey information between peer DS-Users during the processing of a DS primitive. It is carried in the data part of the transport protocol (either TCP or UDP), and is used to convey parameters of the service primitives that cannot be mapped to existing IP or transport header fields. The ATNPKT will also convey information to indicate the Dialogue Service protocol function (e.g. the type of DS primitive). The IPS DS presents an identical interface of the Doc 9880 ULCS to the ATN applications. As such, the parameters of the IPS DS are identical to those of the ULCS, although there is a different mapping of the contents of those parameters.

The IPS DS has been designed to allow a user selection of either TCP or UDP for the transport protocol. As UDP does not guarantee the end-to-end service delivery of the datagrams, additional mechanisms are implemented in the IPS DS to address UDP limitations; basically the truncation, loss, or duplication of UDP datagrams.

3.1.2 SWIM Technical Infrastructure

SWIM defines a system-wide information management concept, where the information management solution is defined at the overall system level, rather than individually at each major subsystem and interface level, as has happened in the past. It consists of standards, infrastructure and governance enabling the management and exchange of ATM-related information between qualified parties via interoperable services (following a Service Oriented Architecture approach).

3.1.2.1 SWIM interoperability framework

The general SWIM interoperability framework (Figure 12) is defined in [11]. It includes information exchange standards and the infrastructure required to exchange information between SWIM-enabled applications, which use SWIM information services but are not part of SWIM.

At the **Information Exchange Services** layer, the characteristics of the requested information service are described in a technology-neutral manner. The definition of a standardized information service indicates: (1) what a service provides; (2) the service message (the structure of the message at the logical level); (3) the behavior; (4) the performance levels; and (5) how the service can be accessed.

At the **Information Exchange Models** layer, the characteristics of the data used by the information exchange services is described to include information content, structure and format, to support a mutually understood syntax and vocabulary. Examples are AIXM (aeronautical information exchange model), FIXM (flight information exchange model) and WXXM (weather information exchange models).

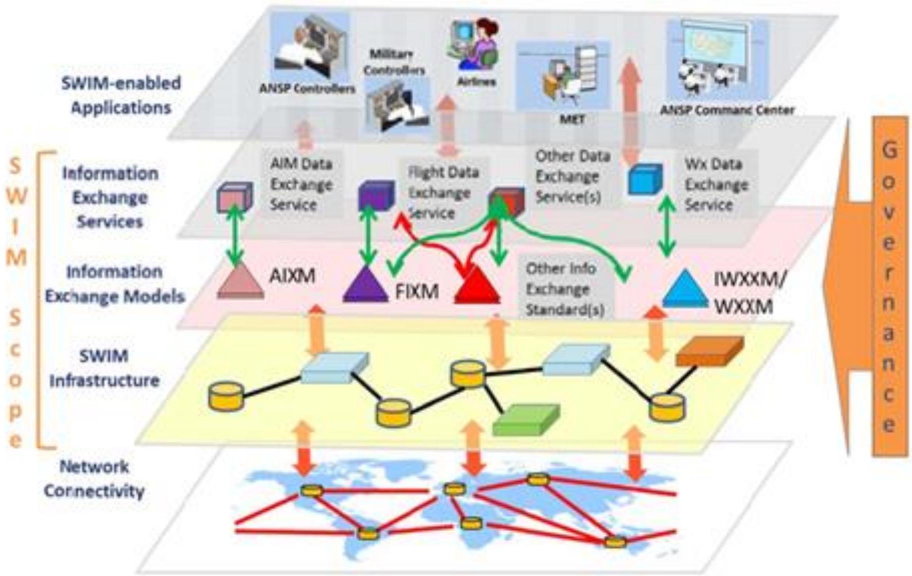


Figure 12 SWIM Global Interoperability Framework

The **SWIM Technical Infrastructure (SWIM TI)** layer provides core SWIM service functions such as:

- **Interface management** includes functions related to the SWIM registry, which maintains and exposes SWIM services.
- **Messaging** includes functions supporting message exchanges with a variety of relationships between message end-points including one-to-one and one-to-many. It enables message routing and the distribution of content, as well as functions for efficiently and reliably delivering that content across SWIM in a secure fashion. It includes functions to support synchronous and asynchronous information exchange.
- Service **security functions** are used to enforce security policies at the core SWIM services level. These functions include authentication, authorization, confidentiality, integrity, and access control functions. They can be applied at transport (e.g., using TLS) or message level.
- **Enterprise service management** supports the management of the information services. It includes the monitoring and control of faults, configuration, accounting, performance and security aspects.

A **SWIM access point** is a logical entity that bundles a number of technical capabilities (e.g., messaging, security, logging, interface management, etc.). The SWIM infrastructure is the collection of the SWIM access points. SWIM access points will be implemented by information providers and consumers.

The **Network Connectivity** layer (not part of SWIM) provides consolidated telecommunications services to transport the data. The FCI is a Network Infrastructure providing the capability to support SWIM applications and services over IPv6. Other public/private IP networks could also support SWIM applications and services over IPv4 or IPv6 (e.g., public internet for non-safety critical messages).

The **SWIM Infrastructure** layer can be implemented by a variety of middleware models and technology standards, which provide an appropriate communication layer abstraction to the applications using SWIM, supporting SOA principles and allow loose coupling of system components. These include SOAP web services, AMQP for asynchronous delivery (e.g. in degraded environments), and Data Distribution Service (DDS) for publication of data objects based on topics and with QoS support.

3.1.2.2 SWIM profiles

The SWIM interoperability framework described in section 3.1.2.1 does not prescribe or expect a single global implementation of the SWIM TI. A SWIM profile is a coherent, appropriately-sized grouping of middleware functions/services for a given set of technical constraints/requirements that permit a set of stakeholders to realize Information sharing. It also defines the mandated open standards and technologies required to realize this coherent grouping of middleware functions/services. Multiple SWIM TI Profiles can coexist, each of them with different scope and applicability.

Yellow profile (YP). The Pilot Common Project Regulation (PCP) EU 716/2014 requires the use of the SWIM TI Yellow Profile specification [12] for the implementation of a number of ground-to-ground exchanges, including:

- aeronautical information exchange
- meteorological information exchange
- cooperative network information exchange
- flight information exchange.

SWIM Yellow Profile is intended for SWIM services that do not require real-time or near real-time uses and do not demand a high availability. A representative implementation of YP is the Eurocontrol NM B2B web services. Conformance with the Yellow Profile requires support for one of ten defined service interface bindings, based on:

- **SOAP Web Services**
  - With different levels of functionality regarding security / message delivery reliability and supported message exchange patterns.
  - A lightweight version running directly on top of HTTP (without SOAP) is also included.
- **AMQPv1.0** messaging framework

Blue profile (BP). For ground/ground exchanges related to flight object and i4D Trajectory, the PCP EU 716/2014 requires the use of the SWIM TI Blue Profile (BP). The SWIM TI BP is an alternative specification to the SWIM TI YP focused on real time communications requiring extremely high availability. The BP has not yet been standardized.

Green profile (GP or YP+). The SWIM Technical Infrastructure Green Profile (GP) – also identified as Yellow Plus+ Profile - aims at supporting ground/ground civil-military SWIM-based non high-critical exchanges. The baseline for GP is the EUROCONTROL Yellow Profile (YP) specification. The GP encompasses Quality of Service (QoS) extensions to YP 1.0 to enable a wider scope of SWIM services requiring more security, resilience, performance (time-constraint SWIM services) and the support of sensitive data. Civil and military stakeholders willing to use SWIM services requiring this extended QoS should deploy GP SWIM nodes (technical systems). The GP is being researched under PJ.14-W2-101 and targeting TRL6 maturity.

Purple profile (PP). The purple profile has been defined to support A/G communications between the ground and the aircraft. It has been defined in PJ17.01 Wave 1 up to TRL6 to support advisory information (information not necessary for command and control of an aircraft, as for example meteorological information based on ED-151 or aeronautical information), with no real-time or near real-time uses.

In SESAR2020 Wave 2, it is being considered in PJ.14-W2-100 for supporting also safety-critical information (TRL4 is expected for the end of Wave 2). The purple profile could in the future support existing data link applications (e.g., “Purple Profile enabled CPLDC”, “Purple Profile enabled ADS-C”) or new applications that would support the profile natively. The Purple profile currently relies on the AMQPv1.0 messaging framework and supports security at different levels.

3.2 Air Traffic Services (ATS)

As defined by ICAO Annex 11 [13] , Air Traffic Services comprise the set of services provided in order to fulfil the following objectives:

a) prevent collisions between aircraft;

b) prevent collisions between aircraft on the manoeuvring area and obstructions on that area;

c) expedite and maintain an orderly flow of air traffic;

d) provide advice and information useful for the safe and efficient conduct of flights;

e) notify appropriate organizations regarding aircraft in need of search and rescue aid, and assist such organizations as required;

The following set of Air Traffic Services are defined in ICAO Annex 11:

1. **Flight Information Service (FIS)** - fulfilling objective d)
2. **Alerting Service** – fulfilling objective e)
3. **Air Traffic Advisory Service**
4. **Air Traffic Control (ATC) Service** -– fulfilling objectives a), b) and c)

Today these services are mainly provided via voice, and in some cases via datalink. While voice will continue to be used for provision of Air Traffic Services (specially for time-critical and non-routine messages as well as for communications with specific aircraft), SESAR Master Plan 2020 recognizes datalink as the main communication means for the provision of Air Traffic Services.

REQ-14-W2-77-OP-004	**The FCI shall support the following ATS services as per ICAO Annex 11:** **- Flight Information Service (FIS)** **- Alerting Service** **- Air Traffic Advisory Service** **- Air Traffic Control Service (ATS Baseline 2) applications as per EUROCAE ED-229**

3.2.1 Flight Information Service (FIS)

Flight Information Service is provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights. FIS commonly include aeronautical and meteorological services - AIS/AIM and MET services are specifically addressed in section 3.3.

A FIS may be provided on its own or in conjunction with an Air Traffic Control Service. In the second case, ICAO Annex 11 requires the provision of air traffic control service shall have precedence over the provision of flight information service whenever the provision of air traffic control service so requires. However, it is recognized that, in certain circumstances, aircraft may require to receive without delay essential information other than that pertaining to the provision of air traffic control service.

FIS include the provision of:

- Operational flight information Service (OFIS) broadcast
- Automatic Terminal Information Service (ATIS) broadcast
- VOLMET broadcast

FIS can be provided via HF/VHF voice channel or via datalink. Datalink Flight Information Services, such as D-ATIS and D-VOLMET allow a pilot to request and receive FIS from ground systems via data link.

3.2.2 Alerting service

Alerting service is part of air traffic service and is therefore provided by ATS units (e.g. area control centres, flight information centres, etc.). The main task is to promptly notify the appropriate organizations (e.g. Search and Rescue) about the situation and provide relevant information about the aircraft in distress.

3.2.3 Air traffic advisory service

Air traffic advisory services are provided on specific types of airspace, when no Air Traffic Control service is provided, to ensure separation, in so far as practical, between aircraft operating on IFR flight plans.

3.2.4 Air Traffic Control (ATC) Service

ATS Baseline 2 defines a set of ATC Services enabling initial Trajectory Based Operations (TBO) and convergent datalink standards supporting global operations. EUROCAE ED-228A [15] identifies three different datalink applications:

- **CPDLC - Controller Pilot Data Link Communication**

  The CPDLC application allows controller and flight crew to exchange information via data link. By using CPDLC, controller and flight crew can exchange messages for the following purposes: general information exchange, clearance delivery, request, and response, altitude/identity surveillance, monitoring of current/planned position, advisories request and delivery, system management functions; and emergency situations.

- **ADS-C - Automatic Dependant Surveillance – Contract**

  The ADS-C application allows the ATSU to obtain information from an aircraft on request, at a specified reporting interval, and/or when logic within the avionics triggers one or more different types of events. The information downlinked can contain one or more of the following data sets: projected profile, ground vector, air vector, meteorological information, extended projected profile, TOA range, speed schedule, RNP profile and final approach speed. Additionally, ADS-C provides functionality which allows the aircraft system to provide an emergency and/or urgency alerts to the ground.

- **CM - Context Management**

  The Context Management application provides initial manual "logon" capability to flight crew when entering an ATSU domain of responsibility. It should be noted that the CM services are not intended to achieve a certain operational goal rather CM is a pre-requisite for the use of CPDLC and ADS-C applications.

These three applications support the provision of ATS datalink services (Table 2 shows the supported ATS Baseline 2 services) and provides Safety and Performance Requirements (SPR) for the provision of such services. It is to be noted that these applications require integration with cockpit systems (e.g. FMS, HMI) and ground systems (e.g. FDPS, HMI) for the criticality of the continuation of the flight and need to be tightly controlled from interoperability, safety and performance perspective.

3.2.5 Use cases for ATS evolution

As traffic continues to increase and grow in complexity, operational actors (airlines, airports, networks, ANSPs, the military, etc.) will continue to seek new operational solutions that will help in dealing with the day-to-day challenges. The Connected Aircraft Concept [16] envisions datalink capabilities beyond current clearance support, to support advanced TBO concepts. The FCI should be designed with scalability in mind, in order to facilitate the compliance with increasing requirements in terms of performance and resilience and support the implementation of future operational solutions.

In terms of ATS evolution, it is important to note that ED-228A [15] defines the ATS B2 Services associated with the three data link applications defined in ICAO Doc 9880 [17] and included in ICAO Doc 9896 [9] as legacy ATN applications. New ATC Services, or a different combination of the ones defined in ED-228A, could be envisaged to be associated with a new set of Data Link applications (e.g. future ATS B3). In this context, it is assumed that new ATS Data Link applications will be defined as ATN/IPS and included in ICAO Doc 9896, or will be IPS native. The following use cases have been identified for the provision of current and future ATS over the FCI (Figure 13):

- ATS over ATN/IPS Dialog Service. This is the case for current ATS B2 applications.
- IPS Native ATS. This may be the case for future ATS applications (e.g. ATS B3).
- ATS over SWIM. This may be the case for future ATS applications (e.g. ATS B3).

REQ-14-W2-77-OP-005	**The FCI shall be capable of supporting evolution of ATS Baseline 2 for support of Trajectory Based Operations (TBO), including ATS Baseline 3**

ATS Baseline 2 services		Datalink Applications		
		CM	CPDLC	ADS-C
DLIC	Data Link Initiation	√		
ACM	ATC Communications Management		√	
CRD	Clearance Request and Delivery		√	
AMC	ATC Microphone Check		√	
DCL	Departure Clearance		√	
D-TAXI	Data Link Taxi		√	
IER	Information Exchange and Reporting		√	√
PR	Position Reporting			√
4DTRAD	4-Dimensional Trajectory Data Link		√	√
ITP	In Trail Procedure		√	
IM	Interval Management		√	√
OCL	Oceanic Clearance Delivery		√	
DRNP	Dynamic Required Navigation Performance		√	√

Table 2 Provision of ATS Baseline 2 services by datalink applications

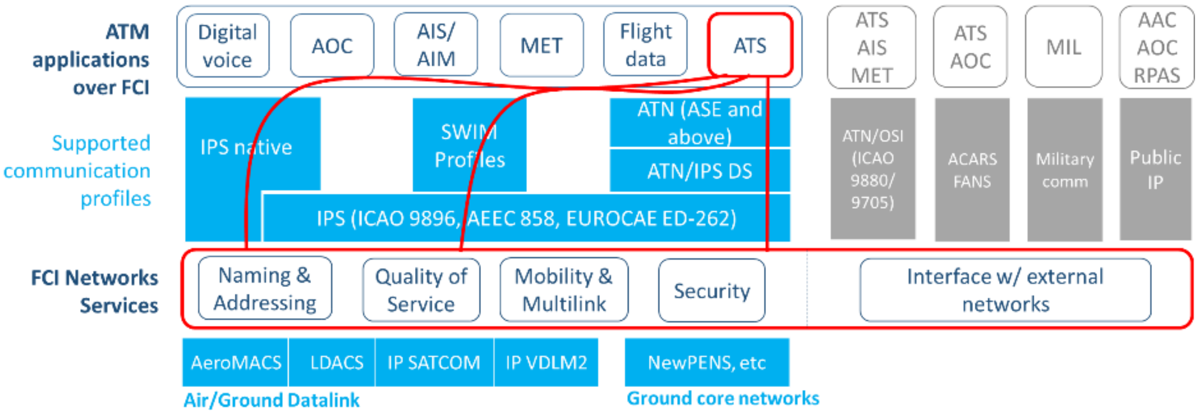


Figure 13 FCI use cases for ATS

3.3 AIS/MET Datalink Services

The availability of timely, accurate and relevant Aeronautical Information Services (AIS) and Aviation Meteorological (MET) information in the cockpit is critical to the safe, regular and efficient conduct of flight. The ability to create an accurate temporal aeronautical information environment shared by all relevant actors involved (Aircraft, FOC, WOC, ATSU, ADSP and NM) constitutes an essential component of the future ATM system [6] and therefore the Future Communications Infrastructure needs to support the continuous update of AIS/MET data via datalink exchanges between aircraft and ground systems.

