INTERNATIONAL CIVIL AVIATION ORGANIZATION

AFI SEAMLESS ATM MASTER PLAN

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This Plan was originally developed by the AFI ATM Master Plan Project Management Team and amended when appropriate by APIRG.

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EXECUTIVE SUMMARY

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ACRONYMS

The following acronyms are used in this document.

Acronym	Definition
A-SMGCS	Advanced Surface Movement Guidance & Control System
ACARS	Aircraft Communication Addressing and Reporting System
ACC	Area Control Centre
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
AFI	African Indian Ocean region
AFIS	Aerodrome Flight Information Services
AFTN	Aeronautical Fixed Telecommunication Network
AIDC	ATS Interfacility Data Communication
AIM	Aeronautical Information Management
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Services
AIXM	Aeronautical Information Exchange Model
AMHS	ATS Message Handling System
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
AODB	Airport Operations Database
APCH	RNP Approach
APIRG	AFI Planning and Implementation Regional Group
APP	Approach
APV	Approach Procedure with Vertical guidance
ASBU	Aviation System Block Upgrade
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information Service
ATS	Air traffic Services
ATS/DS	ATS Direct Speech
ATM	Air Traffic Management
ARO	Aerodrome Reporting Office

AWOS	Automated Weather Observing System
CCO	Continuous Climb Operations
CDO	Continuous Descent Operations
CDR	Conditional Route
CLAM	Cleared Level Adherence Monitoring
CNS	Communication, Navigation and Surveillance
COM	Communication
CPDLC	Controller Pilot Data Link Communication
CTR	Control Zone
DME	Distance Measuring Equipment
ENR	En-route
FIR	Flight Information Region
FIS	Flight Information Service
FL	Flight Level
FMP	Flow Management Position
FUA	Flexible Use of Airspace
GANP	Global Air Navigation Plan
GBAS	Ground Based Augmentation System
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
HF	High Frequency
HMI	Human Machine Interface
HQ	Headquarters
HR	Human Resources
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFP	Instrument Flight Procedure
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LNAV	Lateral Navigation
LOC	Local (runway) controller
LPV	Localizer Performance with Vertical guidance
LVP	Low Visibility Procedure
MET	Meteorology
MLAT	Multilateration

MOU	Memorandum of Understanding
MSAW	Minimum Safe Altitude Warning
MSSR	Monopulse Secondary Surveillance Radar
NAVAID	Navigation Aid
NDB	Non-Directional (radio) Beacon
NM	Nautical Mile
NOF	NOTAM Office
NOTAM	Notice To Air Men
OJT	On-the-job Training
OJTI	On-the-job Training Instructor
OLDI	On-Line Data Interchange
PIA	Performance Improvement Area
PIRG	Planning and Implementation Regional Group
PBN	Performance Based Navigation
PIB	Pre-flight Information Bulletin
PSR	Primary Surveillance Radar
RAM	Route Adherence Monitoring
RCC	Rescue Coordination Centre
RNAV	Area Navigation
RNP	Required Navigation Performance
RPL	Repetitive Flight Plan
RWY	Runway
RX	Receiver
SAR	Search And Rescue
SARPs	Standards and Recommended Practices
SBAS	Satellite-Based Augmentation System
SID	Standard Instrument Departure
SMR	Surface Movement Radar
SMS	Safety Management System
SSR	Secondary Surveillance Radar
STAR	Standard Terminal Arrival Route
STCA	Short Term Conflict Alert
TFG	Traffic Forecasting Group
TMA	Terminal Manoeuvring Area
TRA	Temporary Reserved Area

TSA	Temporary Segregated Area
TWR	Tower
TWY	Taxiway
TX	Transmitter
UNL	Unlimited
UTA	Upper Traffic Area
VCS	Voice Communication System
VDF	VHF Direction Finder
VFR	Visual Flight Rules
VHF	Very High Frequency
VNAV	Vertical Navigation
VOR	VHF Omnidirectional Range
VRS	Voice Recording & Replay System
VSAT	Very Small Aperture Terminal
WAM	Wide Area Multilateration

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PART I

INTRODUCTION

1.1 Scope of the Plan

(a) APIRG 22 **Conclusion 22/35** calls for the establishment of the AFI Seamless ATM system. That in order to improve the flow of air traffic in the AFI region there is need for the development of **an AFI ATM regional Vision Document, Concept of Operations and Master ATM Plan** with enabling **Infrastructure Strategy** for Africa.

(b) The AFI Region aims at the establishment of a seamless upper airspace with the existing FIRs, in accordance with the Global Air Navigation Plan provisions. This will result in the increased harmonization and improvement of the existing services by focusing on implementable arrangements that will increase interoperability and deliver benefits in the Short, Medium and Long Terms.

(c) The AFI Region Member States have recommended the development of the AFI Seamless Air Traffic Management (ATM) Master Plan for which the Performance and benefits of changes will carefully be monitored and evaluated. For the sake of traceability with the Global Air Navigation Plan, it is assumed that the AFI Seamless ATM Master Plan will be aligned with the ASBU Block upgrades.

(d) The AFI Seamless ATM Master Plan (hereinafter referred to as the 'Plan') references different levels. At the upper level is a global perspective, which is guided mainly by references to the *Global Air Navigation Plan* (GANP, Doc 9750), the *Global ATM Operational Concept* (Doc 9854) and the *Global Aviation Safety Plan* (GASP). Beneath this level is regional planning primarily provided by this Plan and other guidance material, in order to define goals and means of meeting State planning objectives, such as:

   (1) AFI Regional Air Navigation Plan objectives;
   (2) The Seamless ANS performance framework, with a focus on technological and human performance within Aviation System Block Upgrade (ASBU) Block 0 elements, non-ASBU elements, and civil-military cooperation elements;
   (3) a deployment plan with specific operational improvements, transition arrangements, expected timelines and implementation examples; and

(4) an overview of financial outcomes and objectives, cross-industry business and performance/risk management planning.

(e) The Plan incorporated the ICAO/CANSO Mombassa Air Traffic Flow Management (ATFM) Roadmap Concept of Operations and the AFI Air Navigation Concept of Operations (both hereinafter referred to as 'CONOPS'), and the AFI PBN Implementation Plan, superseding these documents.

(f) The Regional Air Navigation Plan (RANP) is expected to incorporate key components of this Plan and information on the mechanisms that enable these objectives to be met. High-level support may be necessary from regional bodies that can effectively support the Plan's implementation, such as but not limited to:

(1) Africa Union (AU);
(2) Regional Economic Commissions (RECs);
(3) African Civil Aviation Commission (AFCAC); and
(4) Single Africa Air Transport market (SAATM).

(g) The Seamless ANS Plan is expected to be implemented in several phases. No phase, nor any element, is binding on any State, but should be considered as a planning framework. The Seamless ANS Plan itself is therefore guidance material.

(h) The main assumptions of this plan are:

(1) The operational concepts and CNS/ATM architecture defined in this plan are implemented in a timely manner.
(2) The operational concepts and infrastructure defined in the ICAO GANP and ASBUs Block upgrades remain relevant.
(3) The plans produced for the AFI region are executed.
(4) External projects (such as the implementation of EGNOS in the Africa region) continue to be undertaken in a timely manner.
(5) Traffic Forecasts for the AFI regions are largely accurate, meaning that traffic will grow rapidly during the timeframe of this Plan.
(6) The FIRs that exists will remain largely as they are today, excluding adjustments to better reflect operational requirements.

1.2 Plan Objectives and Development

(a) The objective of the Plan is to facilitate AFI Seamless ATM operations, by developing and deploying ATM solutions capable of ensuring safety and efficiency of air transport throughout the AFI region. The Plan provides a framework for a transition to a Seamless ATM environment, in order to meet future performance requirements.

(b) The Plan provides the opportunity for the AFI region to adopt the benefits from research and development conducted by various States including the NextGen programme (United States of America), the European Single European Sky ATM Research (SESAR), and Japanese Collaborative Actions for Renovation of Air Traffic Systems (CARATS).

(c) ICAO Doc 9854 contains a vision of an integrated, harmonized, and globally interoperable ATM System, with a planning horizon up to and beyond 2025. In this context, the Plan is expected to encourage more partnering relationships among States within sub-regions.

PART II

ANALYSIS OF TRAFFIC FLOWS AND ROUTE NETWORK

2.1 Introduction

(a) This part analyses the current situation in the provision of air navigation services (ANS) in the AFI Region. Particularly, it captures the strengths and weaknesses of the current situation, and the aviation stakeholders' expectations. It is based on the contributions and meetings from Member States. It is a first step towards the development of the "AFI Seamless Air Traffic Management Master Plan".

(b) The Plan does not use 'continental', 'remote' and 'oceanic' areas to refer to an assumed geographical application area, as many AFI States have islands or archipelagos that can support a higher density of Communications, Navigation, Surveillance (CNS) systems than in a purely 'oceanic' environment. In accordance with the CONOPS that air navigation services should be provided commensurate with the capability of the CNS equipment, it is important to categorise airspace in this manner, and simplify the numerous references to this capability throughout the Plan. Thus the Plan categorises airspace by reference to its CNS (Communications, Navigation and Surveillance) capability as:

(1) Category R: remote en-route airspace with Air Traffic Services (ATS) HF or CPDLC communications and outside the coverage of ground-based surveillance coverage; or

(2) Category S: serviced (or potentially serviced) en-route airspace – by direct (not dependent on a Communication Service Provider (CSP) ATS communications and surveillance; or

(3) Category T: terminal operations serviced by direct ATS communications and surveillance.

(c) The word 'States' in the Plan includes Special Administrative Regions and territories.

2.2 Airspace Organization

(a) The upper airspace of the xx AFI Member States comprises **xx Flight Information Regions** (FIRs) which together represent an area of more than xxx million square kilometres (i.e. more than 2.5 times the European airspace).

Insert map

(b) The current airspace organisation is principally based on geographical boundaries and the division of airspace has been dictated for years by national considerations. This particularly impacts long haul and mid haul flights which have to cross several control units along their route and to adapt successively to various quality of service levels, which leads to inefficiencies and potentially problems.

(c) One of the main opportunities offered by the implementation of a regional seamless ATM Master Plan is to contribute to the simplification of the organisation of the airspace and to provide airspace users with seamless services regardless of political boundaries, thus enabling sustainable development of the air transport system within the region.

(d) The first step towards the improvement of the regional airspace organisation is to examine thoroughly the traffic patterns and the evolution of the demand in the time frame of the implementation of the AFI Seamless ATM Master Plan.

2.3 Overview of the Current and Foreseen Aviation Market

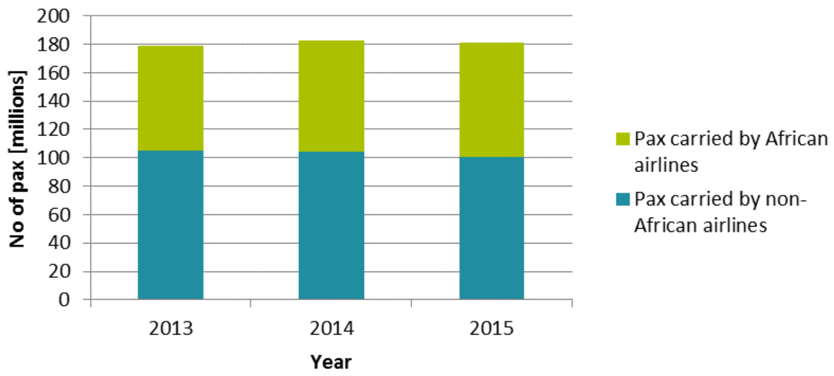
(a) The purpose of this section is to present an overview of the current and foreseen market situation in African airspace in the AFI region. This should enable an understanding of the main goals of the airspace users (AUs) and help to highlight benefits that this plan can bring to them.

(b) The air transport sector in Africa has suffered not only from high prices and unprofitable routes but also from poor safety and reliability, which are significant issues for operators. Although a route structure analysis of the current main traffic flows pointed out only a few routes where the demand meets the current ATM capacity, it is necessary to consider the future traffic forecast.

(c) The traffic growth in the region is expected to be approximately 5% per year over the next 20 years. Therefore, it is important to avoid capacity constraints and congestions in the future, especially for the busiest city pairs. The current route network does not entirely consider AUs' preferences and often prevents AUs from using the most economical routes.

2.4 Airline Performance in the African Region

(a) In 2015, the number of passengers carried in the African continent reached a value of 180 million; more than 2 million tonnes of cargo was carried and 2.9 million movements were flown. The performance of African airlines has been increasing on both domestic and international routes – the total number of passengers carried by African airlines reached almost 80 million and the transported cargo represented more than 800 thousand tonnes in 2015.



Passengers in Africa

(b) However, the average load factor remains significantly below the global average, although African airlines have a generally stronger load factor on domestic routes.

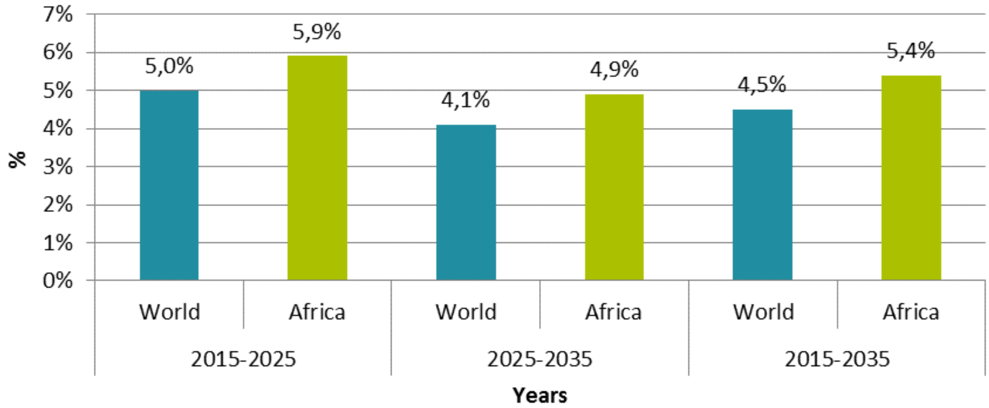
(c) African carriers face stiff competition, especially for Africa – Europe and Africa – Middle East routes where the largest international market is located. In the Africa – Europe market they are being attacked either by strong traditional carriers from Europe and the Middle East or by popular low-cost carriers (LCCs). In the Middle East market, the majority of the capacity is taken by Middle East airlines such as Emirates, Qatar or Etihad. The exception is Egyptian carriers. Recently, the fastest growing market is Africa – Asia, where African carriers dominate in total capacity share and are trying to expand further. For Africa – North America, capacity share is also dominated by African airlines.

(d) The African airlines overview represents the diversity of the different airlines' models in terms of destinations and fleets. Traditional carriers service domestic, regional and also international destinations. For this service they operate more diverse types of aircraft in order to achieve the best operational results. Low cost carriers (LCC) and regional carriers act differently. The fleet is either unified to cut costs for training and maintenance, or consists of small turboprops aircraft. Most of the LCC flights are domestically oriented with some exceptions for close regional destinations. As the price of tickets for LCCs is lower than for traditional carriers, the load factor is higher. Cargo airlines do not provide relevant information for comparison, but a lot of cargo is transported in the belly of passenger aircrafts. Destinations vary from regional to international routes, depending on demand.

2.5 Forecasts

(a) As shown in Figure xx, global forecasts have foreseen that the aviation industry in the African region will grow significantly above global average rates. The fleet of new passenger and cargo aircraft is supposed to double by 2035, and the passenger fleet demand is expected to be focused on single aisle aircraft. Therefore, there is a need in the future to eliminate high level congestion both at airports and en-route.

(b) This process is long lasting but thanks to effective collaboration and cooperation can bring successful results.



Total Revenue Passenger Kilometer (RPK) Traffic Growth Forecast

PART III

OPERATIONAL PLAN (CONOPS)

PART IV

GAP ANALYSIS AND TECHNICAL PLAN

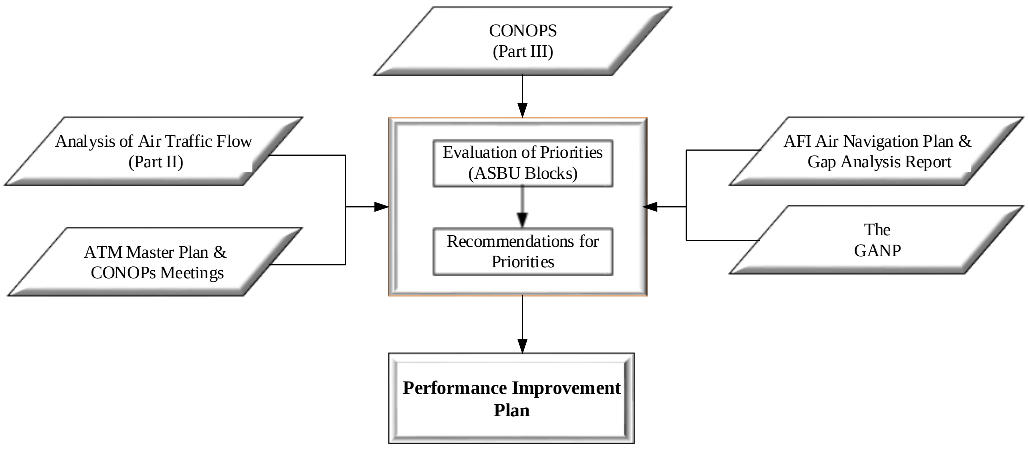
4.1 Introduction

(a) To support the operational plan CONOPs, it is necessary to perform a gap analysis and to define a Technical Plan that will outline the technology needed to enable the target operations to be performed within the AFI Region.

(b) This part therefore presents the **Gap Analysis and Technical Plan** for the AFI Region in the short, medium and long term, explaining the benefits of the technologies and the operational concepts that they will enable. Recommended actions are then developed for the timeframe of the Master Plan.

4.2 Methodology

(a) The analysis performed to define the Technical Plan for the AFI Region is summarised in the following diagram, and described in more detail in the following sections.



4.3 Presentation

(a) The document consists of the following sections into which the technical concepts discussed in the context of this Master Plan are organised:

(1) **Communication,** covering air-ground communications and ground-ground communications (voice and data);

(2) **Navigation**, covering a navigation based on conventional means but also a navigation based on GNSS;

(3) **Surveillance**, covering ground-based surveillance and airport surveillance;

(4) **Automation**, covering ATC systems and ATFM systems; and

(5) **Information Management**, covering Aeronautical Information, the System Wide Information Management (SWIM), and Meteorological Information.

(b) Additionally, a **GBAS and SBAS feasibility study** performed as part of the Master Plan and used as an input to the development of the Technical Plan will be presented.

4.4 Current situation & Seamless Operations

(a) For each technical concept, the current situation in the AFI region is presented, a brief explanation is provided and the requirements for seamless operations are given based on guidelines issued by international organisations and available information from other regions.

4.4.1 Target scenarios

(a) In order to best guide the implementation of the technology defined in this report, the description of evolutions has been considered in three distinct phases:

(1) **Short term (2022-2024)** – initiatives that can be implemented in a relatively short time period, and that will immediately unlock airspace capacity in the AFI region and improve the safety of operations. This will include the implementation of the technology supporting the ASBU Block 0 concepts, if not already present.

(2) **Medium term 2024-2028** –initiatives that will offer significant improvements in capacity, efficiency and safety within the AFI region, but whose implementation is less urgent or requires more preparation. This timeframe is aligned with ASBU Block 1.

(3) **Long term 2028-2032** – concepts which are more advanced and are more complicated to implement, and therefore require more time for planning and trials, or that will become relevant as traffic levels increases within Africa. This timeframe is aligned with ASBU Block 2.

4.5 Qualitative analysis

(a) In order to define the target technical scenarios, the qualitative analysis has been based on the following:

(1) The current situation of the provision of air navigation services (ANS) in the AFI region as defined in the gap analysis presented in section 4.6.

(2) The CONOPs for the AFI region in the timeframe of the Master Plan (as defined in part III (AFI CONOPs)).

(3) The SBAS and GBAS feasibility study which will be presented in this report.

(4) Stakeholders' expectations, including those of national and international airlines that operate in the AFI region. It covers stakeholder expectations in terms of KPAs (safety, efficiency and cost), as well as specific requests such as desired routes.

(5) Global and regional consistency and best practices. In terms of global consistency and for defining best practices, the ICAO Global Air Navigation Plan (GANP) and the associated Aviation System Block Upgrades (ASBUs) are the most important documents.

4.5.1 Current situation in the provision of ANS in the AFI region

(a) The current situation of the provision of ANS in AFI region (en-route, approach and aerodrome) has been defined in part II of this ATM Master Plan.

(b) The current situation is used as a baseline upon which to base recommendations in the Short-Term Scenario.

4.5.2 Stakeholders' expectations

(a) Stakeholders' expectations are largely related to operational procedures, which are of course enabled by technological developments. Feedback will be received from IATA on behalf of the airlines that use airspace in the AFI region.

(b) The feedback from stakeholders is detailed in appendix xxx.

4.5.3 Global consistency

(a) The most important document in terms of global consistency and best practices are the ICAO Global Air Navigation Plan (GANP) and the associated Aviation System Block Upgrades (ASBUs).

4.5.3.1 ICAO Global Air Navigation Plan and Aviation System Block Upgrades

(a) The ICAO Global Air Navigation Plan (GANP) (Doc 9750) is described by ICAO as "an overarching framework that includes key civil aviation policy principles to assist ICAO Regions, sub-regions and States with the preparation of their Regional and State air navigation plans". It is designed to "guide complementary and sector-wide air transport progress over beyond 2030.

(b) The GANP represents a rolling, 15-year strategic methodology which leverages existing technologies and anticipates future developments based on State/industry agreed operational objectives. The GANP contains several technology roadmaps, which depict new and legacy technologies needed to support the Block Modules (see below), and provide timelines for the implementation of these technologies. These roadmaps have been used as a guide when developing the technical plan for the AFI region.

(c) The ICAO Aviation System Block Upgrades (ASBUs) refer to the target availability timelines for a group of operational improvements (technologies and procedures) that will eventually realize a fully-harmonized Global Air Navigation System. There are four ASBU Blocks:

(1) ASBU Block 0, 2013 – 2018;

(2) ASBU Block 1, 2019 – 2024;

(3) ASBU Block 2, 2025 – 2030; and

(4) ASBU Block 3, 2031 onwards.

(d) The Block Modules that are related to technology are used as an input for the development of the technical plan for the AFI region. Those Modules that are related to procedures have been used when developing the CONOPs for the AFI region, but as the technical plan supports and enables the operational concept, they remain relevant for this part.

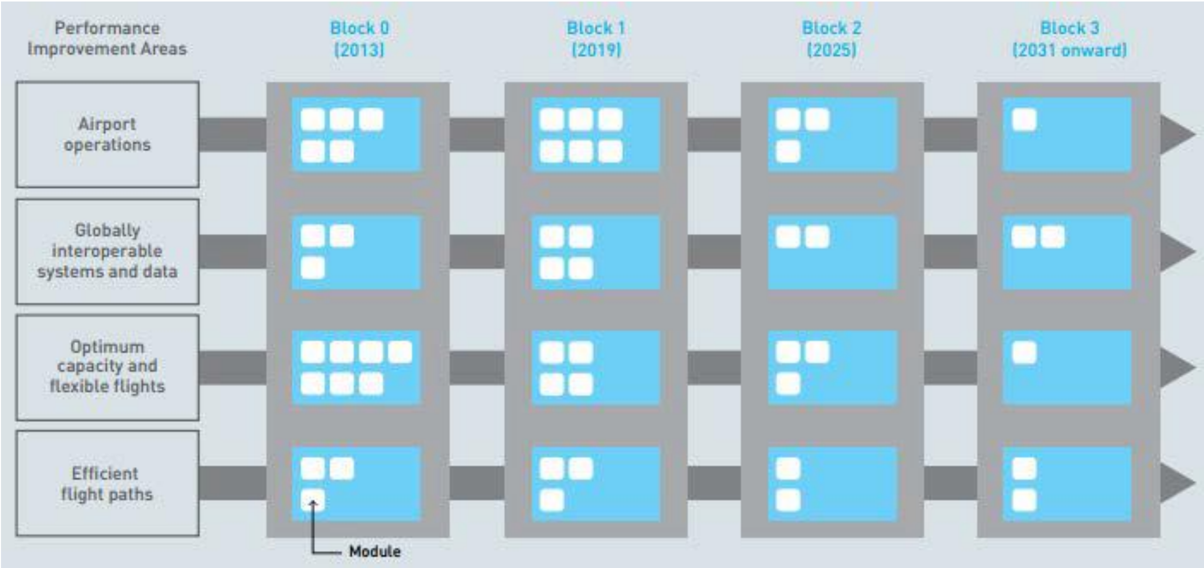


Figure xx - ICAO Aviation System Block Upgrades (ASBUs)

4.5.3.2 *AFI Air Navigation Plan*

(a) An initial version of the "AFI Regional Air Navigation System Implementation Action Plan" was approved in 2013 at the ICAO APIRG 19, based on the Fourth Edition of the Global Air Navigation Plan (ICAO Doc 9750) and the accompanying Aviation System Block Upgrades (ASBUs).