The SESAR Aeronautical Information Management (AIM) and Meteorological Information Management concepts align with the ICAO Roadmap for the transition to a data sharing framework through the ATM network for aeronautical and weather information which targets high levels of timeliness, interoperability and accuracy. The future aeronautical/weather information management concept relies on SWIM and common data formats (e.g. AIXM, WXXM) for interoperable data dissemination.

Datalink services incorporating AIS and/or MET information have been defined by in ED-151 [18] and Safety and Performance Requirements are defined in ED-175 [19]. EUROCAE WG-76 and RTCA SC-206 are currently working on refinement and update of service definitions for AIS/MET services. As defined in these standards, datalink services incorporating AIS and/or MET information are intended for:

1. Pilot decision support;
2. Collaborative Decision Making between ground services, the flight deck, Air Traffic Control (ATC) and, as appropriate, Flight Operations Centres (FOCs) in all flight environments for flight efficiency and/or hazard avoidance.

REQ-14-W2-77-OP-006	**The FCI shall support the following AIS/MET services as per EUROCAE ED-151:** **- AIS: Aeronautical Update Service, Baseline Synchronization Service** **- MET: WPDS, WNDS, WIDS, Weather downlink**

The operational deployments of AIS/MET data link systems may incorporate combinations of AIS and MET information derived from several AISLINK/METLINK services. Under such circumstances, the Safety and Performance requirements describing the capabilities of the datalink would be driven by the most stringent requirements of the services offered over that link. Some AIS/MET services can be provided in the context of ATS (e.g. ATS Baseline 2 IER service is used to send SIGMET reports) over ATN/IPS while others can be AOC services over SWIM or native IP applications.

ED-151 and ED-175 define four different transmission modes that may be used for transmitting AIS and MET information (Table 3). The modes below refer to high-level functionality and are agnostic from underlying datalink and network architecture. The FCI could provide such capabilities via different technical solutions.

AIS/MET Transmission modes at application level	
Broadcast Data Link	A broadcast data link provides continuous, repeated transmissions of AIS/MET information to all aircraft within communications range. The broadcast network has no knowledge of which aircraft are receiving the data link transmissions. To receive AIS/MET information from a broadcast data link, no specific pilot action is required other than to turn on the data link radio receiver. If acknowledgement is required, it may be handled via voice or other appropriate communication.
Demand Data Link (Two-Way)	The demand mode requires a two-way data link system. It provides the opportunity to make an individual request for specific data link information and then receive a single response of the requested information. The request may be through individual pilot action or automatically generated by cockpit avionics based on pilot preferences. If the Demand includes requests for multiple types of information, the request may also specify a priority of need for the different information types.
Downlink Data Link	The downlink mode supports the transmission of AIS/MET information from an aircraft to the ground. Downlink transmissions are automated and may occur on a time-controlled, altitude-controlled, distance-controlled basis or be event-driven. The basis for the occurrence of downlink transmissions is normally pre-programmed but may be specified (or changed) through a ground initiated Demand request if a command and control capability has been established.
Crosslink Data Link	The crosslink mode supports the transmission of AIS/MET information from an aircraft to other aircraft in the vicinity. *NOTE: FCI ConOps supports IPS communication between air and ground IPS hosts, thus AIS/MET transmission mode relies on a ground IPS host.*

Table 3 AIS/MET Transmission modes at application level

3.3.1 AIS Services

ED-151 [18] defines evolutionary steps necessary to implement the real-time distribution of aeronautical information through the establishment of AIS data link services (AISLINK). The intent is to augment and eventually replace the current AIRAC system based on the 28-day cycle and textual NOTAMs. It is also envisaged that, in addition to current aeronautical data, additional data, such as airport mapping databases, may be made available and considered for the AIS data link services. Two different types of AIS data link services are defined in ED-151.

3.3.1.1 Aeronautical Update Service

The Aeronautical Update service is a datalink service that provides both permanent and temporary changes to the cockpit throughout the 28-day AIRAC cycle where the pilots or on-board systems can then include that information in their decision making process. The Aeronautical Update service does not physically modify or change any data contained within the on-board navigation or charting databases, but provides up-to-date data that may supplement the data contained in those databases.

The objective of the Aeronautical Update Services is that ATM community members on the ground and in the air work based on a common data set and share situational awareness, providing for a more effective collaborative decision making.

The timely availability of digital Aeronautical Updates is intended to replace the current means of disseminating permanent and temporary changes (e.g., paper NOTAM), allowing on-board avionics to display the data either as text or as a graphic overlay to the baseline. For aircraft not equipped with datalink, currently existing procedures for exchanging aeronautical data, (e.g., VHF voice communication, NOTAM, and ATIS) will continue to exist.

Various aeronautical information intended for both pre-flight and inflight use are included in the Aeronautical Update Service description (Table 4). Aeronautical information datalink update is relevant to enhance flight safety and will mitigate the risks associated with events such as runway incursions, pilot deviations into Temporary Flight Restriction/Temporary Segregated Areas airspace, or flying without complete and current aeronautical information. Detailed use case scenarios of Aeronautical Update Service are further described in ED-151.

Special Use Airspace (SUA) - *[including Temporary Flight Restriction/Temporary Segregated Areas]*
NOTAMs
BIRDTAMs
SNOWTAMs
ASHTAMs
Airport surface moving map
Global Navigation Satellite System (GNSS) outage depictions
alternate airport diversion information
noise-sensitive environmental impact areas

Table 4 Aeronautical Update Services: List of possible Aeronautical Updates

3.3.1.2 Baseline Synchronization Service

The Baseline Synchronization service refers to the update via datalink of aeronautical data that is resident in the aircraft's on-board database(s). Currently, most databases on board aircraft are maintained under the ICAO AIRAC system and need to be uploaded manually to aircraft every 28 days. Baseline synchronization provides for more frequent updates of the on-board database but not necessarily on a regular cycle. This concept breaks the paradigm of the 28-day cycle, with the intention of laying the foundation for future real-time provision of aeronautical data.

Two different operating principles are applicable to the use of the Baseline Synchronization service:

a. Complete Sync, which replaces an entire database in the Aircraft Data System

b. Update Sync, which contains only the aeronautical information that has changed since the previous sync specific to the dataset.

It should be noted that Complete Sync may require extensive data link capacity since it involves the upload of potentially large amounts of data. It is envisioned that Update Sync would be the preferred method of maintaining the on-board databases, thereby minimizing data link usage. Complete Sync is envisioned to be primarily used while the aircraft is on the ground.

3.3.2 MET Services

A broad portfolio of Aviation Meteorological (MET) products and services is used by pilots to support aircraft operations as described in ICAO Annex 3, Meteorological Service for International Air

Navigation. Today, MET information is mainly provided in paper form for pre-flight planning and by voice radio contact during flight. Once pilots depart the briefing environment and, with the exception of broadcast information obtained from the ATIS, VOLMET, D-VOLMET and similar services, they generally lack the means to access timely and up-to-date MET information. This lack of availability has significant consequences in terms of enhanced flight safety, efficiency, and economy. Similarly to AIS, the ability to have in-flight access to MET information that was previously available only during pre-flight briefings will also greatly enhance Collaborative Decision Making processes in ATM.

Meteorological data link (METLINK) services providing timely distribution of MET information both to and from aircraft will support pilot decision applications (i.e., flight planning decisions, near-term decisions and/or immediate decisions) as well as provide aircraft MET data for use by aircraft in the vicinity and for use in ground weather applications and interpretation by computer-based systems. ED-151 proposes 3 categories for Pilot Decisions supported MET services (Table 5).

A non-exhaustive list of possible MET Datalink service products is provided in Table 7-1 in ED-151 (Table 6). The table identifies the service suitability for each of the decision support classifications, which are dependent on the intended application and human factors considerations. An extract is provided below.

MET Service	Pilot Decision Support time	
Weather Planning Decision Service (WPDS)	> 20 min	Planning decisions relate to a longer time horizon where pilots have the time to deliberate and perhaps coordinate with ATC/AOC prior to taking action on a new or revised piece of information received from any source (in this context, via data link). Pilot action resulting from a planning decision is usually a change in routing or altitude in advance of a potential impact or opportunity related to the current planned flight trajectory. Time is available to identify and evaluate alternative courses of action, and to seek additional information to support the decision.
Weather Near-Term Decision Service (WNDS)	3 min < 20 min	Near-term decisions are of a planning nature, but with limited time available for comprehensive deliberation and/or coordination with ATC/AOC. They become more of a “tactical” nature when new METLINK information reveals hazardous or adverse conditions close to the aircraft’s current position. Near-term decisions can take the form of reroutes, altitude changes, or operational status changes such as alerting and securing the aircraft cabin prior to a possible encounter with turbulence. There is usually time to identify and evaluate available alternative courses of action, and perhaps to seek additional information. Near-term decisions are made mostly to address the safety benefits described in ED-151 Section 3.1.
Weather Immediate Decision Service (WIDS)	<3 min	Immediate decisions are those taken by the pilot within a few seconds to 3 minutes in order to avoid or mitigate an in-flight hazard, or to make a commitment to land or take off. They are generally unilateral decisions made by the pilot with very little or no deliberation. Such decisions are generally rule-or procedural based in nature.
Weather Downlink and Crosslink Service	-	In addition to METLINK transmissions of meteorological information to aircraft, aircraft can be used to carry sensors to detect and report meteorological and other environmental information and transmit that information to the ground and other proximate aircraft. Parameters such as temperature, wind, humidity, turbulence, icing conditions, volcanic ash, and other aircraft parameters as appropriate for wake vortex avoidance can be transmitted.

Table 5 MET services for pilot decision

Candidate METLINK Product	MET Data Category	Pilot Decision Support			Refresh Rate (+)	Validity (hours)	Common Usage Category (#)			
		WPDS	WNDS	WIDS						
Aerodrome Information										
* METAR	P	X	X		24-48	0.5-1	A	B		D
* SPECI	P	X	X		24-48	0.5-1	A	B		D
* Local Special Report	P	X	X	X	24-48	0.5-1	A	B		D
* Local Routine Report	P	X	X	X	24-48	0.5-1	A	B		D
* Trend Forecast	P	X	X		24-48	0.5-1	A			D
* TAF	P	X			1-6	6-30	A	B		D
Aerodrome Forecast - Tabular form	P	X			1-6	24				
Local Area Forecast	T	X			1-4	6				
* Aerodrome Warning	T	X	X		0-12	12				
* Wind Shear Warning	T		X	X	24-48	0.5-1				
* Forecast for Take off	P	X			48	0.5	A	B		
* Actual QNH	P	X	X		24-48	0.5-1				

Legend

MET Data Category		Pilot Decision Support Product Classification		Common Usage Category (circa 2007/8)	
P	Point Data	WPDS	Planning	A	Preflight planning
T	Text Area	WNDS	Near-Term	B	Displayed for crew and operators
V	Vector Graphic	WIDS	Immediate	C	Low level flight
G	Gridded Data			D	In-flight

Table 6 Extract of Table 7-1 in ED-151 (showing only Aerodrome Information Products)

3.4 Aeronautical Operational Control (AOC)

Airlines rely on AOC for communication between the flight crew and the Airline's Operational Control Centre (AOC) for flight regularity and efficiency purposes. AOC is also used by the flight crew to request weather information at airports or NOTAMs. AOC applications use either voice or data communication between the aircraft and the AOC centre, company, or operational staff at an airport. AOC communications are identified as necessary for continued efficient operation by airspace users. AOC services are concerned with the safety and regularity of flight and as such are defined in ICAO Annex 10 [13].

It is recognized that the number of AOC messages exchanged between flight crews and AOC, as well as their size will continue increasing and therefore the FCI neds to provide for the necessary means to accommodate potentially high bandwidth demanding AOC data without prejudice to ATS other safety critical services.

REQ-14-W2-77-OP-007	**The FCI shall support Aeronautical Operational Control (AOC) services**

The SESAR Study - AOC Datalink Dimensioning [20] provides an exhaustive analysis of identified AOC services (Table 7).

Identified AOC Datalink Services		
AOC Data Link Logon (AOCDLL)	Airline Aircraft sequencing	FMC AOC reports
Out-Off-On-In (OOOI)	Airport Delay information	FMC PRG Progress Report
Notice to AirMan (NOTAM)	Airworthiness Statement	Flight Crew Recency Registration
Free Text (FREETEXT)	Autoland Registration	Flight Deck Duty Time Registration
Textual Weather Reports (WXTEXT)	Baggage Loading	Flight Journal Documentation
Position Report (POSRPT)	Catering inventory	Flow Control (CTOT & Routing)
Flight Status (FLTSTAT)	Central Maintenance Computing System	FOQA Data Transfer (DFDR/QAR bulk data download)
Fuel Status (FUEL)	Climb Wind Uplinks	Fuel Tickets / Fuel Release
Gate and Connecting Flight Status (GATES)	Company NOTAM's	Handling process Monitoring
Engine Performance Reports (ENGINE)	Company NOTAM's	Hijack report
Maintenance Problem Resolution (MANTPR)	Credit Card Authorisation service	In flight preparation of next Flight plan
Flight Plan Data (FLTPLAN)	Crew Briefings/Bulletins	In flight, Flight plan destination renegotiation
Load Sheet Request/Transfer (LOADSHT)	Crew List	Landing Performance Calculation
Flight Log Transfer (FLTLOG)	Crew Rotation / Planning / Scheduling	Load documentation Acceptance/Rejection - e-signature
Real Time Maintenance Information (MAINTRT)	Delay Reports (Departure, Takeoff, Enroute, Gate)	Notice to Captain (NOTOC)
Graphical Weather Information (WXGRAPH)	De-Icing Request	On Board video
Real-time Weather Reports for Met office (WXRT)	Descent Wind Forecast	On ground 4D Business Trajectory negotiation
Technical Log Book Update (TECHLOG)	Diversion message	Optimisation of Flight Plan and Information on Weather and traffic Information
Cabin Log Book Transfer (CABIN LOG)	Electronic Flight Folder	Passenger Medical Examination
Update Electronic Library (UPLIB)	Electronic Airway bill	Passenger Information List/Manifest
Software Loading (SWLOAD)	Emergency Data Transfer	Pre-Flight Inspection Signoff
AOC Link Test (Company link Test)	Emergency Report	SIGMET update
Air-to-Air Free text	ETA	Software Loading (Part 25)
Aircraft Briefing Cards	ETA Management	Software configuration management

Identified AOC Datalink Services		
Aircraft Conditioning Monitoring System	ETS Report	Takeoff Performance Calculation
Aircraft Door movements	Enroute Wind Uplink	Transfer Passenger Information
Aircraft Health Management (monitoring)	ETOPS monitoring	Turbulence reporting
Aircraft Rotation/Flight Progress	e-Charts Update	Marketing Announcements
Aircraft Technical Log Rectification	e-Graphical Weather	Passenger e-mail/text messages
Aircraft Telemetry service	e-Reporting	

Table 7 Identified AOC Services

A number of AOC services are used to exchange AIS/MET information such as NOTAM, WXTEXT (used for METARs and TAFs) SIGMET update. As discussed in section 3.3, AIS/MET services may have significant influence on safety of flight. The compilation of QoS requirements for AOC and AIS/MET services needs to take into account these cases and identify the appropriate prioritisation mechanism (e.g. DSCP), if necessary to differentiate AIS/MET from AOC services at network level. Additionally, there are AOC services, such as 'Airline aircraft Sequencing' or 'De-Icing Request', which have a direct impact on ATC provision and therefore may grant for a higher priority treatment at network level.