(b) The plan encourages States to implement those Block 0 Modules applicable to their specific operational needs, and categorises the 18 ASBU Block 0 Modules based on the urgency of their implementation (Essential, Desirable, Specific, or Optional).

(c) This plan and the associated initiatives undertaken by the Africa-Indian Ocean (AFI) Planning and Implementation Regional Group (APIRG) are considered when producing the technical plan for AFI ATM Master plan in the short, medium and long term.

4.6 Gap Analysis

4.6.1 Overview

(a) The gap analysis presented below has been conducted based largely on the information provided to us by the AFI ANSPs through their responses to the questionnaire submitted earlier on in the Project. The information from these questionnaires was complemented by desk-based research of publicly available information (both regional and national).

(b) It should be noted that some ANSPs did not respond to these questionnaires, and so there are necessarily gaps in our knowledge of their technical and operational situation.

(c) In addition, some questionnaires received were incomplete.

(d) Furthermore, we did not receive and were not able to otherwise access the AIPs of some AFI States.

(e) The gap analysis has been undertaken for the following technological and operational areas: Navigation Infrastructure, Communication Infrastructure, Surveillance Infrastructure, Air Traffic Control (ATC) Systems, Performance Based Navigation (PBN,) Aeronautical Information Management (AIM) including SWIM, Search and Rescue (SAR), and Meteorological Services (MET).

(f) The current situation of the AFI States is analysed and compared to the target scenario. The following key is used for the tables presented below:

4.6.2 Communication Infrastructure

4.6.2.1 Summary of Current Situation and Seamless Operations requirements

Area	Current Situation	Seamless Operations
Telecommunication Network	Analogue VSAT networks, leased lines from national telecommunication companies (and sometimes Fiber optic	Use of an AFI Aeronautical Telecommunications Network (ATN) to provide the inter-

Area	Current Situation	Seamless Operations
	links) are used as the media for exchange of messages and/or digital data between aeronautical fixed stations	networking infrastructure for the CNS/ATM environment
Ground-Ground Communications	Much of the coordination between ATC Centres is performed through HF, direct voice through the use of the VSAT network, and the public telephone network. Many States have implemented IP networks, but they are not IPV6. ATFN is often used for the exchange of messages and/or digital data, although some States have implemented a basic version of AMHS (and very few have implemented extended AMHS).	Voice communications will be over Voice over IP (VoIP). IPV6 used for the transfer of data. AMHS (Aeronautical Message Handling Service) used as the system to transmit messages, digital NOTAMS, flight plans etc. AIDC (ATS Interfacility Data Communication) used to exchange flight data and ATC related information between Air Traffic Service Units (ATSUs).
Air-ground communications	Air-ground communications largely conducted over voice, using VHF with 25kHz channel spacing in Continental areas and HF in remote and oceanic areas	Voice communications will continue to be conducted over VHF with 25kHz channel spacing in Continental areas, but migrate to SATCOM (Satellite Communications) in remote and oceanic areas. Air-ground communications will be increasingly conducted over data link, using CPDLC over ATN Baseline 1 (B1) in continental airspace and CPDLC/ ADS-C over FANS-1/A (ACARS) in remote and oceanic airspace. This

Area	Current Situation	Seamless Operations
		will require the use of VHF Data Link Mode 2 as a link media in continental airspace, and SATCOM ACARS (or HF Data Link) in remote and oceanic airspace.

4.6.2.2 Gaps

4.6.2.2.1 Telecommunications Network

(a) The AFI Regional Aeronautical Telecommunications Communication Network (the ATN) is a regional concept yet to be implemented, and so presents an effective gap for all States.

4.6.2.2.2 Ground-Ground Communications

(a) Although many States currently operate IP networks, they must be upgraded to the latest version (IPV6). From the information available, very few States have implemented Voice over IP for voice communications between ATC Centres and other States have reported to be planning its implementation.

(b) The extended version of AMHS is already operated by most of the States while others operate a basic version (which must be upgraded to the extended version) and so present partial gaps.

(c) AIDC has already been installed by some States, although it must be ensured that it is connected with all neighbouring ATCs in the future. Other States have also implemented AIDC/OLDI, but difficulties have been reported with connecting to some neighbouring ACCs due to compatibility issues, which should be addressed.

4.6.2.2.3 Air-Ground Communications

(a) Only a few States (from the information gathered) have planned implementation of VHF Data Link (VDL) Mode 2 (therefore, for those States that did not provide information, we have assumed that a gap exists for VDL). All other States must plan and implement VDL Mode 2 in their airspace. Many States already have a sufficient number of transmitters/receivers and so do not have a gap.

(b) HF Data Link is not currently used by most States in the AFI region, and so presents a gap for each State. HF voice will only be used as back up to HF Data Link and SATCOM ACARS in remote and oceanic regions.

(c) CPDLC will initially be implemented and some Sates must make CPDLC fully available in their ACCs (using CPDLC over ATN Baseline 1 in continental airspace and CPDLC/ADS-C over FANS-1/A (ACARS) in remote and oceanic airspace). SATCOM ACARS will be used to carry voice data in the region – all States currently use HF for voice data in these areas, and so present a gap.

4.6.3 Navigation Infrastructure

4.6.3.1 Summary of Current Situation and Seamless Operations requirements

Area	Current Situation	Seamless Operations
NAVAIDs	Widespread use of conventional NAVAID such as NDBs and VORs, which will not support PBN. DMEs present in most States (either standalone or with VOR), but their number is often insufficient to support PBN operations	Sufficient number/density of DMEs to support RNAV operations. Other conventional NAVAIDs, such as NDB and VOR, to be gradually decommissioned as they finish their life cycle (being used as back-up/contingency in the mean-time).
Use of core GNSS constellations to support PBN operations	GNSS used sparingly in AFI States	GNSS utilised as the primary means of navigation by the end of the Phase, to support PBN
Augmentation Systems for GNSS	No satellite-based augmentation (SBAS) available in the AFI region. No Ground Based Augmentation Systems (GBAS) used.	Use of SBAS and GBAS to enable the use of GNSS as a primary means of navigation for En-Route and approach.
GPMS	No GNSS Performance Monitoring System (GPMS) used in the AFI region	Use of GPMS to enable the use of GNSS as a primary means of navigation

4.6.3.2 Gaps

4.6.3.2.1 NAVAIDs

(a) Most States do not have a sufficient number of DMEs to support PBN operations (i.e. RNAV). It is therefore important that States implement sufficient number of DMEs to support PBN operations.

4.6.3.2.2 GNSS

(a) GNSS must be deployed/extended in every State to enable it to be used as the primary means of navigation, supported by a Satellite Based Augmentation System (SBAS), Ground Based Augmentation Systems (GBAS) (firstly at international airports), and a GNSS Performance Monitoring System (GPMS). An Aircraft Based Augmentation System (ABAS) will also be used to augment GNSS on-board aircraft, but is not presented in the gap analysis as it is to be deployed by airlines.

4.6.4 Surveillance

4.6.4.1 Summary of Current Situation and Seamless Operations requirements

Area	Current Situation	Seamless Operations
Radar	Radar is an important method of surveillance in the region, although coverage is not consistent in many regions.	Radar will not be the primary method of surveillance and will not be extended systematically. MSSR will be expanded only in areas where enhanced surveillance is deemed to be required. Primary Surveillance Radar (PSR) will only be used in areas where there may be conflict between commercial aircraft and military aircraft, and will be increasingly upgraded to multi-static PSR.
Automatic Dependent Surveillance (ADS)	Ground based ADS-B In/Out is used by a few States, but many do not use it at all. ADS-C is used by States who have large areas of remote/oceanic airspace.	Ground based ADS-B In/Out will be the principal means of surveillance in continental areas. ADS-C will initially be used consistently in remote regions and oceanic areas to unlock airspace capacity. By the end of the Phase, satellite-based

Area	Current Situation	Seamless Operations
		ADS-B Out will replace ADS-C in remote and oceanic areas.
Wide Area Multilateration (WAM)	WAM is not used in the AFI airspace.	The use of WAM will be restricted to areas in which it can be shown to provide operational benefits, e.g. mountainous areas.

4.6.4.2 Gaps

4.6.4.2.1 Radar

(a) As PSR and MSSR will be implemented based on State's evolving situations, no gaps are identified for these surveillance technologies. MSSR technologies will be maintained where they already exist.

4.6.4.2.2 ADS-B

(a) Most States have been identified as already having satisfactory ground-based ADS-B In/Out coverage. All other States must implement at least one more ground station during the life of this plan and each State must determine the number required.

(b) All States that require ADS-C (as they have areas that cannot be covered by other means) have already employed the technology.

(c) States with large areas of oceanic/remote will require satellite-based ADS-B Out. As it is a technology that will only become available in the coming years, all of these States present a gap.

4.6.4.2.3 WAM

(a) As implementation of WAM will be restricted to certain areas where it can be shown to provide operational benefits, e.g. mountainous areas, so no gaps are identified for this surveillance technology.

4.6.5 ATC Systems

4.6.5.1 Summary of Current Situation and Seamless Operations requirements

Area	Current Situation	Seamless Operations
Processing Systems	Flight Data Processing Systems (FDPS) and Surveillance Data Processing Systems (SDPS) have	All States will utilise FDPS and SDPS within their ATC systems, to better integrate flight data and

Area	Current Situation	Seamless Operations
	been implemented by a minority of States.	surveillance data (generating system tracks) in the ATC system.
Conflict Management Tools	A number of States have installed conflict management tools, including Short Term Conflict Alert (STCA), Area Proximity Warning (APW), and Medium-Term Conflict Detection (MTCD) in their ATC systems, although many have not.	STCA and APW will be utilised by all ATC systems to increase safety by warning controllers of potential conflicts and incursions into dangerous areas, and MTCD will be used to balance more evenly the workload between tactical and planning tasks.
Recording & Replay System	Most States have implemented a Recording & Replay System (VRS), although most of these do not cover all of surveillance, flight, voice and MET data.	All ATC systems will include a VRRS function for surveillance, flight, voice and MET data. This data will be used for improving the efficiency of ATC operations.
Controller Display	Most States have an Automatic ATM controller situation display.	All ATC systems will have an automatic ATM controller situation display, which will display all relevant ATC data, increasing situational awareness.

4.6.5.2 Gaps

4.6.5.2.1 Processing Systems

(a) Most States already operate both a Flight Data Processing Systems (FDPS) and Surveillance Data Processing Systems (SDPS).

4.6.5.2.2 Conflict Management Tools

(a) Most States all operate Short Term Conflict Alert (STCA), Area Proximity Warning (APW), and Medium-Term Conflict Detection (MTCD) in their ATC systems.

4.6.5.2.3 Controller Display and Recording & Replay System

(a) An automatic ATM controller situation display is used in some States. Other States operate a Recording & Replay System (VRRS) that supports surveillance, flight, voice and MET data.