3.5 Digital voice

FCI is expected to support digital voice communications for the provision of ATS, and possibly AOC. A summary of the current voice operations, and status of future voice concepts are outlined in this section. A revision of the FCI ConOps (this document) is intended at the end of PJ.14-W2-77 to describe the Digital Voice operating concept.

REQ-14-W2-77-OP-008	**The FCI shall support Digital Voice (requirement to be refined)**

3.5.1 Overview on current voice operations

This section describes the current concept of operations and procedures in place for ATS voice communications, and is intended as background information for the development of A/G digital voice.

The Aeronautical mobile service (air-ground voice communications) is currently provided over VHF, HF and Satellite Voice technologies, while the Aeronautical fixed service (ground-ground voice communications) is currently provided via dedicated G/G voice connections and over IP networks using VoIP. Figure 14 shows an example of different environments and control areas where voice communications take place.

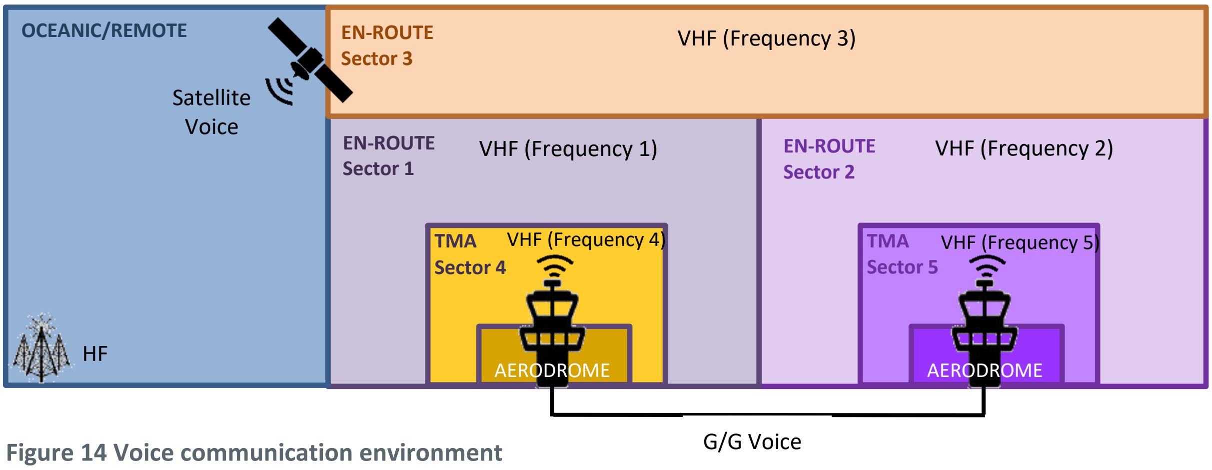


Figure 14 Voice communication environment

3.5.1.1 A/G Voice Communications

ATS operations in controlled airspace are based on continuous two-way radio communication between pilot and controller. ICAO Annex 11 [13] requires air-ground communication facilities to enable two-way communications between a unit providing Air Traffic Control service and appropriately equipped aircraft flying anywhere within a given control area. Whenever practicable, the two-way communication should be "*direct, rapid and continuous*". Further details on Voice Communication Systems can be found in ICAO Annex 10, Volume III, Part II.

Continental airspace and Airport operations

On continental airspace, and according to each ANSP frequency planning, each airspace sector (En-Route/TMA) or aerodrome service (Ground control, Apron control, Delivery) has a VHF frequency assigned. Aircraft flying in a given sector or making use of a given aerodrome service need to use the defined frequency for receiving and transmitting voice communications. Currently deployed and operational radiotelephony VHF technology provides quasi-instantaneous transmission over the air from radio equipment to aircraft.

It is important to note that all information exchanged over a given frequency between controller and pilot, or between pilot and pilot is open to all other aircraft flying in the same sector, thus enhancing situational awareness. In addition, pilots are aware of the frequency usage, which minimises the chances of simultaneous transmissions.

Oceanic or Remote airspace

Air Traffic Control over oceanic or remote areas may, due to lack of VHF coverage, involve voice communication over satellite or over HF frequencies. Aircraft stations are required, if possible, to communicate directly with the air-ground control radio station. If unable to do so, aircraft stations shall use any relay means available and appropriate to transmit messages to the air-ground control radio station.

When operating over HF frequencies, the direct pilot-to-controller relationship that occurs on VHF air-ground channels is often replaced by communication through a communications operator. Use of SELCAL (Selective Call) is described in ICAO Annex 10 Volume II.

3.5.1.2 A/A Voice Communications

Although very rarely used, aircraft flying in the same sector (and therefore tuned to the same frequency) are technically able to communicate among themselves over the frequency in order to exchange messages related to safety and regularity of flight. In such cases, the duration of communication is controlled by the aircraft station which is receiving and the aeronautical station maintains watch on the frequency. A/A voice communications generally make use of specific voice channels allocated in 123.45 MHz (for oceanic airspace in line with ICAO provisions) or in state-allocated frequencies (for continental airspace). The latter assignments are intended for General Aviation in non-controlled airspace, or in special events, and are not aimed to provide line pilots a frequency for private talks while crossing a sector.

3.5.1.3 G/G Voice Communications

The telephone call types needed to meet the operational ground communications requirements of ATM are known as 'primary user ground telephone facilities', and are used for routine and urgent communications between ATS units.

The operation of primary ground telephone facilities between ATS units for ATC purposes is described in Annex 10, Volume III, Part II. Further details on G/G voice communications can be found in ICAO Doc 9804 – 'Manual on ATS Ground-Ground Voice Switching and Signaling' for legacy technologies and in EUROCAE ED-136, ED-137 and ED-138 standards for implementation of ATM VoIP on the ground. These standards include supplementary ground telephone facilities defined in order to support primary ground telephone facilities (e.g. call identification, call priority, call intrusion or conferences).

3.5.2 Digital Voice in SatCom: current status and plans

This section does not intend to provide a definition of operational concepts for Digital Voice over SATCOM, but rather an overview of the implementation currently in use for procedural airspace (oceanic and remote) over the SATCOM air-ground datalink, in preparation for a future update of this document. An evolution of this implementation, with the goal of becoming a full alternative to HF Voice for oceanic and remote continental airspace, is in fact currently under study in the SESAR 2020 PJ.14-W2 Solution 107 "Future Satellite Communications Data link". It is however premature, at the time of writing of the first edition of the FCI ConOps, to integrate any consideration or result of this research.

In PJ.14-W2 Solution 77 we foresee an update of the FCI ConOps (this document) near the end of the project (Q3 2022), with the goal to incorporate the relevant results of the works conducted on Digital Voice by the other SESAR 2020 projects, which, like Solution 107, run in parallel and foresee research activity on this topic.

Existing AMS(R)S systems have been using digital voice for three decades. The predominant operational use is still based on **ground-to-air 2-stage dialing via radio operator**:

1. Air traffic controller calls a "radio operator" and explains which aircraft they need to call and what they need. (e.g. change flight level or request some report.)
2. The radio operator calls a 2-stage dialing gateway at a SATCOM Service Provider used by the aircraft (Inmarsat or Iridium).
3. After reaching the gateway the operators proceed according to instructions to identify themselves and to enter the phone number (ICAO address) of the aircraft they want to reach.

4. After getting connected to the cockpit, the operator and pilot perform the actual call.
5. After finishing the call, the operator notifies the controller about the outcome of the call.

Similarly, in the air-to-ground direction the pilots should typically call the radio operator rather than ATC directly “unless urgency of the communication dictates otherwise” according to ICAO NAT SUPPS. (But there is no 2-stage dialing in air-to-ground direction.). This practice is now migrating towards **1-stage dialing and Direct Controller-Pilot Communication (DCPD)**, where controllers call pilots directly.

Both SSPs (Iridium and Inmarsat) have historically been using bespoke circuit-switch digital voice protocols and codecs on the air-ground link and PSTN on the ground-ground links. The ground-ground links operated by CSP (SITA, Collins) are now migrating towards VoIP. With the arrival of Inmarsat’s SB-Safety and Iridium’s Certus services, the two cockpit voice channels are also migrating towards a combination of circuit switch (1st channel) and VoIP (2nd channel) or 2x VoIP on the air/ground link. Nevertheless, it needs to be noted, that the choice of VoIP vs. CS voice on the air-ground link is driven primarily by the nature of the new systems, which are designed primarily to support IP data services. A bespoke CS voice is (and always will be) more bandwidth efficient than VoIP. It also needs to be re-emphasized, that the use of any particular technology on the air-ground and ground-ground links is independent and none of the currently foreseen concepts for cockpit voice services assumes the use of end-to-end VoIP (i.e. all combinations of ground-ground VoIP or PSTN with air-ground VoIP or CS are supported and are transparent to the users). End to end VoIP calls can still be made using the native non-safety IP services of the SATCOM systems (e.g. use the onboard IPv4 service to connect from a laptop to a Skype, Teams, ZOOM or other type of call).

3.5.3 Digital Voice in LDACS: current plans

This section does not intend to provide a definition of operational concepts for Digital Voice over the LDACS air-ground datalink, but rather an overview of what is currently envisaged by the LDACS Standardization process, which will be further developed by the SESAR 2020 Wave 3 “LDACS Complement” Solution.

In the current version of the LDACS A/G Specification, which is foreseen to serve as the basis for developing the future LDACS Standards, the use of virtual voice circuits is envisaged for supporting Voice Interface (VI) Services, which may either be set-up permanently by the GS (e.g. to emulate voice party line) or may be created on demand.

At the time of writing of the first edition of the FCI ConOps (this document), though, the development of the ICAO LDACS Manual is work in progress and it is premature to make any assumptions about the LDACS digital voice capabilities. The SESAR 2020 Wave 3 “LDACS Complement” Solution is tasked to research the possible implementations, including those based on VoIP, and their technical feasibility.

In PJ.14-W2 Solution 77 we foresee an update of the FCI ConOps near the end of the project (Q3 2022), with the goal to incorporate all relevant results of the works conducted on Digital Voice by the other SESAR 2020 projects, which, like the Wave 3 “LDACS Complement” Solution, run in parallel and foresee research activity on this topic.

3.6 Flight Information exchange for Trajectory Based Operations (TBO)

According to the ICAO TBO Coordination Document [21] (to be published as ICAO Doc 10130), the introduction of TBO is subject to an evolutionary but phased process during which there will be a mix of capabilities and performance levels both from the aircraft's perspective as well as from the ATM service provider's perspective. The TBO concept assumes that such a mixed scenario will evolve as ATM service providers, aircraft, and their FOCs adopt capabilities as dictated by ATM performance needs. The evolution towards TBO is expected to align with the deployment of Aviation System Block Upgrades (ASBU) as described in the "Global Air Navigation Plan", (ICAO Doc. 9750). As the system evolves, some key properties of this evolution are:

a) Pre-Departure Trajectory Information Sharing & Negotiation - The sharing and management of trajectory information provides consistent information which allows the use of each flight's Agreed Trajectory as a unique, common reference for decision-making across concept components. The Airspace User develops trajectory preferences while understanding known constraints and shares a trajectory with the ATM Service Providers. These preferences can also include one or more (alternative) trajectories. For AUs that are not participating, the automation of the service provision would develop a more detailed trajectory based upon known information such as that contained in a flight plan. CDM processes are applied to manage trajectory information. CDM is not limited to any specific domain such as an airport or en-route. As connected aircraft emerge, negotiation will begin to involve the flight deck. This will also allow the flight deck to incorporate known, evolving constraints into the aircraft-derived trajectory.

b) Post-Departure Trajectory Information Sharing & Negotiation - While the Agreed Trajectory provides a common intent to be achieved, the process by which this trajectory is delivered is through the provision of clearances by Air Traffic Control (ATC) which are accepted and executed by the flight crew. In addition, the Agreed Trajectory is revised to include a controlled time to synchronise the arrivals and TS controls to this time. Coordination between systems allows each GATMOC Component to meet their objectives through a single consistent set of trajectory information. Post-departure trajectory sharing and negotiation between the ATSP and the AU FOC may also allow the meeting of additional regulations in specific situations (e.g. regulation of out-of-area traffic as validated to V3 by PJ.25 – Cross Border SESAR Trials for Enhanced Arrival Management). The "Manual on Flight and Flow Information for a Collaborative Environment (FF-ICE)" (ICAO Doc. 9965) describes the end state of this sharing environment.

c) Air-Ground Trajectory Synchronisation- An initial level of synchronisation between airborne and ground systems is realised by sharing the airborne trajectory prediction (by use of ATS Baseline 2 ADS-C and CPDLC applications). This will enable improved and consistent trajectory predictions, sharing of feasibility of constraints, detection and resolution of inconsistencies and therefore be the basis for further improvements leading to efficiency and productivity gains. In the longer term, the goal is the integration of the air (FMS) and ground -predicted trajectory through data communication clearance delivery and loading of clearances dictated by agreed trajectories into aircraft automation. This capability will require a wider set of instructions than what is available today in CPDLC clearances, including time, vertical and speed constraints.

ICAO Doc 9965 [22] describes the flight information sharing concept between members of the ATM community, which constitutes the necessary basis for the development of 4D Trajectory management.

FF-ICE is considered one domain of the collaborative environment, others being aeronautical information (AIM), meteorological information (MET) and surveillance data. FF-ICE will provide the ability to share the same flight information across collaborating participants before and during a flight, and is intended to replace all existing data message formats between ATM community members about flight intent and progression. This flight information is structured into the following groups of data elements:

a) flight identifying information; information to help identify the flight, airframe and participants. Globally Unique Flight Identifier (GUFI) will allow all (with appropriate access rights) to view or modify information related to the same flight;

b) flight SAR information;

c) flight permission information; information on requested and granted permissions and qualifications.

d) flight preference information; information on constraints and preferences expressed by the airspace user. Constraints expressed by an airspace user must be complied with by the ATM Service Provider, but meeting overall system performance takes precedence over these preferences.

e) flight trajectory information (performance information is organized within the trajectory recognizing that flight performance capabilities may differ at different segments along the trajectory);

f) additional information.

FF-ICE relies on a supporting SWIM environment, which forms the technical basis for information management of the entire ATM system and be essential for its efficient operation. Communication functions supported by a standard IPv6 ATM network enable the information flows between FF-ICE stakeholders (e.g. Airspace Users, airport users, ATM Service Providers such as ANSPs), on the national, sub-regional, or regional level. With the FF-ICE concept, data volumes and the level of automation will continue to increase to support the higher levels of coordination and collaboration in the future operational environment.

REQ-14-W2-77-OP-009	**The FCI shall support exchange of flight information for support of the FF-ICE concept for Trajectory Based Operations (TBO)**

3.7 ATM application categorisation based on criticality

The ATM applications described in this ConOps will rely on the FCI to provide the necessary means for A/G and G/G data exchanges. It is thus crucial that the FCI provides an appropriate level of safety and performance, in line with the requirements of the above mentioned communications. The FCI implements the necessary traffic prioritization mechanisms (section 5.3) in order to guarantee the timely delivery of safety critical applications data and to provide efficient traffic management for the rest of ATM applications.

	Tactical	Strategic
Safety-Critical	ATS - Future ATS-B3[5] - ATS-B2 (CM, CPDLC, ADS-C) - FIS - Alerting Service AIS/MET - Aeronautical Update Service (D-AUS) - WIDS - WNDS Flight information for TBO (may be supported by ATS B3) - Post-Departure Trajectory Information Sharing & Negotiation - A/G trajectory synchronisation Digital Voice AOC - Emergency Report, Emergency Data Transfer)	ATS - Air Traffic Advisory Service - Civil/Military Coordination AIS/MET - Baseline Synchronization Service - Ground AIM and MET dissemination Flight information for TBO - Pre-Departure Trajectory Information Sharing & Negotiation AOC - Flight plan, FOQA, AIS/MET information like NOTAM, weather report
Non Safety-Critical	AIS/MET - WPDS AOC[6] - Airline Aircraft Sequencing, De-Icing Request	AIS/MET - Weather Downlink and Crosslink Service AOC - Crew registration, Engine performance

Table 8 Assessment of criticality of ATM applications

The quadrant in Table 8 proposes an initial categorization of ATM applications based on their safety-criticality and time-criticality. This represents a notional classification which sets the base for the security, safety and performance targets in Section 4.

- **Safety criticality.** A service is considered safety-critical if it is necessary to provide traffic separation and weather avoidance, and a failure in the provision of these services create a

[5] Future ATS-B3 services and their associated performance requirements have not been defined yet. It is assumed that ATS-B3 services will provide services supporting higher level of automation in the provision of ATC and therefore will have more stringent performance requirements related to safety and communication delay criticality.

[6] A number of AOC services might not be strictly time-critical, but could be considered as tactical due to their influence in flight and flow efficiency

safety hazard. Non safety-critical services do not have an impact on these functions if they cannot be executed.

Time criticality. A service is considered tactical if it falls within the short-term timeframe (i.e. it needs to be completed within seconds or minutes to be a successful transaction). Strategic services fall within the long-term framework (hours or days).

It is reckoned that further subdivisions may be needed to allow more granularity, especially for Safety and Time Critical services. It should also be noted that, depending on the specific operational environment, service provided, or message exchanged the same application could require different performance levels. This notional categorisation does not intend to enter into such detail, however examples are provided (i.e. AOC).

3.8 Traffic load assessment

The objective of this section is to quantify the data traffic load expectations in the FCI in the foreseeable future in order to derive operational requirements on volume and scale of supported traffic. At the moment of writing, the most updated traffic forecast study for FCI traffic is the FCI Business Case Report **Error! Reference source not found.** and the Iris communications capabilities study [24]. . This study provides a Cost Benefit Analysis to support the forthcoming decisions on the next communication technologies to be deployed in the context of the Future Communication Infrastructure (FCI) for air-ground (A/G) communication service provision, and their potential evolution.

The traffic forecast data was generated for a target fleet covering aircraft flying above FL285 and operated by largest commercial airlines and business aviation operating in Europe. The target fleet is identified as preferably to be equipped with ATN/IPS communication systems and endpoints and make use of FCI services. Table 9 is a summary of the traffic forecast in the FCI Business Case Report and depicts the projection over 20 years of the target fleet, both in terms of number of aircraft and in number of flights.

REQ-14-W2-77-OP-010	**The FCI shall be scalable as to support a number of simultaneously equipped aircraft as shown in Table 9 with peak data throughput as shown in Table 10**

	2025	2030	2039
#aircraft	6,665	7,417	8,564
#flights	7.6M	8.5M	9.8M
#daily flights (assuming uniform distribution)	20,821	23,287	26,849

Table 9. Forecasted yearly aircraft and number of flights for target fleet

The peak application throughput would in this case be sufficient to estimate maximum traffic load expected on the FCI network overall. Adjustments can be made to flatten the value considering that not all A/C make use of the peak throughput at the same time. The Iris communications capabilities study [24] proposes a forecast of data rate for different categories of applications (Table 10). Note that these figures group all ATS without distinction of FANS, ATN/OSI or ATN/IPS equipage. AIS/MET is added although not specifically grouped into ATS or AOC category. In addition, a new category AISD is created, which can be defined as data-heavy future AOC services. Note that digital voice rate is also defined, however it is limited to SATCOM voice.

Application type		Peak Throughput (kbps)		
		2020	2030	2040
Air Traffic Services (FANS 1/A, ATS B1, B2, B3)	Uplink	12.0	104.0	254.2
	Downlink	26.4	137.3	317.6
AOC (ACARS AOC, future evolution)	Uplink	3.8	19.0	39.4
	Downlink	3.5	18.4	40.9
AIS/MET (future aircraft information / meteorological services)	Uplink	-	7,261	15,000
	Downlink	-	161	405
AISD (airline information services)	Uplink	-	5,413	11,747
	Downlink	-	3,651	10,374
Voice (point-to-point SATCOM voice)	Uplink	118.9	178.4	246.6
	Downlink	86.2	129.3	178.7

Table 10 Peak throughput per application for ECAC

To estimate an overall data load in the network for a situation with a specific number of daily flights in the ECAC space, the following formula is applied:

Data load $_{FCI}$ = P $_{flights}$ * #daily flights * SUM $_{applications}$ (F * Application $_{peak}$).

Where:

P $_{flights}$ = % daily flights that are simultaneously operating during peak moment (rule of thumb 15-20%).

F = Correction factor if lower than peak application traffic is to be considered. If worst case (peak application traffic), then F = 1.

For example, to calculate the total data load for Uplink ATS + AOC in 2030, in a worst case scenario:

*Data load = 0.2 * 23,287 * (104 + 19) = 572,860 kbps = 572 Mbps.*

4 Performance, Safety and Security targets

The performance-based CNS concept represents a shift from technology-based to a performance-based CNS framework. Performance requirements could be defined based on the operational requirements, and operators could then be able to evaluate options in respect of available technologies and CNS services that could allow these requirements to be met. The chosen solution would be the most cost effective for the operator, rather than a solution being imposed as part of the operational requirements.

The ICAO Performance-based communication and surveillance (PBCS) concept provides a framework for managing performance of the communication and surveillance aspects of ATM with a purpose of ensuring that emerging technologies for communication and surveillance that are designed to support ATM operations are implemented and operated safely. It is crucial that the FCI achieves an appropriate level of performance, safety and security for ATM data and voice communications to become acceptable.

In practice, the performance, safety- and security requirements allocated to the FCI follow a top-down process. This means that operational safety and performance assessment, and a security risk analysis, are performed on communications services that support ATM operations in different airspaces. Such analysis for FCI were performed in the Transversal Studies of SESAR PJ14.02.04 [3]. Based on these assessments, end-to-end targets are specified in terms of operational requirements. The end-to-end requirements are allocated to the different elements of the communication chain, amongst other things the communication service provider (CSP).

This section derives end to end performance, safety and security targets for the provision of ATM applications over FCI, based on the application classification in terms of safety and time criticality (section 3.8).

4.1 Performance targets

This section describes the currently applicable end-to-end performance targets for ATM applications over FCI. These targets apply to the applications that are classified as time-sensitive. Performance is mainly defined in terms of maximum transaction times. In addition, availability, continuity and integrity figures define reliability of communication which also affects successful transaction time of the service.

REQ-14-W2-77-OP-011	**The FCI shall be capable to support ATM applications complying with the end to end performance levels indicated in Tables 9-12.**

4.1.1 ATS Baseline 3

ATS-B3 Application	Required Performance	1-way e-t-e delay RCP *[s]*	1-way 95% e-t-e delay RCP *[s]*	Integrity RCP	Availability RCP
ADS-C	RSP 60	60	25	1E-5 per FH	0.999

Table 11 compiles the performance requirements for ATS B3 as proposed in PJ 14.02.04. Note that these values are an initial proposal and have not been standardized yet. It is expected that this level of performance will be applied to the rapid exchange of simple clearances, and also the exchange of complex 4D trajectory and D-TAXI clearances, which usually require considerable cognitive workload from the flight crew and coordination with the AU FOC before a response can be provided. No new RSP values have been proposed compared to ATS B2.

It can be assumed that yet-to-be defined future ATS alerting service and FIS make use of ATS B3 applications. Post-Departure Trajectory Information Sharing & Negotiation, and Air/Ground trajectory synchronisation are likely to have similar performance levels to ATS B3.

Two Required Communication Performance (RCP) levels are defined:

- RCP60 for the exchange of simple CPDLC clearances and ATC communication management within all airspaces, including TMA.
- RCP240 for any complex clearance (4D Route) in en-route Continental and Oceanic/Remote airspace and at the airport (D-Taxi, Departure) for which the largest contributor is the Responder.

ATS-B3 Application	Required Performance	2-way e-t-e delay RCP *[s]*	2-way 95% e-t-e delay RCP *[s]*	Integrity RCP	Availability RCP
CPDLC	RCP 60	60	30	1E-5 per FH	0.999
	RCP 240	240	110	1E-5 per FH	0.999

ATS-B3 Application	Required Performance	1-way e-t-e delay RCP *[s]*	1-way 95% e-t-e delay RCP *[s]*	Integrity RCP	Availability RCP
ADS-C	RSP 60	60	25	1E-5 per FH	0.999

Table 11 ATS B3 performance figures

4.1.2 ATS Baseline 2

4.1.3 ATS-B2 Application	Required Performance	1-way e-t-e delay RCP [s]	1-way 95% e-t-e delay RCP [s]	Integrity RCP	Availability RCP
ADS-C	RSP 160	160	90	1E-5 per FH	0.989
	RSP 180	180	90	1E-5 per FH	0.989 *(safety)* 0.9899 *(efficiency)**
	RSP 400	40	300	1E-5 per FH	0.989

Table 12 compiles the performance requirements for ATS-B2 Applications as defined in ED-228A [15] (if exchanged over ATN) and in PJ14-W2-100 TRL4 TS/IRS (if exchanged over SWIM Purple Profile). This standard defines RCP levels for CPDLC exchanges and for ADS-C exchanges. Performance allocations to participating actors are further defined in ED-228A. It is reasonable to assume that ATS alerting services and FIS have similar performance levels to ATS B2.

ATS-B2 Application	Required Performance	2-way e-t-e delay RCP [s]	2-way 95% e-t-e delay RCP [s]	Integrity RCP	Availability RCP
CPDLC	RCP 130	130	67	1E-5 per FH	0.989
	RCP 240	240	210	1E-5 per FH	0.989 *(safety)*

					0.9899 *(efficiency)**
	RCP 400	400	350	1E-5 per FH	0.989

ATS-B2 Application	Required Performance	1-way e-t-e delay$_{RCP}$ *[s]*	1-way 95% e-t-e delay$_{RCP}$ *[s]*	Integrity$_{RCP}$	Availability$_{RCP}$
ADS-C	RSP 160	160	90	1E-5 per FH	0.989
	RSP 180	180	90	1E-5 per FH	0.989 *(safety)* 0.9899 *(efficiency)**
	RSP 400	40	300	1E-5 per FH	0.989

Table 12 ATS B2 performance figures

** Note: This value applies to services supporting operational efficiency and orderly flow of air traffic.*

4.1.4 Digital Voice

Performance levels for the future Digital Voice concept are not yet defined. They will be re-assessed at the final revision of the FCI ConOps.

4.1.5 AIS/MET

Table 13 compiles the performance requirements for time-critical AIS/MET Applications as defined in ED-175. Note that, at the time of writing of this document, EUROCAE WG-76 is working on future AIS/MET services and associated safety- and performance requirements. Thus, these requirements should not be considered definitive neither those that dimension the performance of the system until a new release of ED-175 is available.

FIS Application	Operational Environment	Datalink Mode	e-t-e delay$_{RCP}$ *[s]**	95% e-t-e delay$_{RCP}$ *[s]**	Integrity$_{RCP}$	Availability$_{RCP}$
D-AUS	Enroute	Broadcast	260	180	0.999999	0.999999
		Demand				0.99999
		Contract				0.9999
	Terminal	Broadcast	90	45	0.999999	0.999999

FIS Application	Operational Environment	Datalink Mode	e-t-e delay RCP [s]*	95% e-t-e delay RCP [s]*	Integrity RCP	Availability RCP
		Demand				0.99999
		Contract				0.9999
		Broadcast				0.999999
	Airport	Demand	120	60	0.999999	0.99999
		Contract				0.9999
		Broadcast	260	180	0.999	0.999
	Enroute	Demand	440	210	-	-
		Contract	260	180	0.999	0.999
		Broadcast			0.999	0.999
D-WPDS	Terminal	Demand	180	90	-	-
		Contract			0.999	0.999
		Broadcast	240	120	0.999	0.999
	Airport	Demand	440	210	-	-
		Contract	240	120	0.999	0.999
		Broadcast			0.999	0.9999
	Enroute	Demand	210	105	0.9999	
		Contract				0.999
		Broadcast			0.999	0.9999
D-WNDS	Terminal	Demand	90	45	0.9999	-
		Contract				0.999
		Broadcast			0.999	0.9999
	Airport	Demand	120	60	0.9999	-
		Contract				0.999
	Enroute	Broadcast		30	0.99998	0.99999
		Contract	-	30	0.99998	0.99999
D-WIDS	Terminal	Broadcast	-	10	0.99998	0.99999
		Contract	-	10	0.99998	0.99999
	Airport	Broadcast	-	30	0.99998	0.99999
		Contract	-	30	0.99998	0.99999

Table 13 AIS/MET performance figures

** E-t-e delay and 95% e-t-e delay values are specified 1-way for Broadcast mode, and 2-way for Demand and Contract modes*

Note: Demand service mode is not appropriate for WIDS since the pilot will not know when such immediate METLINK information is needed and available.

4.1.6 AOC

Table 14 recuperates the performance requirements for time-critical AOC as proposed in PJ.14-02-04.

	1-way 95% e-t-e delay	1-way 95% delay$_{CSP/SSP}$	Integrity	Availability$_{CSP/SSP}$	Availability$_{AIRCRAFT}$
AOC Services	90s	45 seconds	1E-5/FH	0.999995	0.99

Table 14 AOC performance figures

4.2 Safety targets

This section summarises the safety analysis conclusions from PJ.14-02-04. These provisions affect the ATM services classify as safety-critical (i.e. ATS and TBO flight information, AIS/MET, Digital Voice, and safety-critical AOC).

The PJ.14-02-04 safety analysis concluded that the Severity Class for services supported by the FCI should not be worse than SC3. Additional services compared to ATS (Digital Voice, safety-critical services such as AIS/MET and AOC likely to be exchanged via SWIM Purple Profile) are not expected to be more stringent in terms of safety impact.

The PJ.14-02-04 safety analysis also highlights that the FCI segment of the service transaction should provide an availability figure of 99.9995, which imposes a corresponding availability figure greater than “six nine” for each network component (assuming they are in functional series).

As stated in the safety analysis, these safety objectives are very difficult to achieve with one single network equipment in the communication chain, and very expensive especially for avionics equipment. As a reference, availability of complex avionics equipment items is generally known to be lower than 1.0 10-5/FH. It is thus required that ground components and airborne IPS router are implemented with redundancy. Consequently, airborne radio equipment will need to support interfaces with two redundant airborne routers, and ground radio equipment with two redundant A/G routers.

On the mobile subnetwork (aircraft), operators have a choice between two options regarding the Development Assurance Level of the ATN/IPS router equipment:

1. Option 1: Two dissimilar, redundant ATN/IPS routers, which can be DAL D
2. Option 2: Two identical ATN/IPS routers, which will have to be DAL C

It is assumed that option 2 will be generally preferred by air framers, as it will be generally cheaper and simpler.

REQ-14-W2-77-OP-012	**FCI shall provide mechanisms to mitigate detected loss of communications due to a failure of the aircraft IPS routing system, the radio system, or an FCI ground component, leading to a situation where safety-critical applications cannot be used anymore**
REQ-14-W2-77-OP-013	**Redundancy should be considered to FCI components on the aircraft (mobile subnetwork), access network and/or ground infrastructure between two connected IPS hosts** ***Note: This requirement applicable to ground infrastructure is augmented by REQ-14-W2-77-OP-017 for security purposes***
REQ-14-W2-77-OP-014	**Aircraft (mobile subnetwork) FCI components shall be implemented at Design Assurance Level C**
REQ-14-W2-77-OP-015	**Software assurance levels for FCI components should be commensurate to, either:** **- Severity Class 3** **- Severity Class 4, if proper mitigations are implemented**

Note: Requirements 012 to 015 above are tentative, and dependent on the conclusions from the SAF Analysis. This analysis is part of Deliverable D5.1.120 "Final TS/IRS FCI Services".