4.6.6 Performance Based Navigation (PBN) and Free Route Airspace (FRA)

4.6.6.1 Summary of Current Situation and Seamless Operations requirements

Area	Current Situation	Seamless Operations
Route network	Much of the route network is based on conventional routes, where aircraft must fly between NAVAIDS, although many countries have implemented a significant number of RNAV routes	The implementation of RNAV routes in continental, remote and oceanic, and terminal airspace is a priority and should be completed by 2022. Later, advanced RNP routes, allowing greater route density, will be implemented. The route network, based on RNAV, will enable direct routes to be flown between major city pairs.
Approach and Departure	Although some approaches/ departures in the region are RNAV, most are conventional. There is very little evidence of the use of Continuous Descent and Climb Operations (CDOs and CCOs).	Advanced RNP approach procedures will be implemented using GNSS, replacing current instrument procedures. International airports should be prioritised. CDOs and CCOs will be implemented at all major international airports, using VNAV.
Free Route Airspace (FRA	There are no examples of FRA in the AFI region, although its implementation is planned in most States	Ideally, Free Route Airspace will be implemented in all regions, although it is understood that direct routing using RNAV will be a priority.
Airspace Design and Planning Coordination	Limited examples of cooperation in the planning and design of airspace exist.	Local level cooperation in airspace design and planning will take place, largely at a bilateral level between States.

4.6.6.2 Gaps

4.6.6.2.1 En-route

(a) Most States have implemented a sufficient number of En-Route RNAV routes.

(b) Most Staes however have conventional routes and therefore present a gap.

4.6.6.2.2 Approach and Departure

(a) Most States are known to have implemented RNAV approach/departures. Additionally, other States have implemented some RNAV approach procedures.

(b) Few States have implemented CDOs and CCOs at their international airport and other States are planning their implementation at their main airports.

4.6.6.2.3 Free Route Airspace

(a) All countries should implement FRA – the only country that is known to have planned its implementation is Sudan.

4.6.6.2.4 Airspace planning coordination

(a) All States must improve cooperation with neighbouring States for airspace planning and design.

4.6.7 Aeronautical Information Management

4.6.7.1 Summary of Current Situation and Seamless Operations requirements

Area	Current Situation	Seamless Operations
Consolidation and compliance with ICAO Annex 15	AFI States are largely compliant with ICAO Annex 15 (compliant with AIRAC, use WGS-84, and have Quality Management Systems). However, a few gaps remain in these areas.	All States are fully compliant with ICAO Annex 15, including the use of Quality Management Systems and compliance with AIRAC. WGS-84 is used as a standard geodetic reference for all States.
AIM	The transition to AIM has begun recently. The AIXM 5.1 standard required is implemented or planned by many States. Most States do not yet publish electronic AIPs, and the provision of eTOD is variable. Although information is lacking, it is expected that most States do not publish Digital NOTAM.	The AIXM 5.1 standard will be used by all States to transfer Aeronautical Information, and all States will publish eAIPs. eTOD will be provided for all States and international airports. Digital NOTAMs will be issued over IP. States will implement Data quality and integrity monitoring.

4.6.7.2 Gaps

4.6.7.2.1 Consolidation and compliance with Annex 15

(a) Some States are known to present gaps for WGS-84, AIRAC and/or QMS, which are the building blocks of AIM (based on the most recent versions of their AIPs at the date of preparation of this report and other feedback received) but are currently under survey, and QMS is implemented for MET services but not for AIS.

4.6.7.2.2 AIM

(a) Some States have already implemented the AIXM 5.1 standard, while others have planned its implementation. Others operating different systems present a gap for AIXM 5.1, while other States are unknown.

(b) Some States already publish electronic AIPs and most States are yet implement one.

(c) Data on eTOD was difficult to source – from the information gathered only some Sates publish eTOD for international airports. Some States are also fully compliant with Area 1 and Area 4 Terrain and Obstacle requirements, and plans to be compliant with Area 2 and 3 requirements by 2022.

(d) Information on the publication of Digital NOTAMs is scarce. As a relatively new concept, it can be expected that most countries do not yet publish one.

(e) In addition, all States will need to implement data quality and integrity monitoring. Due to a lack of information on whether States currently carry this out, it has not been presented as a gap.

4.6.8 Search and Rescue

4.6.8.1 Summary of Current Situation and Seamless Operations requirements

Area	Current Situation	Seamless Operations
State level SAR	Most States in the AFI region are compliant with ICAO Annex 12. Software tools, if used at all, are not harmonised.	All States fully compliant with ICAO Annex 12. States will use harmonised SAR software tools to improve the efficiency of operations. Civil/military cooperation for SAR operations clearly defined at national level through the use of MoUs
Cooperation	Some coordination initiatives exist within States in the AFI region. Regional SAR Plans	Bilateral agreements will be agreed between neighbouring States for Assistance and Cooperation in SAR

Area	Current Situation	Seamless Operations
	have not been developed though some States are in the process of doing so.	operations. Regional SAR Plans will have been developed at an appropriate level.

4.6.8.2 Gaps

4.6.8.2.1 SAR at national level

(a) From studying the AIPs that are available, almost all States are compliant with ICAO Annex 12.

(b) Other States are showing some small discrepancies and are therefore not fully compliant and should become so.

(c) It is recommended that a **SAR software** tool be introduced in each State. This SAR software would integrate and process data from various external sources to facilitate the search of the probable area of the accident and then to coordinate the rescue effectively.

(d) **Civil-military cooperation** should be defined through the use of Memorandums of Understanding – no information on this subject has been, and so gaps cannot be verified.

4.6.8.2.2 SAR cooperation

(a) Some States have cooperation agreements in place with neighbouring AFI States and States that have not so will need to define formal SAR cooperation agreements. Even those States which are not deemed to have a gap could benefit from extending their SAR agreements to other neighbouring States.

(b) A Regional SAR Plan will be developed at an appropriate level and so a country-by-country gap analysis has not been presented.

4.6.9 Meteorological Systems

4.6.9.1 Summary of Current Situation and Seamless Operations requirements

Area	Current Situation	Seamless Operations
Availability of MET information	Most States publish SIGMETs and make regional forecasts from, world area forecast centres (WAFCs), volcanic ash advisory centres (VAACs) and tropical	Forecasts provided by WAFCs, VAACs and TCAC will be made available to all ACCs in the AFI region. SIGMETs and other operational meteorological

Area	Current Situation	Seamless Operations
	cyclone advisory centres (TCAC) available, as required by ICAO Annex 3, although a couple of gaps remain.	(OPMET) information will be issued to provide information on occurrence or expected occurrence of specific En-Route weather phenomena which may affect the safety of aircraft operations.
Exchange of meteorological information	Inconsistent formats are used for coding meteorological data, and OPMET data is provided and exchanged in text, making the handling of global data difficult to use correctly and expensive to maintain.	The IWXXM standard will be used for operational exchanges of meteorological information, enabling the use of standard application and techniques for handling and processing of data.
Common procedures for MET reports to pilots	Each State defines their own procedures for reporting meteorological information to pilots	The procedures for reporting meteorological information to pilots will be consistent throughout the region.
Integrated meteorological information	Meteorological constraints are manually assessed and the mitigation of those constraints calculated by humans, through the use of forecasts. MET data is not integrated into the ATM decision making process.	Meteorological information will be integrated into the ATM system, and will support automated decision processes, in line with ICAO ASBU B1-AMET, allowing near-term planning taking into account MET conditions.

4.6.9.2 Gaps

4.6.9.2.1 Availability of MET information

(a) Most States in the AFI region comply with the requirements of ICAO Annex 3 for the availability of Meteorological information (ie regional forecasts and SIGMETs) although all States should ensure that the information they provide is as comprehensive as possible.

4.6.9.2.2 Exchange of meteorological information

(a) No States use the IWXXM standard, as it is a new concept contained in ABSU B1-DATM – therefore, all States present a gap.

4.6.9.2.3 Common procedures for MET reports to pilots

(a) Since each State currently defines their own procedures for reporting meteorological information to pilots, there is an effective gap for all States to introduce common procedures.

4.6.9.2.4 Integrated meteorological information

(a) This is a new concept (ASBU B1-AMET) and so presents a gap for all States.

4.7 Technical Plan (Performance Improvement Plan)

4.7.1 Technological Roadmap

The roadmaps illustrated in this section have been designed to depict:

(a) New and legacy technologies needed to support the Block Modules:

  (1) Modules that require the technology are shown in black.

  (2) Modules that are supported by the technology are shown in grey.

(b) The date by which a technology is needed to support a Block and its Modules.

(c) The availability of a technology (if it precedes the Block).

For ease of reference, CNS, IM and avionics roadmaps have been divided on the following basis:

DOMAIN	COMPONENTS	ROADMAP
Communication	Air-ground data link communications	COM1
	Ground-ground communications	COM2
	Air-ground voice communications	
Navigation	Dedicated technology	NAV1
	Performance-based navigation	NAV2
Surveillance	Ground-ground surveillance	SUR1
	Surface surveillance	

	Air-air surveillance	SUR2
Information Management	SWIM	IM1
	Flight & Flow	
	AIS/AIM	
	Meteorology	
	Time	
Avionics	Communications	AV1
	Surveillance	
	Navigation	AV2
	Airborne safety nets	AV3
	On-board systems	

4.7.1.1 Communication

Air-ground data link services fall into two basic categories:

(a) Safety-related ATS services where performance requirements, procedures, services and supporting technology are strictly standardized and regulated; and

(b) Information-related services where performance requirements, procedures and supporting technology are less critical.

In general, the enablers (link media technologies) will be developed and deployed based on the need to support safety-related ATS services. It should however be noted that in a radio regulatory context, AOC and certain other information services are considered as being safety related and should operate in spectrum allocations associated with safety and regularity of flight and so their needs may also have to be considered at the technology development stages.

To prepare for Block 3, research and development is needed in the Blocks 1 and 2 time frames; there are three areas of investigation where standards are being developed:

(a) Airports – a ground-based high capacity airport surface data link system is currently under development. The Aeronautical Mobile Airport Communications System (AeroMACS) is based on IEEE 802.16/WiMAX standard).

(b) SATCOM – a new satellite-based data link system targeted at oceanic and remote regions. This link may also be used in continental regions as a complement to terrestrial systems. This could be a dedicated ATS SATCOM (e.g. European ESA Iris initiative) system or a multi-mode commercial system (e.g. Inmarsat Swift Broadband, Iridium).

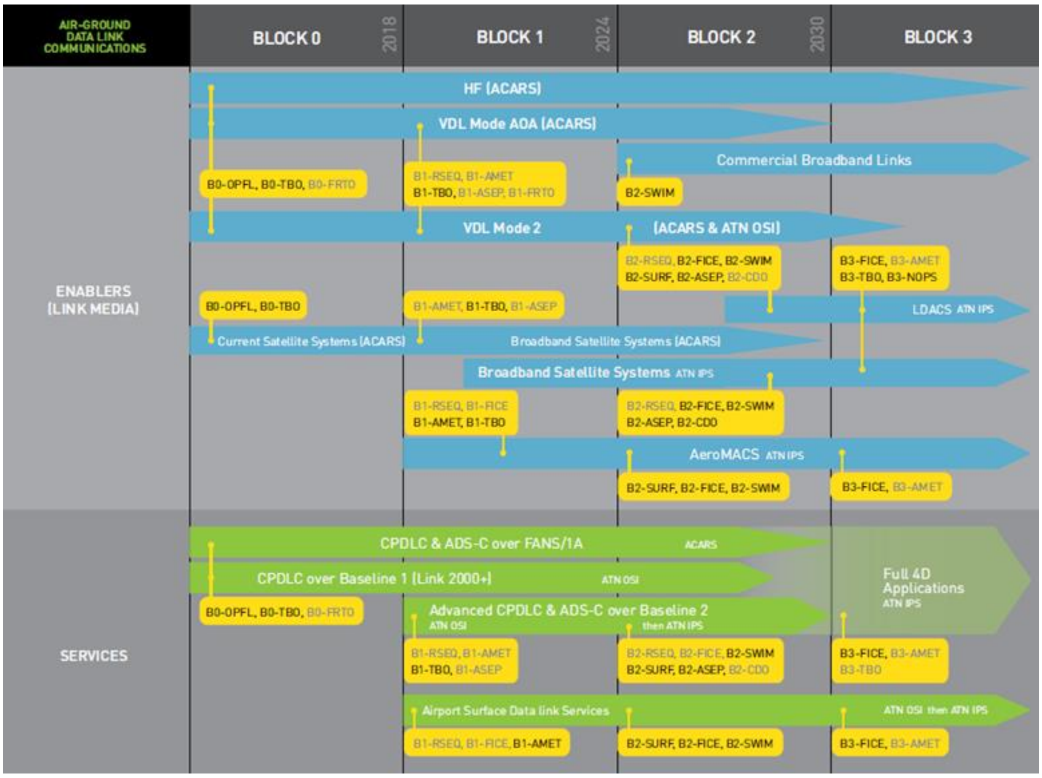
(c) Terrestrial (terminal and en-route) – a ground-based data link system for continental airspace is currently under investigation. This has been termed the aeronautical L-band digital aeronautical communications system (L-DACS).

In addition, studies are needed to a) review the role of voice communications in the long-term concept (primarily data centric); and to b) consider the need to develop a new appropriate digital voice communication system for continental airspace.

ROADMAP COM1:

DOMAIN: COMMUNICATION

COMPONENT(S): AIR-GROUND DATA LINK COMMUNICATION
- ENABLERS (LINK MEDIA TECHNOLOGY)
- SERVICES



Roadmap COM1 - in the Block 0-time frame

ENABLERS:

- Aviation will rely on existing communications systems, i.e. VHF ACARS and VDL Mode 2/ATN in continental areas.
- VHF ACARS will begin transitioning towards VDL Mode 2 AOA (i.e. providing higher bandwidth) since VHF channels

SERVICES:

- Data link service implementation is used in oceanic, en-route airspace and at major airports (FANS1/A and/ or ICAO ATN based – ATN B1). Today's data link service implementations are based on different standards, technology and operational procedures, although there have become a very scarce resource in several regions of the world.

- SATCOM ACARS will continue to be used in oceanic and remote regions.

are many similarities. There is a need to converge quickly to a common approach based upon ICAO approved standards. The common global guidance material continues to be developed, namely the *Global Operational Data Link Document* – GOLD (Doc 10037).

- Services such as aeronautical operational control (AOC) are carried by aircraft for communication with airline company host computers. The air-ground communications media (such as VDL Mode 2) are shared with the ATS services due to cost and avionics limitations. The use of these media for AOC is also consistent with the radio regulatory requirements of the aviation safety bands used.

Roadmap COM1 - in the Blocks 1 and 2 time frame

ENABLERS:

- ATS services will continue to exploit existing technology to maximize return on investment, hence VDL Mode 2/ ATN will continue to be used for converged data link services in continental areas. New service providers may enter the market (mainly for service in oceanic and remote regions), provided they meet the ATS service requirements.

- AOC may begin to migrate towards new technologies at airports and in the en-route environment (e.g. AeroMACS at airports) as they become commercially attractive. This may also apply to some information-based ATS.

- VHF ACARS will continue to transition to VDL Mode 2.

SERVICES:

- An important goal is to harmonize the regional data link implementations through a common technical and operational standard, applicable to all flight regions in the world. RTCA and EUROCAE have developed common safety, performance and interoperability standards for this next generation of ATS data link services (ATN B2) for both continental and oceanic and remote regions. These standards, supported by validation results, have been made available in an initial release in 2014 with the full standard in 2016, to be followed by a comprehensive validation phase and will be available for implementation in some regions from 2020. These standards will form the basis of data link services for the long term and will

- HF ACARS will be phased out as a better suitable datalink becomes capable of providing service over polar regions.
- The Aeronautical Telecommunications Network can be adapted to operate over new broadband Aeronautical Satellite Systems.

support the move towards trajectory-based operations.

- As avionics evolve, new high-volume information services such as weather advisories, map updates, etc. will become possible. These services could take advantage of new communication technology that could be deployed at some airports and in some en-route airspace, this may be seen as the beginning of air-ground SWIM. These new data link services could be either AOC or ATS. Some of these services may however not need the same levels of performance as strictly safety-related ATS services and could therefore possibly make use of commercially available mobile data services, thus reducing the load on the infrastructure or spectrum allocation supporting the safety-related ATS services.

Roadmap COM1 - in the Block 3 time frame

ENABLERS

- Data link will become the primary means for routine communication. In such a data-centric system, voice will be used for urgent messages; increased data link performance, availability and reliability, will be available supporting greater levels of safety and capacity.
- For oceanic and remote regions, it is expected that the migration from HF to SATCOM will be completed by the Block 3 time frame.

SERVICES:

- the ATM Target Concept is a "net-centric" operation based on full 4D trajectory management with data link (based on ATN Baseline 2) used as the prime means of communication, replacing voice due to its ability to handle complex data exchanges. In such a data-centric system, voice will be used only in exceptional/ emergency situations.
- Full air-ground SWIM services will be used to support advanced decision-making and mitigation. SWIM will allow aircraft to participate in collaborative ATM processes and provide access to rich voluminous dynamic data including meteorology.

	Commercial information-based services to companies and passengers may also be implemented using the same technology.

ROADMAP COM2:

DOMAIN: COMMUNICATION

COMPONENT(S): GROUND-GROUND COMMUNICATION
AIR-GROUND VOICE COMMUNICATION

Roadmap COM2 - in the Block 0 time frame	
ENABLERS: • IP networks will continue to be deployed. Existing IPV4 systems will be gradually replaced by IPV6. • Until now, inter-centre voice ATM communications were mainly based on analogue (ATS-R2) and digital (ATS-QSIG) protocols. A move has begun to replace ground-ground voice communications with voice over IP (VoIP). • Air-ground voice communications will remain on 25 kHz VHF channels in continental regions (note: 8.33 kHz VHF voice channels will continue to be deployed in Europe). Migration from HF to SATCOM in oceanic and remote regions is expected to start during this time.	**SERVICES:** • Two major ground-ground communications services will be in operation: – ATS messaging operating over AFTN and/or AMHS in some areas. – ATS interfacility data communications (AIDC) for flight coordination and transfer. • ATS messaging is used worldwide for the communication of flight plans, MET, NOTAMS, etc. over AFTN technology. Migration towards AMHS (directory, store and forward services) over IP (or using ATN in some regions) will progress in all regions. • AIDC is used to provide inter-centre coordination and transfer of aircraft between adjacent air traffic control units. Migration from legacy data network (e.g. X25) to IP data network is progressing in various regions. • The beginnings of SWIM will start to appear. Operational services will be offered by some SWIM pioneer implementations over IP, surveillance data distribution and MET data will also be distributed over IP. Migration to

digital NOTAM has started in the United States and in Europe.

Roadmap COM2 - in the Blocks 1 and 2 time frame	
ENABLERS:	**SERVICES:**
• Traditional ground-ground voice communications will continue to migrate to Voice-over Internet Protocol (VoIP). • Digital NOTAM and MET (using the AIXM and IWXXM data exchange formats) will be widely implemented over IP networks. • FIXM will be introduced as the global standard for exchanging flight data prior to (Block 1) and during the flight (Block 2). • To prepare for the long term, research and development is needed in the medium term for new satellite and terrestrial based systems. Voice communications will remain on 25 kHz VHF channels in continental regions (note: 8.33 kHz VHF voice channels will continue to be deployed in Europe). Migration from HF to SATCOM in oceanic and remote regions is expected to be progressing during this time.	• ATS messaging will migrate to AMHS supported by directory facilities that will include common security management by the end of Block 1. AIDC services will fully migrate towards using IP networks. • Initial 4D air-ground services will require ground-ground inter-centre trajectory and clearance coordination via AIDC extensions or new flight data exchanges compatible with the SWIM framework. • SWIM SOA services will mature and expand publish/ subscribe and request/reply services in parallel to the more traditional messaging services based on AMHS but both will use the IP network. • Information security, integrity, confidentiality and availability will be managed in order to mitigate the risks of intentional disruption and/or changes to safety critical ATM information.

Roadmap COM2 - in the Block 3 time frame
It is quite likely that future digital systems will be used to carry voice. Where satellite communications are used, it will most likely be via the same systems used to support air-ground data link. In the terrestrial environment, it is not clear whether L-DACS will be used to carry this traffic or a separate voice system will be used. This will need to be the subject of R&D efforts in the Blocks 1 and 2 time frames.

4.7.1.2 Navigation

Navigation concepts such as RNAV, RNP and PBN provide a range of options for the use of navigation technology. As these are very much dependent on local requirements, this section will provide a narrative description of the considerations for the use of navigation technology.

4.7.1.2.1 GNSS infrastructure

(a) GNSS is the core technology that has led to the development of PBN. It is also the basis for future improvements in navigation services. The core historical constellations GPS and GLONASS have been in operation for well over a decade, and SARPs in support of aviation operations are in place. Other core constellations, e.g. the European Galileo and China's BeiDou, are being developed. Multi-constellation, multi-frequency GNSS has clear technical advantages that will support the provision of operational benefits. To realize these benefits, ICAO, States, ANSPs, standards bodies, manufacturers and aircraft operators need to coordinate activities to address and resolve related issues.

(b) Satellite-based Augmentation System (SBAS) based on GNSS is available in North America (WAAS), Europe (EGNOS), Japan (MSAS) and will soon be available in India (GAGAN) and the Russian Federation (SDCM). Several thousand Localizer Performance with Vertical Guidance (LPV) and Localizer Performance (LP) approach procedures are implemented. SBAS typically supports APV operations, but can also support precision approach (Category I) operations. However, it is challenging for SBAS to support precision approach operations in equatorial regions using single-frequency GPS because of ionospheric effects.

(c) GBAS CAT I based on GPS and GLONASS is available in the Russian Federation and, based on GPS, on some airports in several States. SARPs for GBAS CAT II/III are under operational validation. Related research and development activities are ongoing in different States. It is also challenging for GBAS to support a high availability of precision approach, in particular in equatorial regions.

(d) Conventional radio navigation aids (VOR, DME, NDB, ILS) are in widespread use globally, and most aircraft are equipped with the relevant avionics. The vulnerability of GNSS signals to interference has led to the conclusion that there is a need to retain some conventional radio navigation aids or an alternative navigation service solution as a back-up to GNSS.

(e) Mitigating the operational impact of a GNSS outage will rely primarily on the use of other constellation signals or employing pilot and/or ATC procedural methods, while taking advantage of on-board inertial systems and specific conventional radio navigation aids. In the case of a general GNSS outage in an area, reversion to conventional radio navigation aids and procedures could result in capacity or flight efficiency reduction. In such cases where there is a loss of signals from a specific constellation, the reversion to another constellation could allow maintaining the same PBN level.

(f) The implementation of PBN will make area navigation operations the norm. DME is the most appropriate conventional radio navigation aid to support area navigation operations (i.e. assuming DME multilateration on-board capability), since it is currently used in multi-sensor avionics for this purpose. DME installations and their coverage will need to be optimized. Similarly, ILS remaining widely used, will provide, where available, an alternate approach and landing capability in case of GNSS outage.

Roadmap NAV1 depicts the expected evolution of navigation infrastructure and avionics.

4.7.1.2.2 Current navigation infrastructure

(a) The current navigation infrastructure comprising VOR, DME and NDB navigation beacons was initially deployed to support conventional navigation along routes aligned between VOR and NDB facilities. As traffic levels increased, new routes were implemented which in many cases necessitated additional navigation facilities to be installed.

(b) As a result, navigation aid deployment has been driven by economic factors and has led to a non-uniform distribution of navigation aids with some regions, notably North America and Europe, having a high density of navigation aids with many other regions having a low density, and some areas having no terrestrial navigation infrastructure at all.

(c) The introduction of RNAV in the last decades has led to setting up new regional route networks that no longer relied on these conventional radio navigation aids infrastructure thus allowing wider flexibility to tailor the route network to the traffic demand. This essential move has clearly stopped the direct link between the ground-based navaids and the route network in the busiest air traffic regions.

(d) With the continuous evolution of aircraft navigation capability through performance-based navigation, and the widespread use of GNSS positioning, regions of high traffic density no longer need as high a density of navigation aids.

4.7.1.2.3 Future terrestrial infrastructure requirements

(a) The GANP has the objective of a future harmonized global navigation capability based on area navigation (RNAV) and performance-based navigation (PBN) supported by the global navigation satellite system (GNSS).