Note: It is assumed that the listed operational requirements have to be met in order to support ATS-B3 services. These requirements may yet have to be confirmed, and will be revisited at the FCI ConOps review at the end of PJ.14-W2-77.

Another conclusion from the safety analysis is the provision of functional mechanisms detecting timely/effectively any "undetected loss or misbehaviour (corruptions, excessive delays, etc) of communications" with an acceptable level of confidence. These failures should be addressed by the FCI network (i.e. by the airborne router and by one or several network components on the ground) to avoid the need for each radio system to implement this function in DAL C. The alternative proposed is to require the ATN/IPS routers perform "multi-transmission" (i.e. simultaneous transmission over each available A/G subnetwork).

Note: On ground side, the association between the Severity Class and the Software Assurance Level (SWAL) is a matter that shall be in charge to the ANSPs. However, a dedicated SWAL level between 3 and 4 allows the usage of network COTS products without being fully compliant to SWAL 3

REQ-14-W2-77-OP-016	**The FCI should implement, either: - A functional mechanism that timely and confidently monitors any undetected loss or misbehaviour of air/ground communications, implemented in DAL C or - A mechanism ensuring that safety-critical communications cannot be disrupted in the event of an undetected loss or misbehavior of air/ground communications (e.g. multiple transmission)**

4.3 Security targets

PJ.14-02-04 performed two Security Risk Analyses according to Security Risk Assessment (SecRA) methodology for the FCI ground segment and the airborne segment (mobile subnetwork). A number of security requirements were derived, and are summarised here as FCI operational requirements.

REQ-14-W2-77-OP-017	**The FCI shall implement redundant communication infrastructure which does not rely on the same CSP network domain**
REQ-14-W2-77-OP-018	**Proper security control and security management practices shall be implemented on the FCI, including: - Configuration and operational audits - Secure monitoring and management - Attack monitoring and correction, and patch management - Self-protection and network security design practices**
REQ-14-W2-77-OP-019	**The FCI shall implement integrity and privacy protection of the control and data plane of the communications**

5 FCI Network Services

5.1 Naming and addressing

The naming, addressing and node discovery functions of IPS relate to the mechanisms to identify various entities within the IPS system. Addressing is the fundamental way for an entity to direct digital communications to its recipients.

5.1.1 IPv6 Addressing

Aviation services require global interoperability and uniformity of services to ensure operational efficiency, security and safety of flight. In addition, every node in the aviation IPS needs to be positively and undeniably identified to ensure that safety and security of the aviation internet is not compromised. The FCI is a private overlay IPS network over existing enterprise and public networks. A permanently allocated IPv6 address block for aviation will facilitate deployment of this private IPS network overlay.

REQ-14-W2-77-OP-020	**The FCI shall support IPv6 unicast addressing**
REQ-14-W2-77-OP-021	**The FCI should support IPv6 multicast addressing for:** **- G/G communications** **- A/G communications in the ground-to-air direction if group sessions are required for ATM services (e.g. AIS/MET or Digital Voice)**

Each IPS node in the ATN IPS network shall have at least one routable, unique IPv6 address which uniquely identifies a network interface. The currently ICAO defined general format for a globally unique IPv6 address prefix has the format shown in Table 15.

Field Name	**ICAO Prefix**	**Type**	**To Be Defined**	**Interface ID**
Field Description	Assigned by IANA to ICAO for aviation use	Defines encoding for remaining prefix bits depending on community of interest	These bit definitions will depend on the address "Type". The following address types are envisioned: air transport aircraft, business/general aviation aircraft, RPAS, operator-based aircraft, ATS fixed, aircraft operator fixed, airport fixed, and Mobility Service Provider (MSP)	Interface ID as defined in RFC 4291
Field Length	16 bits	4 bits	44 bits	64 bits
IPv6 Bit #	1 to 16	**17-20**	21 to 64	65 to 128

Table 15 General IPv6 address prefix format

The purpose of the Type field is to subdivide each of the ICAO network addressing domains. It allows e.g. a separate and specific IPv6 prefix format for aircrafts. It also permits address allocation of ground domains to an individual State or organization. It is assumed that Operator-based aircrafts are the primary user of the IP address space and ATN/IPS communication infrastructure for ATS and AOC services and that ICAO will sub-allocate this portion of the IP address block to the aircraft operators (airlines) for administration of the IPv6 addresses within their jurisdiction.

The global routable IPv6 address of an operator-based aircraft shall be derived from the aircraft Mobile Network Prefix (MNP). Such an MNP shall be nomadic, fixed, globally unique and independent of its subnetwork point of attachment (connected access network). The MNP is assigned by ICAO or its delegate. IPv6 addresses from this prefix are accessible through all aircraft interfaces.

Data plane traffic originating from or destined to an IPS aircraft uses the aircraft's nomadic IPv6 address as the source or destination IP address regardless of the air-to- ground media. As an aircraft moves from one service region to another region, its access network may change. If the IPv6 address prefix of the aircraft is independent of the connected aircraft, ground can route uplink IPv6 packets to the aircraft without new address discovery.

Note: Some specific control plane messages. e.g. to exchange multilink related information between the aircraft *and the ground infrastructure may have different source or destination IPv6 addresses.*

REQ-14-W2-77-OP-022	**Each IPS host in the FCI shall have at least one routable, globally unique IPv6 unicast address uniquely identifying a network interface**
REQ-14-W2-77-OP-023	**The globally routable IPv6 address of an operator-based aircraft shall be derived from the aircraft Mobile Network Prefix (MNP) and independent of an access network point of attachment.**

The IPv6 address structure of an operator-based aircraft is shown in Table 16.

Field Name	ICAO Prefix	Type	Operator Code	Aircraft ID	Subnet ID	Interface ID
Field Description	Assigned by IANA	Type = 0100 (Operator Based Aircraft)	3 Character Airline Code, each character encoded as 5-bit ASCII per ITA-2 with MSB 5 bits selected	24-bit ICAO ID	Subnet ID assigned by local Admin	Interface ID as defined in RFC 4291
Field Length	16 bits	4 bits	16 bits	24 bits	4 bits	64 bits
IPv6 Bit #	1 to 16	17-20	21 to 36	37 to 60	61-64	65 to 128

Table 16 Operator-based aircraft IPv6 address prefix format

The "Operator Code" field contains the 3-character airline designator. When aircraft ownership changes, the new Operator Code can be derived automatically from the Aircraft Personality Module or other aircraft configuration information.

The "Aircraft ID" filed contains the '24-bit ICAO address' of the aircraft as specified in ICAO Annex 10, Volume III, Part I, Chapter 3. The Airborne IPS system assigned fixed nomadic IPv6 prefix is derived from the operator code and the 24-bit ICAO ID. Use of the 24-bit ICAO ID in the IPv6 prefix assures that the address prefix will be unique. Since the 24-bit ICAO ID is available to all avionics systems on the aircraft through the data buses from the transponder code and the Aircraft Personality Module, each IPS Node on the aircraft would be able to auto-configure its IPv6 prefix without any additional administration process.

Link Local addresses (LLA) are used as specified by the IPS Profiles in RTCA DO-379 and EUROCAE ED-262. LLA in Airborne IPS Nodes are assigned to each of its system network-layer interface. The network-layer interfaces facing the air-ground datalinks shall configure LLAs with a unique address derived from the MNP. Other Airborne IPS Nodes network interfaces (e.g., interfaces facing the on-board local area network) may adopt the same approach or may configure LLAs in accordance with the IPv6 Addressing Architecture RFC that is specified by the IPS Profiles in RTCA DO-379 and EUROCAE ED-262.

REQ-14-W2-77-OP-024	**Link Local Addresses (LLA) on the network-layer interfaces of the IPS Nodes facing air-ground datalink shall be configured with unique address derived from the MNP**

5.1.2 Naming conventions and Name Lookup

This section contains preliminary provisions as naming conventions and Name Lookup are still under discussion in different ICAO Groups. The main such groups are the ICAO Trust Framework Study Group and WG-I (Internetworking).

Naming permits an entity within the IPS to obtain the specific IPv6 address of another entity using its generic name. This allows the networks and systems provide redundancy, resiliency and administration flexibility. However, it requires either support of Name and Address Servers within the IPS or a locally stored information about the mapping.

In principle, ATN/IPS systems must follow the naming convention established by the ICAO. Unfortunately, there are no specifications for this in Doc9896 yet. There are proposals that for IPS only a handful of centralized and regional servers on the ground should maintain the ground peer IP addresses that cover most of the global ATS deployment. In addition, it should be possible that the naming convention allows the pilot to enter a shorthand name like the currently defined ATSU name. This should map to the fully qualified DNS name. For example, when the crew enters LSAZ, the avionics can construct the name, such as "LSAZ.ATSU. icao.int".

Unlike ATN, all AOC requests can be initiated by the ground or by the airline. Since each airline is likely to use a customized AOC for its specific needs, the address and naming should be managed using the AOC customization.

Regarding Lookup Service, ICAO Doc 9896 requires the IPS system to provide the capability for a host to query and receive the IPv6 address of a peer host using its generic host name. This is necessary to overcome the difficulty of aircraft to maintain all the possible IPS peer names for address lookups in the local database as is done for ATS B1.

REQ-14-W2-77-OP-025	**The FCI shall provide the capability for an IPS host to query and receive the IPv6 address of a peer host using its generic host name (e.g. Ground Facility Designator, GUFI, or other)**

For ground located IPS hosts, an aviation specific Domain Name Server (DNS) is used to provide a host name to IPv6 address translation service. The DNS is an application layer protocol that operates by exchanging messages between client and server to resolve names from a distributed database implemented in a hierarchy of many name servers. Operating in a client/server configuration, DNS principal function is to resolve host names into machine readable IP addresses. ICAO provides name label and IPv6 global address space for aviation use.

For aircraft located IPS hosts, a Simple Name Lookup is proposed for queries from the aircraft to the ground. In the aircraft, the IPS Management Service provides the Simple Name Lookup (SNL) service to permit an Airborne IPS Node to request the IPv6 address associated with a facility or ground system. An Airborne IPS host may generate multiple name lookup requests at any given time; however, each request must a separate message.

The service name end point is defined by the IPv6 address and port number. ICAO Doc 9896 specifies the UDP/TCP port service definition of ATS (CM, CPDLC, ADS-C, AMHS), AIS/MET, Digital Voice, air/ground SWIM, and Distress and Safety data.

5.2 Mobility and multilink

For air/ground communications, it is assumed that multiple data link services may be available at all flight phases. This leads to a common multilink scenario, where it is intended to utilize all data links for transferring ATM application data.

A Mobility Service Provider (MSP) is the network functionality of a CSP which controls the connectivity between aircraft mobile subnetworks and a mobility anchor point on the ground infrastructure. The same or a different CSP then provides connectivity between MSPs and the networks operated by ATM service providers.

5.2.1 Mobility providers federation

The roles of MSP and CSP can be provided by a single administrative domain. There could be an arbitrary number of MSPs and other CSPs interconnected without imposing a specific topology (similar to the Internet). The MSP and CSP networks composing the global FCI network are dedicated to exclusive aviation usage in the form of an aviation private exchange network (modelled similarly to the GSMA GRX/IPX network). In this approach, race conditions with other services must be avoided, and if network resources are shared with other services, then a proper separation must be implemented.

The mobility-specific control plane information exchange is limited by default to a single administrative domain. A federation of such control plane information databases is required to create a globally connected FCI network. This federation is based on some common principles implementing the distributed mobility management (DMM) requirements from DMM IETF WG.

Individual peering agreements might be needed to define the details of such interconnections. For safety-related traffic, it is recommended to make available mobility control plane information exchange for all members of the global FCI network. The individual ATM service providers must have the possibility of not having a direct contract with each MSP required for proper geographical and technological coverage, but rather use an aggregator for providing access to other MSP or CSP capabilities.

REQ-14-W2-77-OP-026	**The FCI shall provide mobile connectivity among IPS hosts served by a DMM federation of multiple, independent CSPs**

5.2.2 Multilink concept

Multilink is a concept where at least two future independent A/G datalinks are simultaneously available and operationally deployed in the airspace and managed to comply with the performance requirements of the user applications.

From PJ14.02.04 D5.1.020.2 - FCI Initial Transverse Complementary Studies [3], it can be concluded that in the long-term, the required QoS of the FCI user applications will result into more stringent values for availability and latency for the technical systems. As a result, ICAO WG-I/21 WP6 [25] discussed potential implications on the Aircraft ATN/IPS protocols and systems architecture and concluded that either of the following mechanisms should be implemented:

- Multi-transmission of a same message over multiple link (simulcast),
- Network–level mechanisms for detecting any undetected loss or misbehaviour (corruption, excessive delays, etc) of the communication links, and performing link re-selection.

Note: The SESAR W1 FCI Initial Concept states that voice is not intended for multilink integration. Manual selection of the link should be required for digital voice with dedicated "voice interfaces" on the access interfaces of Data Links networks.

The Multilink Management Function (MMF) is defined to support the two following network functionalities implementing these mechanisms in the FCI.

- Monitoring of the status of the existing A/G data links
- Selection of the most appropriate A/G data link for the user application in accordance to a configured link policy, considering link quality and load distribution

5.2.2.1 Link monitoring strategy

Both air and ground sides of the access network need to detect any significant changes in link status either locally or by received control plane messages. The multilink optimization cycle will be triggered by such changes. Optional hysteresis and dampening algorithms might be added for improving the stability.

The up/down status shall be defined by each mobility access technologies based on the special circumstances of the used radio access technology (RAT). This status will be communicated cross-layer from the link layer to the network layer.

REQ-14-W2-77-OP-027	**The FCI shall support monitoring of A/G data links in the access networks available for communication with A/C, including at a minimum UP/DOWN status**

Note: It is recommended that additional quality indicators of each available A/G link are provided for flow distribution optimisation. Direct QoS parameters may also be provided for each available A/G link.

The A/G radio links are expected to have either a point-to-point or a non-broadcast multiple-access (NBMA) topology. Broadcast services might be limited to special use cases, so the mobility solutions cannot rely on a full-duplex broadcast capability. These limitations could be based on the limited bandwidth available, so it cannot be circumvented by technology updates. The limited bandwidth also means that active probing should not be used on the A/G radio link in the network layer. Generic routing protocols would also have too much overhead, so an aviation specific link status update message needs to be defined.

The aircraft shall send the link status message in parallel on each available link. The messages will be triggered by significant changes in A/G link status. Periodical messages are optional and would be carefully evaluated based on resource consumption. These messages should be made accessible for each MSP that could be potentially used by an aircraft.

REQ-14-W2-77-OP-028	**The FCI shall support signalling of link monitoring status from A/C to ground infrastructure**

The ground will not send such a generic status message by default to spare on radio resources. This implies that the ground network must be highly reliable and available. Otherwise, the aircraft could send important traffic into a black hole. This problem could be mitigated by administratively shutting down the A/G link layer by the ground station if the supporting ground network connectivity does not work.

5.2.2.2 Link selection policy

Note: Additional work on the Multilink policies is being proposed within the SESAR 3 FCDI Work Package 4 "IPS Enhancements". This covers definition, management, deployment and responsibility of link selection policies.

As the airplane moves it could connect to multiple MSPs both in parallel and sequentially. A single MSP might provide multiple RAT solutions, but the used RAT links might belong to different MSPs. The FCI ground infrastructure needs to inform the connected ATM service providers about the actual reachability of the airplane. It is required that for ATS, this occurs transparently to the services session and does not result in a service loss.

As there is no fixed mobility anchor in the federated mobility topology provided by the FCI network, if a better route becomes available, the traffic should switch to the better route. By default, the multilink optimization shall select a single network path for each traffic class or flow to spare limited radio resources. The best possible experience in this case is what is available at the best quality link. This needs to be performed by means of routing policies for the Class of Service associated to a traffic type. ICAO WG-I/31 WP19 [27] outlined the user needs to specifically apply link selection policies according to the application traffic type.