(b) The optimistic planning that was considered at the time of the Eleventh Air Navigation Conference for all aircraft to be equipped with GNSS capability and for other GNSS constellations to be available, together with dual frequency and multi-constellation avionics capability being carried by aircraft have not been realized.

(c) The current single frequency GNSS capability provides the most accurate source of positioning that is available on a global basis. With suitable augmentation as standardized within Annexes, single frequency GNSS has the capability to support all phases of flight. The current GNSS has an extremely high availability, although it does not have adequate resilience to a number of vulnerabilities, most notably radio frequency interference and solar events causing ionospheric disturbances.

(d) Until a solution to this adequate resilience problem is available, it is essential that a terrestrial navigation infrastructure, suitably dimensioned to be capable of maintaining safety and continuity of aircraft operations, be provided.

(e) The FANS report from April 1985 stated: *"The number and development of navigational aids should be reviewed with the aim of providing a more rational and more cost-effective homogeneous navigation environment."*

(f) The current status of aircraft equipage for PBN operations supported by GNSS and terrestrial navigation aids, together with the availability of the ICAO PBN Manual and the associated design criteria provide the necessary baseline to commence the evolution to the homogeneous navigation environment envisaged within the FANS Report.

4.7.1.2.4 Infrastructure rationalization planning

(a) It had initially been expected that the rationalization of the legacy navigation infrastructure would have been a consequence of a top-down process where the implementation of PBN and GNSS within volumes of airspace would result in navigation aids being made totally redundant so they could be simply be switched off.

(b) All stakeholders generally agree that PBN is "the right thing to do" and although PBN offers the capability to introduce new routes without additional navigation aids, it remains difficult to justify the case for full scale implementation of PBN within a volume of airspace, unless there are capacity or safety issues to be addressed.

(c) Many States have utilized PBN to implement additional routes as they are required to secure gains in capacity and operational efficiencies. This has resulted in volumes of airspace which contain a combination of new PBN routes and existing conventional routes.

(d) It is now clear that for numerous reasons, which include being unable to establish a positive business case for a large-scale airspace redesign, a top-down PBN implementation followed by infrastructure rationalization will take many years to complete, if ever.

(e) As an alternative strategy, a bottom-up approach should be considered as at the end of each navigation aid's economic life, an opportunity exists to consider if a limited PBN implementation to alleviate the need for the replacement of the facility is more cost-effective than replacement of the navigation aid.

(f) The replacement cost opportunity only presents itself if the navigation aid is fully depreciated and replacement is considered: it therefore arises on a 20-25-year cycle. In order to realize any cost-saving, rationalization opportunities need to be identified and the necessary route changes planned and implemented to enable the facilities to be decommissioned at the end of their lifetime.

(g) This bottom-up approach to rationalization also provides a catalyst to start the airspace transition to a PBN environment, facilitating future changes to optimize routes to deliver gains in efficiency such as shorter routings and lower CO_2 emissions.

(h) In planning for the rationalization of navigation infrastructure, it is essential that all stakeholders' needs and operational uses of the infrastructure be considered. This may include military instrument flight procedures, aircraft operational contingency procedures, such as engine failure on take-off, and used for VOR-based separations in procedural airspace or general aviation.

(i) Additional guidance on navigation infrastructure rationalization planning is provided in Annex 10, Volume I, Attachment H, entitled "*Strategy for rationalization of conventional radio navigation aids and evolution toward supporting performance based navigation*".

ROADMAP NAV1:

DOMAIN: NAVIGATION

COMPONENT(S): ENABLERS

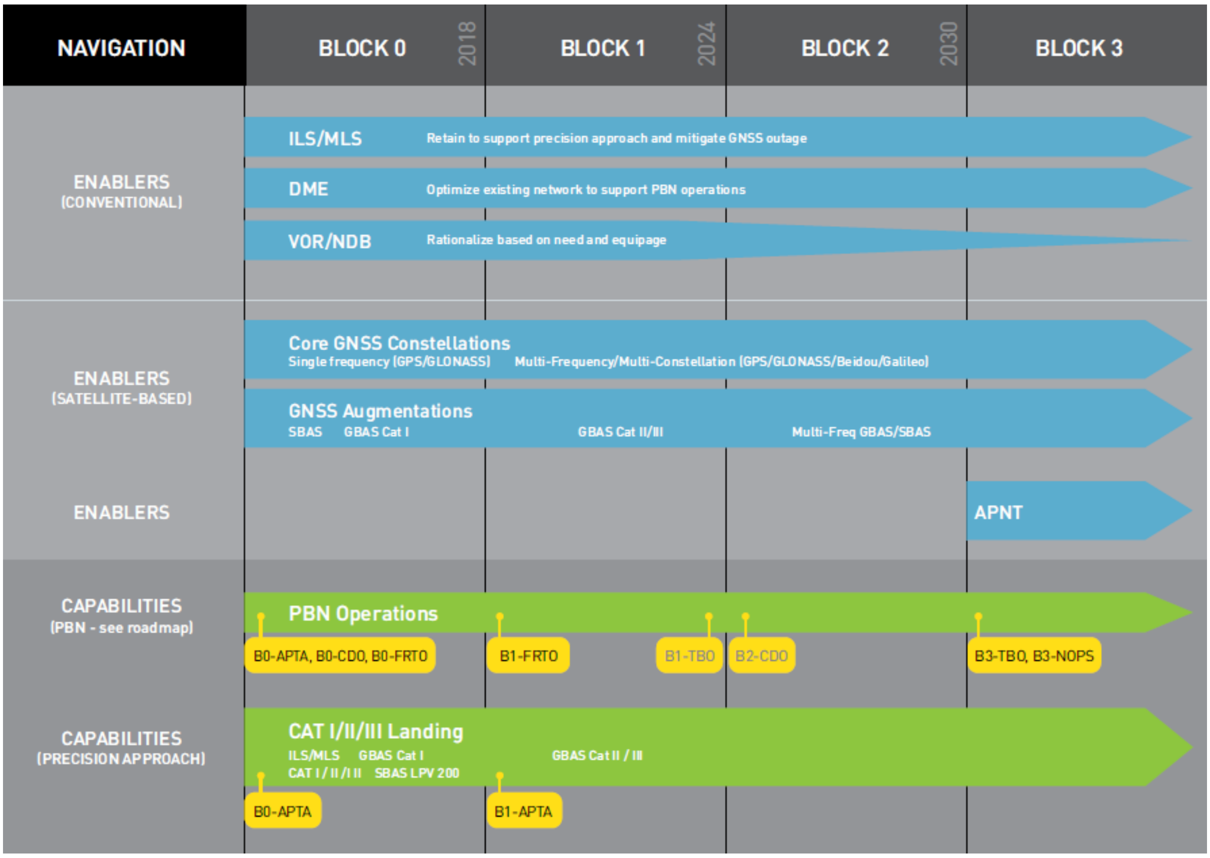
- CONVENTIONAL

- SATELLITE-BASED

CAPABILITIES

- PBN

- PRECISION APPROACH



4.7.1.2.5 Performance-based navigation

(a) **Roadmap NAV2** depicts the migration paths for the implementation of PBN levels and precision approaches for the following operations: en-route oceanic and remote continental, en-route continental, TMA arrival/departure, and approach. There is no attempt to show detailed timelines because regions and States will have different requirements; some may need to move quickly to the most demanding PBN specification while others will be able to satisfy airspace users' requirements with a basic specification. The figures do not imply that States/regions have to implement each step along the path to the most demanding specification. The *Performance-based Navigation (PBN) Manual* (Doc 9613) provides the background and detailed technical information required for operational implementation planning.

(b) The PBN Manual identifies a large set of navigation applications. Among these applications, one subset is the RNP applications. It is important to realize that the implementation of RNP applications within an airspace contributes de facto to a re-distribution of the surveillance and conformance monitoring functions. The RNP concept introduces an integrity check of the navigated position at the aircraft level and allows the automatic detection of non-conformance to the agreed trajectory while this function is today the full responsibility of the controller. Therefore, RNP implementation should provide additional benefits to the air traffic service unit that is traditionally in charge of the conformance monitoring.

ROADMAP NAV2:

DOMAIN: PERFORMANCE-BASED NAVIGATION (PBN)

COMPONENT(S): EN-ROUTE, OCEANIC AND REMOTE CONTINENTAL

EN-ROUTE CONTINENTAL

TERMINAL AIRSPACE: ARRIVAL AND DEPARTURE

APPROACH

4.7.1.3 Surveillance

The important trends of the next 20 years will be that:

(a) Different techniques will be mixed in order to obtain the best cost-effectiveness depending on local constraints.

(b) Cooperative surveillance will use technologies currently available using 1 030/1 090 MHz RF bands (SSR, Mode-S, WAM and ADS-B).

(c) While refinements to capabilities may be identified, it is expected that the surveillance infrastructure currently foreseen could meet all the demands placed upon it.

(d) The airborne part of the surveillance system will become more important and should be "future proof" and globally interoperable in order to support the various surveillance techniques which will be used.

(e) There will be growing use of downlinked aircraft parameters bringing the following advantages:

(1) Clear presentation of call-sign and level.

(2) Improved situational awareness.

(3) Use of some downlinked aircraft parameters (DAPs) and 25 ft altitude reporting to improve surveillance tracking algorithms, including safety nets.

(4) Display of vertical stack lists.

(5) Reduction in radio transmission (controller and pilot).

(6) Improved management of aircraft in stacks.

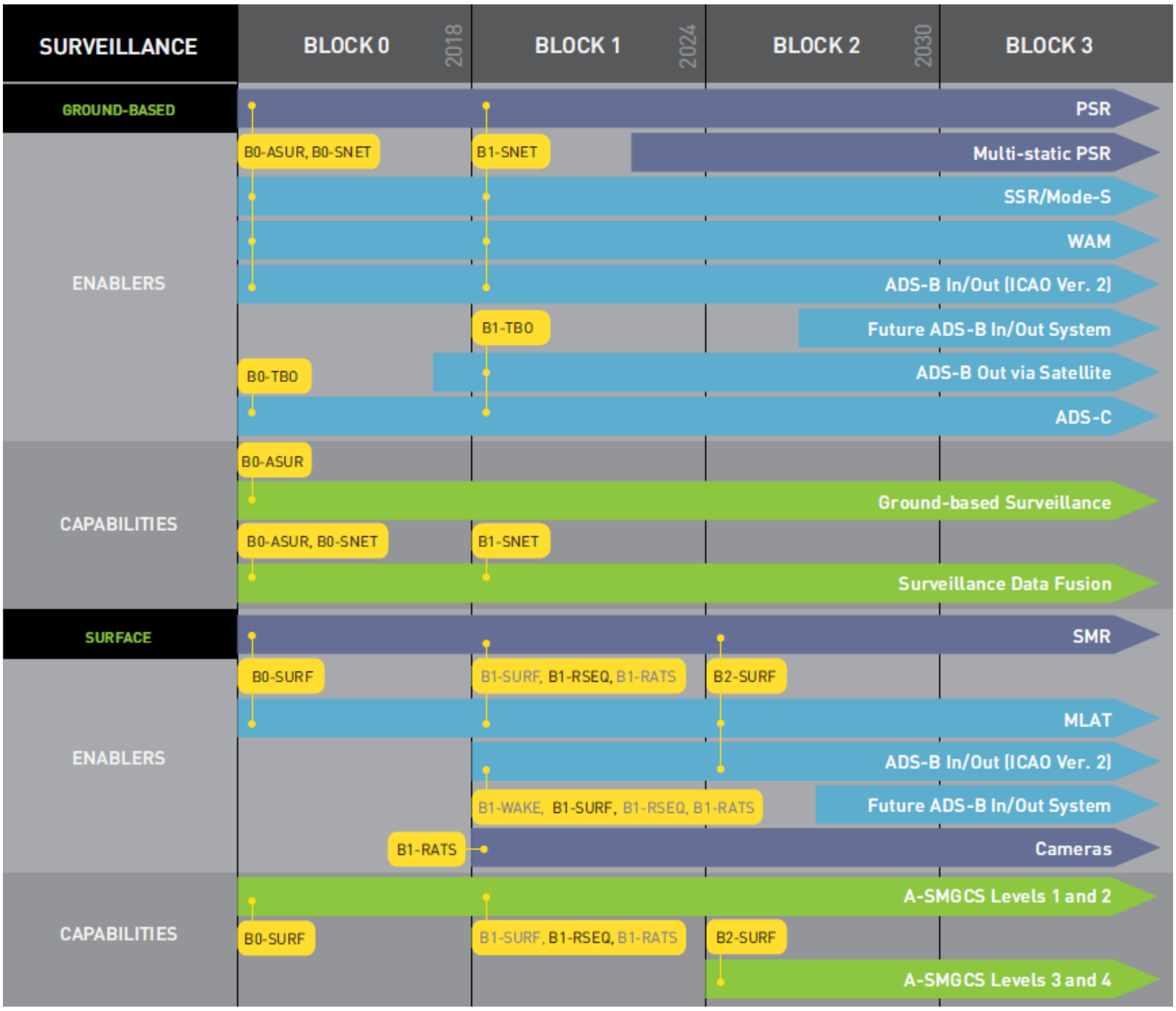
(7) Reductions in level busts.