REQ-14-W2-77-OP-029	**The FCI shall support link selection policy depending on the application type, including:** **- ATS dictated by ATSP** **- AOC dictated by the airspace user (A/C or FOC)**

Note: AIS/MET link selection policy is be indicated by the respective data provider (ATSP, ADSP or airspace user).

A link selection policy is a set of rules followed by an IPS node to select the outgoing path preferences for an incoming PDU under certain operational conditions such as flight status, or status of active links. It is critical that a link policy contains only parameters that can be realistically generated by the datalink system and applied during flight. According to these environmental conditions, the link selection policy generates routing tables for the routers in its network, thus formalizing these preferences.

An **example** of a link selection policy could be the following set of rules:

- Only links with UP or DEGRADED status are permitted
- Links with DEGRADED status have lower priority than links with UP status
- Any link other than SATCOM is not permitted in Oceanic airspace
- LDACS not permitted over a specific FIR (since not deployed yet)
- A link technology deemed by regulator (based on long-term performance) or service provider (based on SLA) as not being able to meet the RCTP for the CSP allocation of RCP130 performance is not permitted for time-critical applications
- If both SATCOM and LDACS performance are defined as acceptable over a specific FIR, use LDACS

The rules of a link policy may be driven by either regulations or business reasons. Both types of rule should have properly defined mechanisms for monitoring and enforcement. In a properly defined link policy, the regulatory rules must take precedence over the business rules:

- **Regulatory rules** are defined to comply with safety/performance requirements or other datalink usage regulations defined globally, regionally or nationally. Performance should be monitored continuously and in strategic time horizons (e.g., as average and variance values within daily to yearly periods). Strategic monitoring is feasible and stable, and allows for a proper process to regulate the suitability of link policies, as opposed to monitoring of instantaneous values. Monitoring should involve different entities, including end users and network providers, and allow for result reconciliation against levels of compliance (e.g., ED-228A for ATS Baseline 2). Monitoring should be done at different levels (bottom-up hierarchical monitoring recommended, starting from link level up to network and end-to-end application level). Regulatory link selection rules are applied based on pre-defined rules that are not dependent on changes in the environment during flight.
- **Business rules** are defined by an FCI actor (airspace user, ground end user, or CSP) to indicate datalink usage preferences in line with their business goals. Business rules can also consider compliance to SLAs that have been contracted between end user and network provider. Monitoring of SLA is responsibility of the parties as contractually agreed. Business rules can be pre-defined (e.g. following commercial agreements) or dynamically applied. In the latter case, real-time monitoring of link status (relative to other available air/ground links) and traffic characteristics are necessary, in order to make link selection with changing environment during flight.

The following components participate in multilink operation:

- The Multilink Management Function (MMF) is also called Policy Decision Point (PDP) and Multilink Decision Engine (MDE) in other contexts. This component stores one or more link selection policy defined by the appropriate stakeholder for a specific network or group of networks. The policy is loaded as a set of rules that will be evaluated based on status awareness and create a policy decision to be sent to the Policy Enforcement Point (PEP). It can be hosted directly in an IPS router or in a separate component. The MMF/PDP/MDE may have two additional functions:

  - Monitor environmental conditions, reported by either link status monitoring functions, or by other systems (e.g., if located in aircraft, flight status reported by other avionics. If located on a ground network, indications of airspace reconfigurations within a FIR/UIR, or network degradations reported by CSP).
  - Provide updates to the routing table based on the policy defined for the most current environmental conditions.
- The routing table, also called Policy Enforcement Point (PEP). This component implemented in an IPS router, and defines the egress interfaces for incoming PDUs, based on IPv6 header fields and the routing table entries. The egress interfaces are selected as next-hop in the route towards a selected Radio Access Technology (RAT). The table entries can be reorganized according to updates received from the MMF/PEP/MDE.

- The IPS host is the application endpoint running the communication service and sending PDU traffic. The IPS host is the end system tagging outgoing traffic with the appropriate fields used for in-band signaling (Type of Service, DSCP, CoS).

Figure 1 depicts the conceptual architecture of multilink functions within the FCI. This architecture is applicable to both aircraft and ground systems. Note that, in a datalink system, multilink architectures can be different for uplink (ground) and downlink (aircraft) selection. In addition, the functional components do not necessarily have to be physically co-located. As an example, PDP and PEP for downlink traffic may be collocated in the aircraft, while PDP for uplink traffic may be located in the aircraft and PEP updates signaled to the ground. A PDP could also be located on the ground (for local policy overrides when needed) providing updates to uplink PEP.

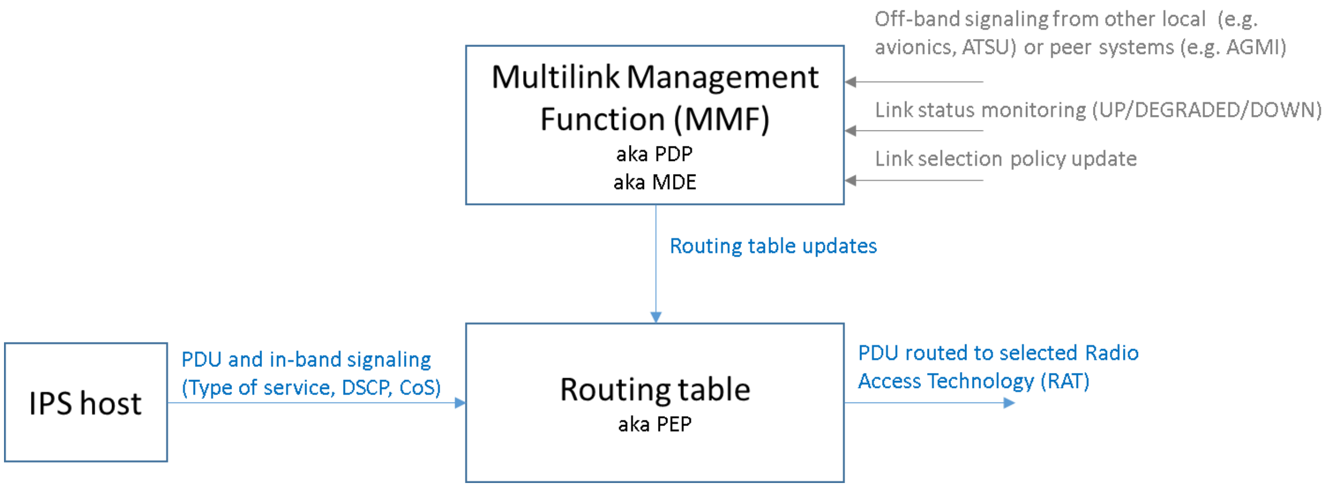


Figure 15. Multilink functions architecture

REQ-14-W2-77-OP-030	**The FCI shall support link selection for A/G communications among available access networks, which does not result in a loss of ATS services, based on: - Administrative policy and/or - Link performance based on link status monitoring**
REQ-14-W2-77-OP-031	**The FCI shall support link selection override by manual selection of data or voice communications in the case of a degraded link performance, or for testing and validation purposes**

Critical traffic might potentially use a simulcast scheme. If a packet de-duplication is used at the receiving end, then the quality experience could be significantly better than any of the composing radio links. This method might be also applied in the ground network for providing the assumed high availability. Simulcast would use up additional bandwidth, so on narrowband links it might not be practical.

5.2.2.3 Location of the link selection policy

There are three possible physical locations for the link policies hosted in an MMF/PDP/MDE. Note that the location of the link selection policies indicates the entity responsible for updating and maintaining them, but not necessarily the entity responsible for defining them:

- **In the MMF/PDP/MDE of the FCI mobile node (aircraft).** Airspace user is responsible for maintaining the link selection policy. PEP is implemented in the airborne router. The MMF/PDP/MDE updates the routing table in the PEP based on:
  - the link policy configured in this aircraft,
  - current link monitoring reports, AND
  - flight operation conditions.

  The link interface is selected by the PEP for each incoming downlink PDU, based on the current routing table.

- **In the MMF/PDP/MDE hosted in the CSP (e.g., GB-LISP MS/MR server).** This is for scenarios where a CSP centralizes the link selection process (scenario 5), or hybrid solutions (scenario 3) where the CSP makes the selection considering preferences provided by the aircraft over off-band signaling (e.g., AGMI). The CSP (also acting as MSP) is responsible for maintaining the link selection policy. PEP is implemented in G/G routers of the CSP network. The MMF/PDP/MDE updates the routing able in the PEP based on:
  - the link policy configured AND
  - the preferences (e.g., GB-LISP preferences) to reach each aircraft in the FCI.

  PEP forwards incoming uplink PDU to the path to the selected A/G subnetwork, based on the routing table.

- **In the MMF/PDP/MDE hosted in the G/G Boundary Router (GGBR) of a ground end user (ATSP or FOC).** This is for scenarios where ground end users can connect to several CSPs, each managing one link subnetwork (scenario 4). This also covers hybrid solutions (scenario 2) where ground end users make the link selection considering preferences provided by the aircraft over of-band signaling (AGMI). The end user is responsible for maintaining the link selection policy. PEP is implemented in the G/G router. The MMF/PDP/MDE updates the routing table in the PEP based on:

- the link policy configured AND
- the aggregated preferences (e.g., GB-LISP preferences) shared by the MSP to reach each aircraft served by the end user

PEP forwards incoming uplink PDU to the path to the selected A/G subnetwork, based on the routing table.

5.2.2.4 How policies are updated and distributed in the MMF/PDP/PEP

Link selection policies may need to be updated due to changes in the regulations, performance levels, or business rules. The roll-out time of a link policy change is dictated by the applicable regulatory or business entity requiring the update. Automatic update or redefinition of link selection policies is currently not supported by the FCI ConOps, thus an entity needs to actively launch the update. There are three main link policy update mechanisms.

- **Maintenance intervention of the MMF/PDP/MDE directly**. For aircraft-hosted MMF/PDP/MDE, this is done during an avionics maintenance cycle (days). For network-hosted, updates normally require a service downtime (hours). This update approach does not produce a distribution mechanism with other peers, and requires a separate update in each MMF/PDP/MDE.

  Note: A risk may arise if link policies reconfigured in the network are mutually contradictory in different network nodes in the communication chain during a window of time. It is thus recommended to perform simultaneous updates during the same maintenance cycle.

- **Update of a common link policy repository covering a group of MMF/PDP/MDE**. This requires some type of link policy publication service that is shared by a group of end users (e.g., for an operator fleet, or a group of ATSPs). Link policy updates are then disseminated through all the MMF/PDP/MDEs in the group (e.g., via web service subscriptions) at the appropriate intervals. The advantage of this approach, assuming the distribution mechanism allows immediate distribution, is that changes across the network are near-immediate once the link policy repository is updated (MMF/PDP/MDE hosted in aircraft likely require to be in flight preparation phase), however potential bugs in the link policy definition are also disseminated in the network.

- **Selection by end user (air or ground) of a pre-defined link selection policy previously loaded into the MMF/PDP/MDE**. This is useful in failure scenarios where a backup policy selection is necessary to restore connectivity.

Note that policy-based link selection is a function transparent to the end user during operations, and thus link selection cannot be made from an end user interface (e.g. cockpit or ATCO/FOC position). Such mechanism would fall under manual override, which is out of the scope of this analysis.

5.2.2.5 Multilink (link selection policy) operating scenarios

Table 17 describes the possible operating scenarios, defined as the entity/entities responsible of defining link selection policy. Each scenario describes the operation, the location of link selection policies, and the feasible mechanisms to update and distribute link policies.

	Responsible for defining link policy	Operation	Possible locations of link policy	Update of link policies
1	**AU**	Downlink: 1. Global/regional/national regulations applicable to operating airspace, and regulations of the aircraft registered state 2. Status and performance of links 3. AU business policy Uplink: Link policy on ground dictated by link selected by aircraft. PEP follows according to signaling on downlink preferences or current downlink selection	Mobile node (aircraft) Ground end user network or CSP (MSP) network	Due to changes in regulations, contractual agreements between AU and CSP, business strategy or feedback from operational/technical personnel. AU modifies its link policy by either: - Maintenance intervention on avionics hosting MMF/PEP/MDE when aircraft on ground - Subscription to AU FOC managed link policy - Pilot selection of pre-defined backup policy
2	**AU and Ground end user (ANSP/AOC)**	Downlink: 1. Global/regional/national regulations applicable to operating airspace, and regulations of the aircraft registered state 2. Status and performance of links. May use uplink signaling from end user (current link, preferences) if wants symmetry 3. AU business policy Uplink: 1. Global/regional/national regulations applicable to operating airspace 2. Status and performance of links (GB-LISP provider preferences provided by MSP). May use downlink signaling from aircraft (current link, preferences) if wants symmetry 3. Ground end user business policy	Mobile node (aircraft) Ground end user network	Due to changes in regulations, contractual agreements between AU/ground end user and CSP, business strategy or feedback from operational/technical personnel. AU modifies its link policy by either: - Maintenance intervention on avionics when aircraft on ground - Subscription to AU FOC managed link policy when aircraft on ground - Pilot selection of pre-defined backup policy Ground end user modifies its link policy by either: - Maintenance intervention on G/G routers - Subscription to policy link repository (managed by e.g. regional entity) - ATCO selection of pre-defined backup policy

3	**AU and CSP**	Downlink: 1. Global/regional/national regulations applicable to operating airspace, and regulations of the aircraft registered state 2. Status and performance of links. May use uplink signaling from CSP (current link, preferences) if wants symmetry 3. AU business policy Uplink: 1. Global/regional/national regulations applicable to operating airspace 2. Status and performance of links (GB-LISP preferences). May use downlink signaling from aircraft (current link, preferences) if wants symmetry 3. CSP business policy	Mobile node (aircraft) CSP (MSP) network	Due to changes in regulations, contractual agreements between AU and CSP, business strategy or feedback from operational/technical personnel. AU modifies its link policy by either: - Maintenance intervention on avionics when aircraft on ground - Subscription to AU FOC managed link policy when aircraft on ground CSP modifies its link policy by maintenance intervention on MS/MR
4	**Ground end user (ANSP/AOC)**	Downlink: Link policy on aircraft dictated by link selected by ground. PEP follows according to signaling on uplink preferences or current uplink selection. Uplink: 1. Global/regional/national regulations applicable to operating airspace 2. Status and performance of links (GB-LISP provider preferences provided by MSP) 3. Ground end user business policy	Mobile node (aircraft) Ground end user network	Due to changes in regulations, contractual agreements between ground end user and CSP, business strategy or feedback from operational/technical personnel. Ground end user modifies its link policy by either: - Maintenance intervention on G/G routers - Subscription to policy link repository (managed by e.g. regional entity) - ATCO selection of pre-defined backup policy
5	**CSP**	Downlink: Link policy on aircraft dictated by link selected by ground. PEP follows according to signaling on uplink preferences or current uplink selection. Uplink: 1. Global/regional/national regulations applicable to operating airspace 2. Status and performance of links (GB-LISP preferences). May use downlink signaling from aircraft (current link, preferences) if wants symmetry 3. CSP business policy	Mobile node (aircraft) CSP (MSP) network	Due to changes in regulations, contractual agreements between AU/ground end user and CSP, business strategy or feedback from operational/technical personnel. CSP modifies its link policy by maintenance intervention on MS/MR

Table 17 Multilink (link selection policy) operational scenarios

5.2.3 Mobility operation concepts

The aircraft pilot and avionics need both a situational awareness about the mobile connectivity services and the possibility to intervene if necessary. It is thus expected that the airborne IPS hosts will support the following functions:

- Display the available A/G datalinks and their current status.
- Optionally, display historical and forecasted trends for A/G links for improved situational awareness. It is recommended to display the application utilization of these links (i.e. which application flow is served by each access network) both in downlink and uplink directions.
- Display list of pre-defined administrative policies on multilink usage.
- Select an administrative policy with one button push from approved policies. In case of serious problems with A/G links a manual fall-back to legacy services, such as non-IP digital voice or analogue voice should be covered by one of the administrative policies listed.
- Optionally, the geographical coverage forecast may be provided for each link. In addition, ground systems me provide hints on optimum datalink usability.