(f) Functionality will migrate from the ground to the air.

ROADMAP SUR1:

DOMAIN: SURVEILLANCE
COMPONENT(S): GROUND-BASED SURVEILLANCE
- ENABLERS
- CAPABILITIES

SURFACE SURVEILLANCE
- ENABLERS
- CAPABILITIES



Roadmap SUR1 - in the Block 0 time frame

- There will be significant deployment of cooperative surveillance systems: ADS-B (ground- and space-based), MLAT, WAM.
- Ground processing systems will become increasingly sophisticated as they will need to fuse data from various sources and make increasing use of the data available from aircraft.
- Surveillance data from various sources along with aircraft data will be used to provide basic safety net functions. Surveillance data will also be available for non-separation purposes.

Roadmap SUR1 - in the Block 1 time frame

- Deployment of cooperative surveillance systems will expand.
- Cooperative surveillance techniques will enhance surface operations.
- Remote operation of aerodromes and control towers will require remote visual surveillance techniques, e.g. cameras, to provide visual situational awareness. This visual situational awareness will be

• Additional safety net functions based on available aircraft data will be developed. • It is expected that multi-static primary surveillance radar (MPSR) will be available for ATS use and its deployment will provide significant cost savings.	supplemented with graphical overlays such as tracking information, weather data, visual range values and ground light status, etc.

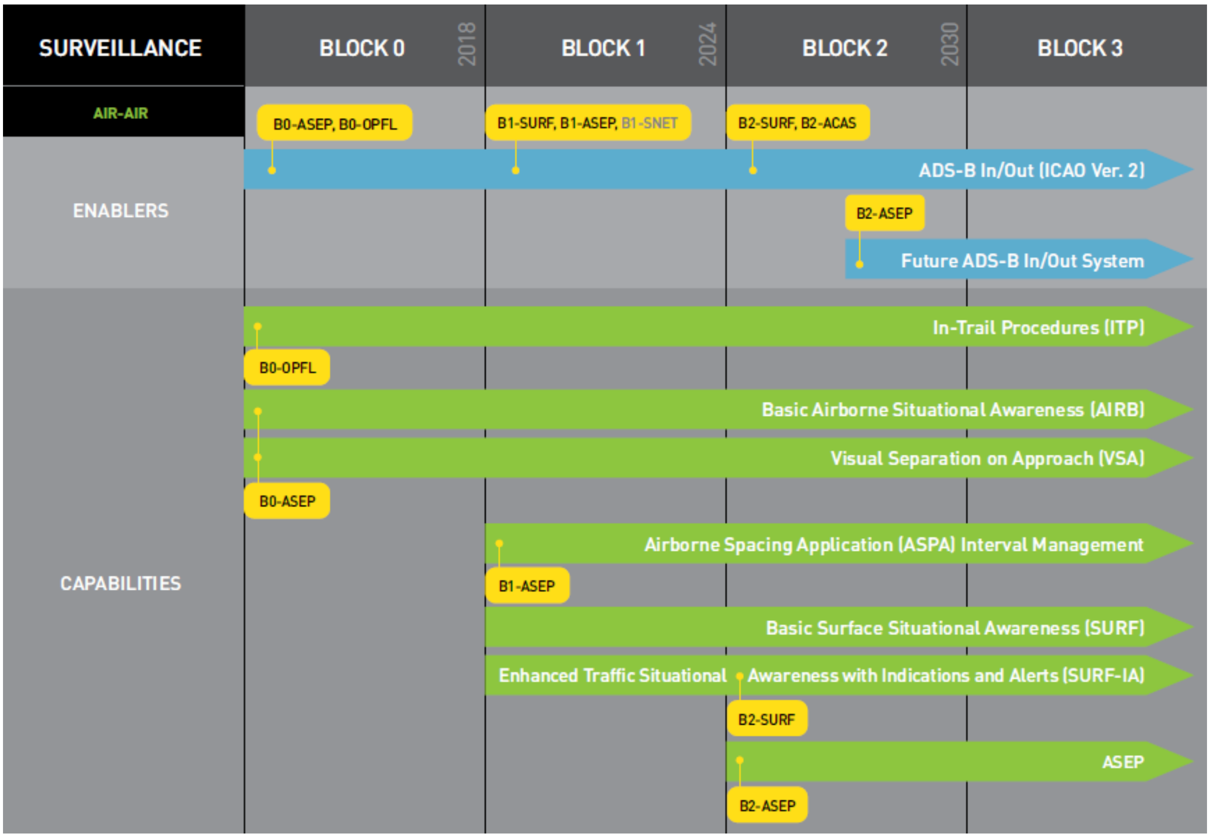
Roadmap SUR1- in the Block 2 time frame	
• The twin demands of increased traffic levels and reduced separation will require an improved form of ADS-B.	• Primary surveillance radar will be used less and less as it is replaced by cooperative surveillance techniques. • Space-based ADS-B is likely to be fully available.

Roadmap SUR1- in the Block 3 time frame
Cooperative surveillance techniques will be dominant as primary surveillance radar (PSR) use will be limited to demanding or specialized applications.

ROADMAP SUR2:

DOMAIN: SURVEILLANCE

COMPONENT(S): AIR-AIR SURVEILLANCE
- ENABLERS
- CAPABILITIES



Roadmap SUR2**- in the Block 0 time frame**

Basic airborne situational awareness applications will become available using ADS-B In/Out (ICAO Version 2)

Roadmap SUR2 **- in the Block 1 time frame**

Advanced situational awareness applications will become available, again using ADS-B In/Out.

Roadmap SUR2 **- in the Block 2 time frame**

- ADS-B technology will begin to be used for basic airborne (delegated) separation.
- The twin demands of increased traffic levels and reduced separation will require an improved form of ADS-B.

Roadmap SUR2 **- in the Block 3 time frame**

The ADS-B technology which supported Block 2 will be used for limited self-separation in remote and oceanic airspace.

4.7.1.4 Information Management

(a) The goal of the AFI ATM Operational Concept (CONOPs) is a net-centric operation where the ATM network is considered as a series of nodes – including the aircraft – providing or using information.

(b) Aircraft operators with flight/airline operational control centre facilities will share information while the individual user will be able to do the same via applications running on any suitable personal device. The support provided by the ATM network will, in all cases, be tailored to the needs of the user concerned.

(c) The sharing of information of the required quality and timeliness in a secure environment is an essential enabler for the ATM Target Concept. The scope extends to all information that is of potential interest to ATM including trajectories, surveillance data, aeronautical information, meteorological data, etc.

(d) System-wide information management (SWIM) is an essential enabler for ATM applications. It provides an appropriate infrastructure and ensures the availability of the information needed by the applications run by the members of the ATM community. The related geo-referenced/time-stamped, seamless and open interoperable data exchange relies on the use of common methodology and the use of a suitable technology and compliant system interfaces.

(e) The availability of SWIM will make possible the deployment of advance end-user applications as it will provide extensive information-sharing and the capability to find the right information wherever the provider is. Cyber-security becomes an increasing issue through time and of ever growing importance in the migration to information management.

4.7.1.4.1 Need for a common time reference

(a) In moving towards the AFI ATM Operational Concept, and in particular 4D trajectory management and intensive exchanges of information through SWIM, some of the current provisions for time management might not be sufficient and could become a barrier to future progress.

(b) The time reference for aviation is defined to be the Coordinated Universal Time (UTC). Requirements surrounding accuracy of time information depend on the type of ATM application in which it is used. For each ATM application, all contributing systems and all contributing users must be synchronized to a time reference that satisfies this accuracy requirement.

(c) UTC is the common time reference, but the present requirements for the accuracy with which aviation clocks are synchronized to UTC may be insufficient to cover future needs. This relates to the integrity and timeliness of information or the use of dependent surveillance for closer separations, as well as more generally 4D trajectory operations.

System requirements for synchronization using an external reference must also be considered.

(d) Rather than defining a new reference standard, the performance requirement for accuracy has to be defined with respect to UTC for each system in the ATM architecture that relies on a coordinated time requirement. Different elements require different accuracy and precision requirements for specific applications. The increased exchange of data on SWIM creates the necessity of efficient "time stamping" for automated systems that are in communication with each other. The time information should be defined at the source and incorporated in the distributed data, with the proper level of accuracy maintained as part of the data integrity.

(e) GNSS is an appropriate and cost-efficient system to distribute accurate timing to an increasing number of ATM systems and applications. The use of multiple GNSS constellations will provide a diversified source of time reference. An alternative time source to GNSS is developed over time to reduce the potential for interruption (alternative positioning, navigation, and timing, APNT).

ROADMAP IMA1:

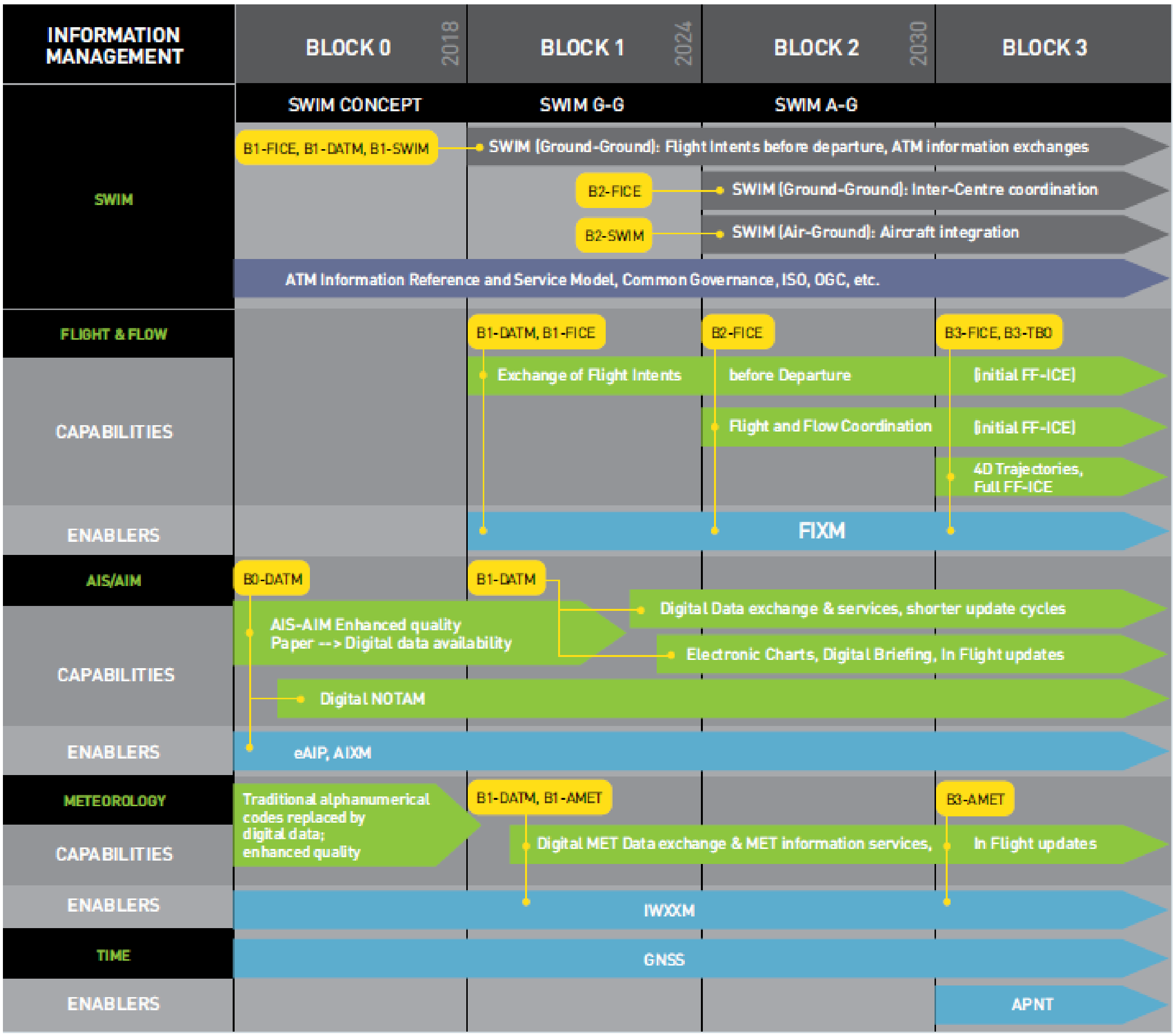
DOMAIN: INFORMATION MANAGEMENT

COMPONENT(S): SWIM
FLIGHT AND FLOW
- CAPABILITIES
- ENABLERS

AIS/AIM
- CAPABILITIES
- ENABLERS

MET
- CAPABILITIES
- ENABLERS

TIME
- ENABLERS



Roadmap AMA1 - in the Block 0 time frame

- SWIM will start to appear in Europe and the United States. The SWIM concept will be developed and refined.