REQ-14-W2-77-OP-032	**The mobile node (aircraft) IPS host shall provide situational awareness about connectivity services**
REQ-14-W2-77-OP-033	**The mobile node (aircraft) IPS host shall provide means to intervene on connectivity services when necessary**

The MSP function of a CSP is expected to have a network operation centre (NOC) with a 7/24 continuous human supervision. The operators in this NOC will need the following functions for the mobility management:

- Display all A/C with connectivity and show the status of each A/G link.
- Optionally, display the history and forecast for A/G connectivity. It is recommended to display what link is used for which flows, both in downlink and uplink directions.
- Display list of available, approved and applied administrative policies for global, group, and individual airplane scopes.
- Select an approved administrative policy per aircraft, group of aircrafts, or globally. It is recommended that the NOC allows the creation of ad-hoc aircraft groups to manage administrative policies.
- Display connectivity status to ATM service providers.
- It is recommended that the NOC provides flow monitoring in the ground network. Optionally, the NOC may receive network debugging messages from aircraft, and send messages to aircraft on multilink usage hints.

The CSP providing the MSP might want to hide the internal topology from the other administrative domains. Those would see this network with a simplified topology, not revealing all the details of the used architecture. Other CSPs will provide IPv6 connectivity between the FCI A/G border routers of the MSP and the FCI G/G border routers of the ATM service providers. They are not required to know anything about the mobility and multilink services, so they will not provide any mobility or multilink specific services. The only requirement for their operations is to be compliant with the committed SLA that was used as a basis for the network design.

REQ-14-W2-77-OP-034	**The CSP providing the MSP should operate a Network Operations Centre (NOC) with a 7/24 continuous human supervision**

The ATM service providers will have a NOC with a 7/24 continuous human supervision. The mobility solution specific functions required for proper operations are the following:

- Display all A/C with connectivity and show the status of the access to mobility service providers for each airplane.
- Optionally, provide historical and forecasted trends for A/G links for improved situational awareness. It is recommended to display the application utilization of these links (i.e. which application flow is served by each access network) both in downlink and uplink directions. It is also recommended to display a list of pre-defined and approved administrative policies, to be selected and applied globally, per group of aircraft, or for an individual aircraft.
- Send messages to pilots for fallback to other communications means;
- Optionally, send messages to A/C on multilink usage hints.

The ATM service providers might also monitor the SLA compliance on their own and reconcile it with the SLA measurements provided by the CSPs.

REQ-14-W2-77-OP-035	**The ATM service providers should operate a Network Operations Centre (NOC) with a 7/24 continuous human supervision**

5.3 Quality of Service (QoS)

Traffic routing in the FCI should be performed on the basis of ATM operational needs, without being constrained by institutional or commercial factors. In practice, this means that critical traffic (and especially ATS) should not be constrained by other applications. This could be achieved in air-ground segments by dedicated datalink infrastructure, however in the objectives of CNS as a service and infrastructure rationalisation, the communication infrastructure is mostly a shared resource.

The FCI mobility and multilink functionality requires a policy-driven routing procedure. The basic criterion that defines which policy has to be used and which way traffic shall be managed for ATN traffic is the ATSC Routing Class, as defined in ICAO Doc 9896 [9]. The ATSC value for a particular ATN application is set by the air end system (if the application is air-initiated) or the ground end system (if the application is ground-initiated). Other ATM applications may use other classification methods.

The use of a priority mechanism is useful to discriminate safety/time critical traffic from less critical traffic when communication resources are scarce in relation to the application traffic. When sufficient resources are available then all users get the level of service required. However, when resources become scarce, applying priority can be a way of more efficiently using available resources by giving lower priority to applications for which the loss or the delay of a message will have a lower safety impact. Therefore, the implementation of a priority mechanism shall be supported by the FCI and applied as a routing policy for differentiated traffic.

REQ-14-W2-77-OP-036	**FCI shall support traffic classification for packet forwarding and routing policy**
REQ-14-W2-77-OP-037	**The FCI shall support the following QoS functions:** **- Data rate guarantee for required applications (e.g. Digital Voice)** **- Packet differentiation, prioritization and pre-emption in situations of congestion** **- Packet scheduling to support applications with different latency budgets**

Table 18 proposes general Classes of Service (CoS) per application type according to its characteristics and criticality level. The ordered prioritization is based on PJ14.02.04 QoS classification and modified to support the ATM applications defined in the ConOps. This classification is qualitative, implementations of FCI routing policies can assign specific assignments to DiffServ traffic classes, QoS parameters, routing policy, and priority mechanisms as applicable to ensure the compliance to application performance levels.

Class of Service (CoS)	Traffic characteristics
Very high	Digital Voice - Minimum latency/jitter - Constant availability of resources
High	ATS B3 (RCP60), Digital Voice signalling - Low latency - Reliable - A/G transmission of short messages
	ATS B2, ATS B3 (RCP130), FIS, Alerting Service - Limited latency - Reliable - A/G transmission of short messages
	ATS advisory and Civil/Military Coordination, Ground dissemination of AIM/MET/Flight information - Reliable - G/G transmission of variable size messages

Class of Service (CoS)	Traffic characteristics
	Safety-critical, tactical AIS/MET and AOC - Limited latency - Reliable - A/G transmission of short messages
Normal	Safety-critical, strategic AIS/MET and AOC - Reliable - A/G transmission of variable size messages
	Non-safety-critical, tactical AIS/MET and AOC - Limited latency - A/G transmission of variable size messages
Best-effort	Non-safety critical, strategic AIS/MET and AOC - A/G transmission of variable size messages

Table 18 Class of Service categorisation for ATM applications over FCI

5.4 Security

The changing role of data communications has a very significant impact on the communications services and requires an appropriate level of security if data communications is to become acceptable. Introducing one or more levels of security in FCI is a demanding balancing act between security requirements, safety requirements, flight regularity, economic impact on stakeholders and technical interoperability.

The required security criticality (The need for protection against modification of message attacks, leading to loss of separation and denial of service attacks) is determined using a qualitative value (high, medium, low), for which it considers 3 parameters: Availability, Integrity and Confidentiality. The values of these parameters are part of the QoS policies configured for reliable applications. The FCI should also provide a mechanism to log and report security events to support security audits.

5.4.1 Authentication and Integrity

Security attacks are common in IP networks. In the FCI, where air/ground and ground/ground networks are interconnected, unauthorized electronic interactions can affect the integrity and availability of the entire communication infrastructure. Intentional modification of messages or masquerading a controller or pilot may lead to a loss of separation or confusion.

The goals of authentication and Integrity are to:

a) prevent unauthorized modification of messages (loss of integrity);
b) provide data origin authentication for uplink and downlink messages to prevent mis-delivery.

The network layer assumes that radio links are properly authenticated, authorized, and accounted in the lower layers. It is also assumed that in the upper layers the Baseline 2 defined context management (CM) is available for implementing certain required security functions that does not need to be repeated in the network layer. That could mean that no additional authentication or authorization is needed in the network layer.

However, security measures to improve protection against intentional breach of integrity and mis-delivery are still required. This may include the use of IPSec, a public key infra-structure (PKI) for mutual peer authentication, verification and authentication of routing information exchanged over an air/ground data link, message integrity verification, and verification of packet source network address.

REQ-14-W2-77-OP-038	**The FCI shall provide protection against intentional breach of integrity and mis-delivery for safety-critical applications**

5.4.2 Availability

Denial of Service (DoS) attacks are the most common in IP networks, and can include packet flooding, radio jamming, and masquerading of routing information. Although it is assumed that radio subnetworks will support Layer 2 access authorization mechanisms, thus mitigating security attacks entering through the air interface, network measures need to be implemented to mitigate DoS impact and support a quick recovery of the system. This may include techniques such as packet filtering, port filtering and firewalls.

In addition, technical and legal measures would need to be implemented to identify, trace and pursue unauthorized radio transmissions. Also physical security mechanisms have to be deployed by Administrations and Service Providers to prevent access to their Ground Networks to unauthorised parties, thus limiting opportunities for this mode of attack.

REQ-14-W2-77-OP-039	**The FCI shall provide security measures to protect and mitigate against Denial of Service attacks**

5.4.3 Confidentiality

Confidentiality is not expected to be required for ATS and AIS/MET applications. However, AOC services may require a medium to low confidentiality ranking against interception of AOC confidential information especially where it concerns commercially sensitive data, such as maintenance reports, log books and load-sheets.

It is assumed that datalink encryption is implemented by underlying RAT, and end-to-end encryption is implemented at application layer (e.g. TLS/DTLS). Network layer encryption in the FCI for ATM applications is thus considered optional. However, control plane information and applications for network management need to be adequately protected.

REQ-14-W2-77-OP-040	**The FCI shall provide protection against interception of confidential information for network control and system management data**

5.5 Interface with external networks

5.5.1 ATN/OSI and FANS1/A accommodation by Ground Gateway

An important aspect of harmonization is the transition from FANS1/A over ACARS, or ATS B1 over ATN/OSI, towards ATS B2 and B3 over ATN/IPS. There will likely not be a triple stack (FANS 1/A, IP, OSI) in the aircraft, thus the accommodation is required to be done on the ground. The US/EUR Data Link Harmonisation Task Force is currently evaluating the development and deployment of multi-stack Ground Gateways which should be able to accommodate aircraft between the legacy networks (ACARS, ATN/OSI) and the new ATN/IPS network.

PJ14-W2-77 Deliverable D5.1.800 "Deployment & Transition strategy" [26] also concludes that OSI/IPS gateways are the recommended means for transition from OSI to IPS.

REQ-14-W2-77-OP-041	**The FCI shall provide ground accommodation of:** **- ATN/OSI equipped aircraft for ATS communication with IPS host** **- FANS1/A equipped aircraft for ATS communication with IPS host** **- IPS equipped aircraft for ATS communication with FANS or ATN/OSI endpoint**

The multi-stack gateway concept focuses on establishing a connection and correlation between the gateway and the aircraft, and the gateway and associated peer ground system, with which it is communicating. This can be done for both FANS-1/A and OSI-based applications. A functional depiction of this is given in Figure 16.

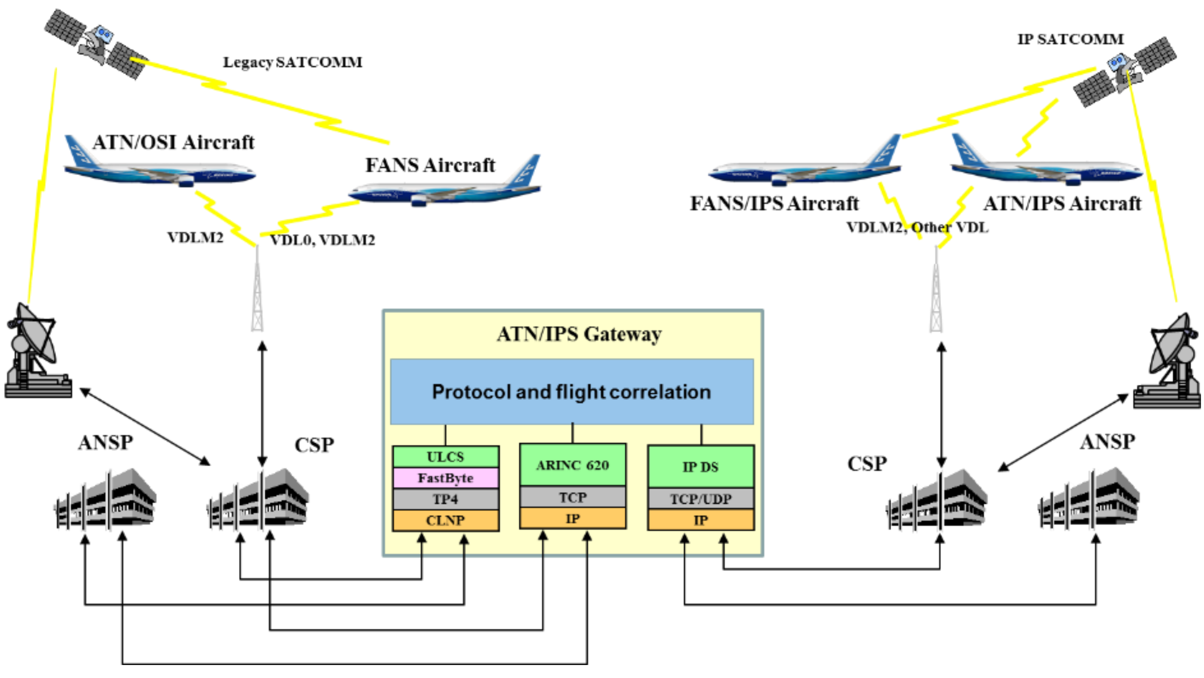


Figure 16 Conceptual ATN/IPS Gateway Operation

Aircraft can fly and communicate as equipped, and communicate with the gateway over their preferred protocol. Upon authentication and communication establishment, the gateway determines the path for the messaging to the correct end system. This would likely be done by a combination of lookup tables for addresses, flight plan correlations based on flight ID, tail number and/or 24 bit aircraft address as well as supplementary information (e.g. aircraft location or departure and destination), and the protocols supported by the aircraft and end system. The communication between the gateway/aircraft and the gateway/ground system would be done via the supported protocols.

The fact that application-level data is not affected is advantageous in some aspects. It also means that the gateway would need to have additional mechanisms to solve application differences (e.g. between FANS-1/A and ATS B2 as per ED230A/DO352A: FANS 1/A – B2 INTEROP standard). For IPS and OSI, no application conversion is performed as the application data itself is not changed; it will remain untouched, in whatever format it was originally, leaving such aspects as checksums intact.

The above diagram includes both CSPs and ANSPs; the gateway itself could be either part of a CSP or ANSP domain; the architecture is flexible depending on the specific needs of the target airspace to be served.

5.5.2 Military communication networks

State aircraft operating as General Air Traffic (GAT) military transport type aircraft are considered within the scope of this document with respect to their A/G communication capabilities over FCI datalinks (i.e. this document does not cover specific military/tactical datalink operations (e.g. JTIDS/MIDS).

Coordination between the units providing services remains essential. Civil-Military coordination has a focus on Military Air Defence tasks for National security aspects. The SWIM technical infrastructure being developed for this application exclusively centres on SWIM-based exchanges between military systems, such as ATC, air defence (AD) or wing operations centres (WOC), and civil systems, such as ATC and Network Manager (NM) systems on the ground. Typical domains of interest include management of priority flights, military-specific requirements for air policing, sensitive data handling and resilience.

The FCI needs to provide the necessary integration and interfacing in order to ensure effective and secure G/G data exchange between civil and military stakeholders, including military ATC, AD Units and WOC. To be relevant to all sectors, the military SWIM-enabled systems can be located in a military unclassified sub-domain, or in a military classified sub-domain – such as AD (Figure 17). In the second case, the bidirectional data exchanges with military classified networks would require an Information Exchange Gateway (IEG), as identified in PJ.17-W2-03 and introduced in PJ.14-02-04 W1 FCI Document D5_3_070 “Assessment of civil-military Information Exchange Gateway”. The IEG connects both sub-domains in order to reach the military SWIM node located in the military unclassified sub-domain, which is connected to the civil infrastructure network (FCI). This IEG implements key functions related to multi security domain connectivity, content inspection, information release verification and network threat protection.

REQ-14-W2-77-OP-042	**The FCI shall provide integration and interfacing to ensure effective and secure G/G data exchange between civil and military stakeholders**

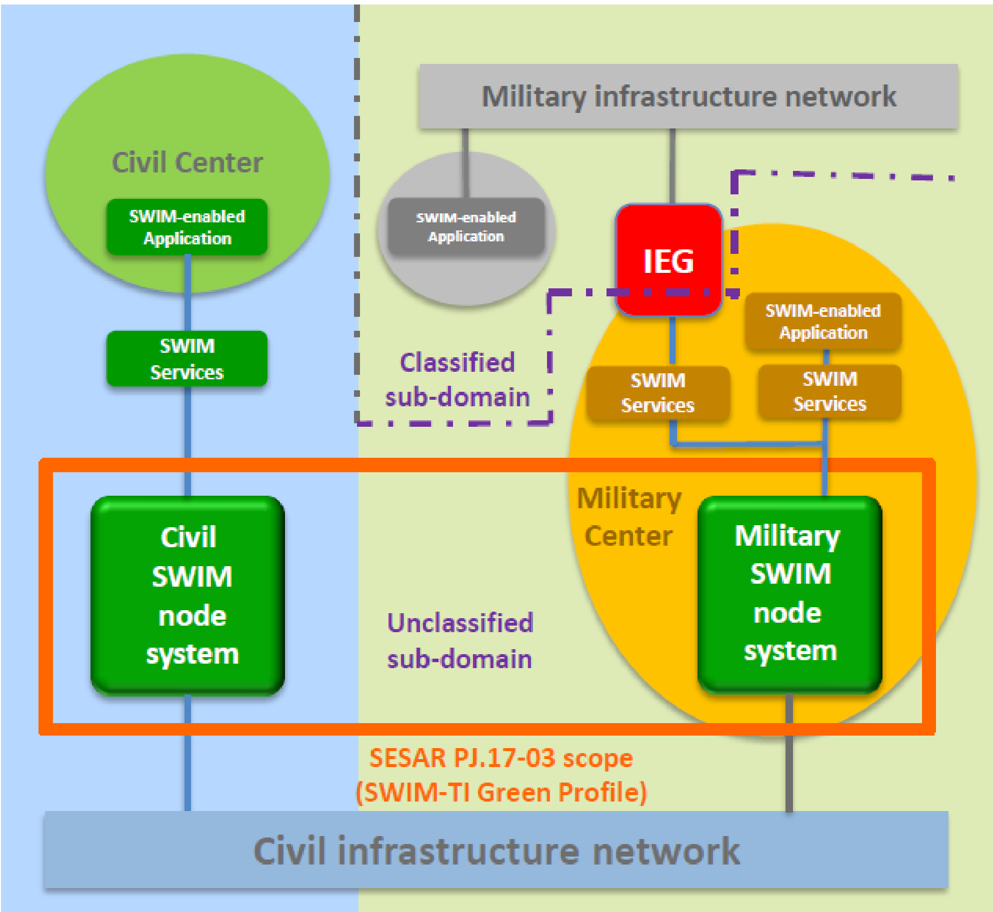


Figure 17 Civil-military coordination domain

5.5.3 Non-FCI IP networks

The FCI is expected to leverage the high standardisation and interoperability level of IP protocols and architectures to provide interoperable interfaces with other IP networks. This will enable dissemination of ATM information for relevant users outside the FCI (e.g. RPAS users).

REQ-14-W2-77-OP-043	**The FCI shall interface with other IP networks (e.g. U-Space, commercial networks) implementing the appropriate mechanisms for inter-domain routing and security**

5.5.3.1 U-Space/RPAS networks

The European Commission has developed a vision for the phased introduction of procedures and services to support safe, efficient and secure access of RPAS/UAS to airspace, called U-space. EASA Opinion No 01/2020 [28] proposes a regulatory framework, to be adopted in 2020, for manned and unmanned aircraft to operate safely in the U-space. However, in the short term, it is not considered that future CNS infrastructure will support Command and Control (C2) or ATC service by U-space providers.

It is assumed that U-Space will operate its own communications infrastructure including radio and beyond radio line of sight technologies for RPAS C2. However, ATM information exchanges may be necessary between FCI users (ATSP and ADSP) and the Remote Pilot Station (RPS) for safe integration of RPAS missions within controlled airspace, as shown in Figure 18. There are two use cases for ATC information transmission within the RPAS network: 1) Making use of the ground network infrastructure (indicated by a solid line in Figure 18), 2) Relaying through the RPAS vehicle (indicated by a dash line). In any case, FCI is considered to potentially interface with U-Space via an application gateway or Border Router (BR). This interface likely does not require protocol conversion, but should implement the appropriate security mechanisms to protect the FCI perimeter from malicious traffic outside the network, via packet filtering or firewalls.

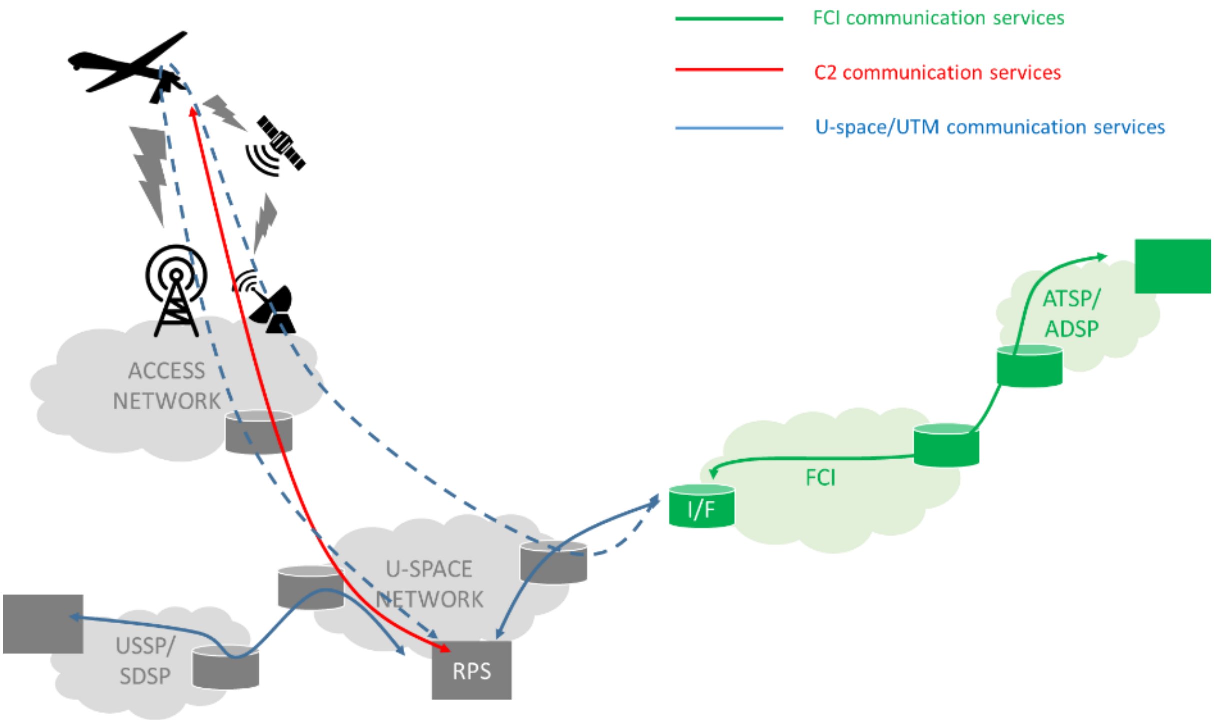


Figure 18 Interface of FCI with U-Space

5.5.3.2 Commercial networks

There is a myriad of IP-based networks used for commercial purposes outside aviation, including cellular and satellite communication networks, and which provide exponentially increasing communication capabilities which could support future ATM concepts. It is reasonable to assume that FCI may interface with these commercial networks for specific exchanges of ATM supporting services using shared communication infrastructure and common mobility service provision. This concept is currently being researched by SESAR PJ14-W2-61 "Hyper Connected ATM" and is out of the scope of this ConOps.

6 Conclusions

This ConOps describes the operational use of the Future Communications Infrastructure (FCI) at its maturity stage. It defines the overall architecture, operational context, applications, levels of performance, safety and security, and network functions to be provided by the FCI. This results in the definition of a set of Operational Requirements, which are summarized in Table 19. These are a starting point to drive the transition aspects, technical specifications, and validation activities in PJ.14-W2-77.

This deliverable is an initial ConOps specification. A review and refinement will be performed at the end of the project, considering new research results, especially from related SESAR operational solutions, updated traffic load analysis, and the Digital Voice concept.

Requirement ID	Requirement description
REQ-14-W2-77-OP-001	The FCI shall support the communication of ATM applications between IPS hosts located in the ground infrastructure (G/G communications)
REQ-14-W2-77-OP-002	The FCI shall support the communication of ATM applications between IPS hosts located in the ground infrastructure and IPS equipped airborne systems located in aircraft mobile subnetworks (A/G communications) at all phases of flight while aircraft is located over the geographical coverage area
REQ-14-W2-77-OP-003	The FCI shall interface with the following IP stacks: - ATN/IPS as per ICAO Doc 9896 - SWIM Technical Infrastructure using Yellow, Blue, Purple-Advisory, Purple-Safety and Green Profile specifications - Native IP stack based on IETF RFC for ATM applications
REQ-14-W2-77-OP-004	The FCI shall support the following ATS services as per ICAO Annex 11: - Flight Information Service (FIS) - Alerting Service - Air Traffic Advisory Service - Air Traffic Control Service (ATS Baseline 2) applications as per EUROCAE ED-229
REQ-14-W2-77-OP-005	The FCI shall be capable of supporting evolution of ATS Baseline 2 for support of Trajectory Based Operations (TBO), including ATS Baseline 3
REQ-14-W2-77-OP-006	The FCI shall support the following AIS/MET services as per EUROCAE ED-151: - AIS: Aeronautical Update Service, Baseline Synchronization Service - MET: WPDS, WNDS, WIDS, Weather downlink
REQ-14-W2-77-OP-007	The FCI shall support Aeronautical Operational Control (AOC) services
REQ-14-W2-77-OP-008	The FCI shall support Digital Voice
REQ-14-W2-77-OP-009	The FCI shall support exchange of flight information for support of the FF-ICE concept for Trajectory Based Operations (TBO)
REQ-14-W2-77-OP-010	The FCI shall be scalable as to support TBD simultaneously equipped aircraft and TBD peak data throughput

Requirement ID	Requirement description
REQ-14-W2-77-OP-011	The FCI shall be capable to support ATM applications complying with the end to end performance levels indicated in Tables 9-12.
REQ-14-W2-77-OP-012	FCI shall provide mechanisms to mitigate detected loss of communications due to a failure of the aircraft IPS routing system, the radio system, or an FCI ground component, leading to a situation where safety-critical applications cannot be used anymore (tentative, dependent on SAF in D5.1.120 “TRL6 Final TS/IRS FCI Services”)
REQ-14-W2-77-OP-013	Redundancy should be considered to FCI components on the aircraft (mobile subnetwork), access network and/or ground infrastructure between two connected IPS hosts (tentative, dependent on SAF in D5.1.120 “TRL6 Final TS/IRS FCI Services”) *Note: This requirement applicable to ground infrastructure is augmented by REQ-14-W2-77-OP-017 for security purposes*
REQ-14-W2-77-OP-014	Aircraft (mobile subnetwork) FCI components shall be implemented at Design Assurance Level C (tentative, dependent on SAF in D5.1.120 “TRL6 Final TS/IRS FCI Services”)
REQ-14-W2-77-OP-015	Software assurance levels for FCI components should be commensurate to, either: - Severity Class 3 - Severity Class 4, if proper mitigations are implemented (tentative, dependent on SAF in D5.1.120 “TRL6 Final TS/IRS FCI Services”)
REQ-14-W2-77-OP-016	The FCI should implement, either: - Functional mechanism that timely and confidently monitors any undetected loss or misbehaviour of air/ground communications, implemented in DAL C - A mechanism ensuring that safety-critical communications cannot be disrupted in the event of an undetected loss or misbehavior of air/ground communications (e.g. multiple transmission)
REQ-14-W2-77-OP-017	The FCI shall implement redundant communication infrastructure which does not rely on the same CSP network domain
REQ-14-W2-77-OP-018	Proper security control and security management practices shall be implemented on the FCI, including: - Configuration and operational audits - Secure monitoring and management - Attack monitoring and correction, and patch management - Self-protection and network security design practices
REQ-14-W2-77-OP-019	The FCI shall implement integrity and privacy protection of the control and data plane of the communications
REQ-14-W2-77-OP-020	The FCI shall support IPv6 unicast addressing
REQ-14-W2-77-OP-021	The FCI should support IPv6 multicast addressing for:

Requirement ID	Requirement description
	- G/G communications - A/G communications in the ground-to-air direction if group sessions are required for ATM services (e.g. AIS/MET or Digital Voice)
REQ-14-W2-77-OP-022	Each IPS host in the FCI shall have at least one routable, globally unique IPv6 unicast address uniquely identifying a network interface
REQ-14-W2-77-OP-023	The globally routable IPv6 address of an operator-based aircraft shall be derived from the aircraft Mobile Network Prefix (MNP) and independent of an access network point of attachment.
REQ-14-W2-77-OP-024	Link Local Addresses (LLA) on the network-layer interfaces of the IPS Nodes facing air-ground datalink shall be configured with unique address derived from the MNP
REQ-14-W2-77-OP-025	The FCI shall provide the capability for an IPS host to query and receive the IPv6 address of a peer host using its generic host name (e.g. Ground Facility Designator, GUFI, or other)
REQ-14-W2-77-OP-026	The FCI shall provide mobile connectivity among IPS hosts served by a federation of multiple, independent CSPs
REQ-14-W2-77-OP-027	The FCI shall support monitoring of A/G data links in the access networks available for communication with A/C, including at a minimum UP/DOWN status
REQ-14-W2-77-OP-028	The FCI shall support signalling of link monitoring status from A/C to ground infrastructure
REQ-14-W2-77-OP-029	The FCI shall support link selection policy depending on the application type, including: - ATS dictated by ATSP - AOC dictated by the airspace user (A/C or FOC)
REQ-14-W2-77-OP-030	The FCI shall support link selection for A/G communications among available access networks, which does not result in a loss of ATS services, based on: - Administrative policy and/or - Link performance based on link status monitoring
REQ-14-W2-77-OP-031	The FCI shall support link selection override by manual selection of data or voice communications in the case of a degraded link performance, or for testing and validation purposes
REQ-14-W2-77-OP-032	The mobile node (aircraft) IPS host shall provide situational awareness about connectivity services
REQ-14-W2-77-OP-033	The mobile node (aircraft) IPS host shall provide means to intervene on connectivity services when necessary
REQ-14-W2-77-OP-034	The CSP providing the MSP should operate a Network Operations Centre (NOC) with a 7/24 continuous human supervision
REQ-14-W2-77-OP-035	The ATM service providers should operate a Network Operations Centre (NOC) with a 7/24 continuous human supervision

Requirement ID	Requirement description
REQ-14-W2-77-OP-036	FCI shall support traffic classification for packet forwarding and routing policy
REQ-14-W2-77-OP-037	The FCI shall support the following QoS functions: - Data rate guarantee for required applications (e.g. Digital Voice) - Packet differentiation, prioritization and pre-emption in situations of congestion - Packet scheduling to support applications with different latency budgets
REQ-14-W2-77-OP-038	The FCI shall provide protection against intentional breach of integrity and mis-delivery for safety-critical applications.
REQ-14-W2-77-OP-039	The FCI shall provide security measures to protect and mitigate against Denial of Service attacks
REQ-14-W2-77-OP-040	The FCI shall provide protection against interception of confidential information for network control and system management data
REQ-14-W2-77-OP-041	The FCI shall provide ground accommodation of: - ATN/OSI equipped aircraft for ATS communication with IPS host - FANS1/A equipped aircraft for ATS communication with IPS host - IPS equipped aircraft for ATS communication with FANS or ATN/OSI endpoint
REQ-14-W2-77-OP-042	The FCI shall provide integration and interfacing to ensure effective and secure G/G data exchange between civil and military stakeholders
REQ-14-W2-77-OP-043	The FCI shall interface with other IP networks (e.g. U-Space, commercial networks) implementing the appropriate mechanisms for inter-domain routing and security

Table 19 Summary of Operational Requirements

7 References

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