- Operational services will be supported by service-oriented architecture (SOA) pioneer implementations.

- Meteorological data will also be distributed over IP.

- Migration to digital NOTAM has commenced and will be distributed over IP.

Roadmap AMA1- in the Blocks 1 and 2 time frame

- SWIM in the Block 1 time frame: – An initial SWIM capability supporting ground-ground communications will be deployed. – Strong cyber-security is introduced to support information management.

- Flight objects will be introduced, improving interfacility
- coordination and providing multi-facility coordination for the first time. Flight objects will be shared on the SWIM network over an IP backbone and updated through SWIM synchronization services.

- SWIM in the Block 2 time frame: – The aircraft will become a node on the SWIM network with full integration with the aircraft systems. – Information security, integrity, confidentiality and availability will be managed in order to mitigate the risks of intentional disruption and/or changes to safety critical ATM information.

- Digital NOTAM and MET information distribution (using the AIXM and IWXXM information exchange formats) will be widely implemented over the SWIM network.

- The more traditional point-to-point ATS interfacility data communication (AIDC) message exchange will still coexist for some time with SWIM.
- Flight information exchange model (FIXM) will propose a global standard for exchanging flight information, replacing the flight plan used today.
- Common elements across the exchange Modules will be managed by a cross-cutting control board.
- More generally it is expected that SWIM will support the implementation of new concepts such as virtual ATS facilities, which control airspace remotely.

Roadmap AMA1 - in the Block 3 time frame and beyond

- Full SWIM deployment is expected allowing all participants, including the aircraft, to be able to access a wide range of information and operational services including full 4D-trajectory sharing.

- Full implementation of flight objects will be achieved as the FF-ICE concept is realized.

- An alternative time source to GNSS for timing will be available (APNT).

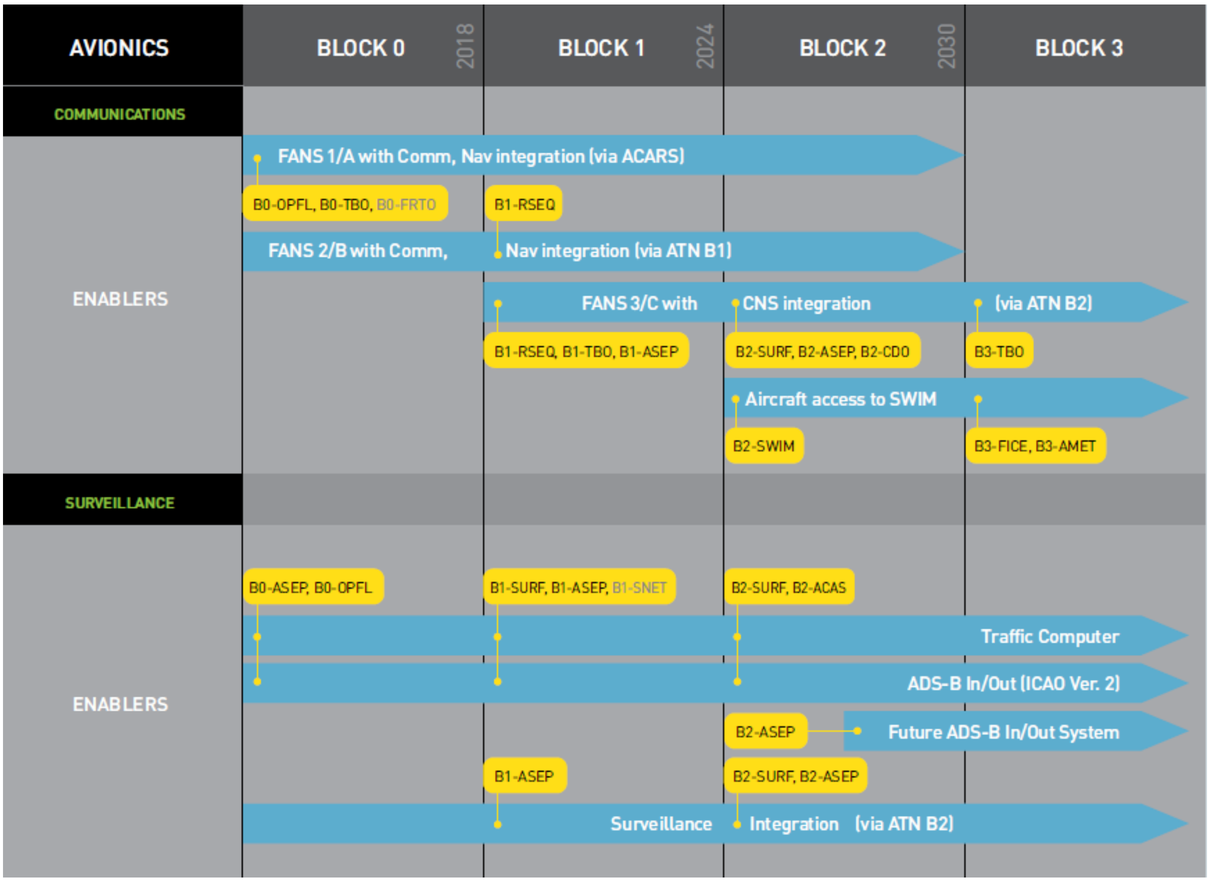
4.7.1.5 Avionics

(a) A key theme with the avionics evolution is the significant increase in capability that is possible through the integration of various on-board systems/functions.

(b) Communication, navigation and surveillance systems are becoming more interconnected and interrelated. For example, GNSS provides positioning to navigation, surveillance and a number of other avionics functions, creating both common mode concerns as well as opportunities for synergies. In addition to harmonizing the evolution of CNS capability deployment, there is an increasing need to ensure that new digital CNS systems do not introduce undue complexity while ensuring that advanced CNS capabilities can be supported with the required level of robustness, in a failure-tolerant and cost-effective manner.

ROADMAP AVI1:

DOMAIN: AVIONICS
COMPONENT(S): COMMUNICATIONS & SURVEILLANCE



Roadmap AVI1 - in the Block 0 time frame

- FANS-2/B will be introduced which supports data link initiation capability (DLIC), ATC communications management (ACM) service, ATC microphone check (AMC) service and ATC clearances and information (ACL) service over ATN, thus providing better communication performance than FANS-1/A. In this first step with data link implementation over ATN, ACL is commonly used by ATC for the notification of

- The existing FANS-1/A system will continue to be used as there is a large base of equipped aircraft and it also supports both communication and navigation integration.
- Aircraft will have a traffic computer hosting the “traffic collision avoidance system”, and possibly the new air traffic situational awareness functions and airborne separation assistance systems. This capability is expected to undergo successive improvements in order to meet the requirement of later Blocks.

	voice frequencies changes to the aircraft. The more integrated solutions provide a connection between the FANS and the radio communication equipment. This integration enables the automatic transmission and tuning of these voice frequencies.	

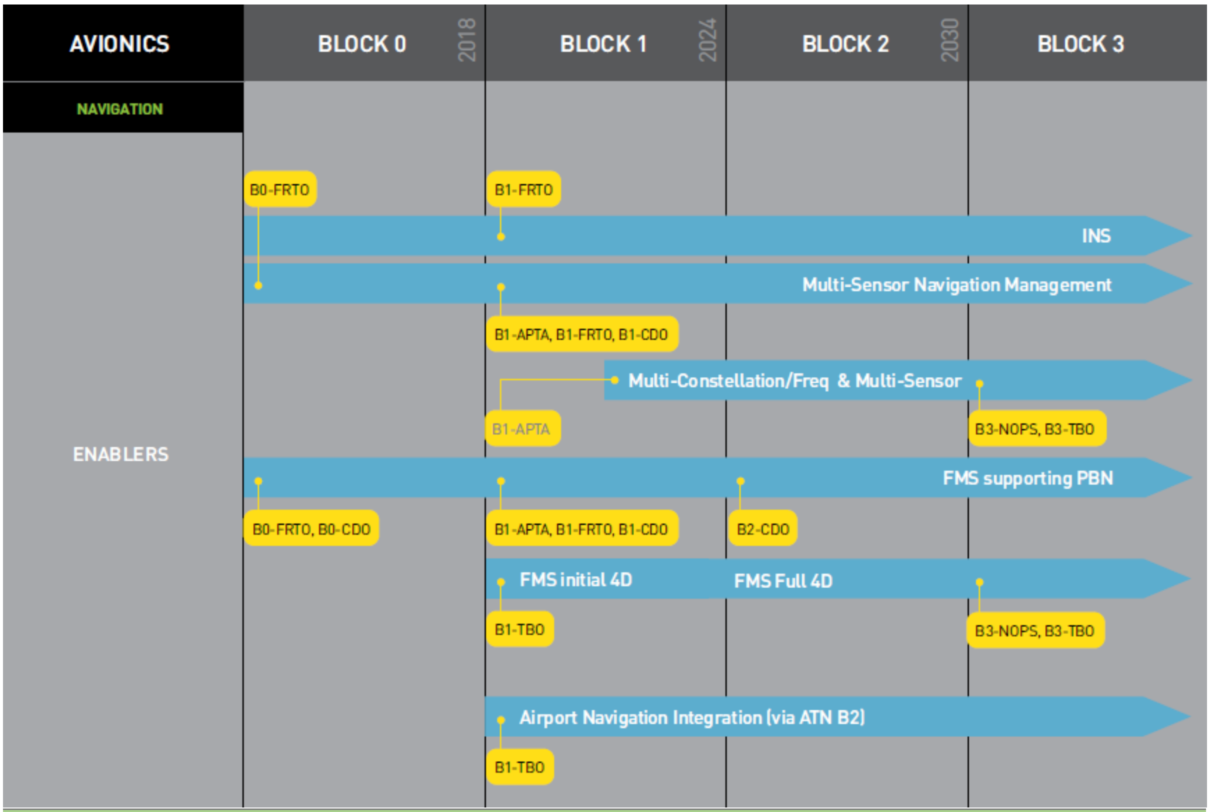
Roadmap AVI1 - in the Block 1 time frame	
• FANS-3/C with CNS integration (via ATN B2) will be available providing communication and surveillance integration through a connection between the FANS and NAV (FMS) equipment. This avionics integration typically supports the easy loading in the FMS of complex ATC clearances transmitted by data link.	• Surveillance integration (via ATN B2) will provide an integrated surveillance through a connection between the FANS equipment and the traffic computer. This avionics integration typically supports the easy loading (within the traffic computer) of ASAS manoeuvres transmitted by data link.

Roadmap AVI1 - in the Block 2 time frame
Aircraft access to SWIM will be provided using the various means described in the roadmap for air-ground data link communications.

ROADMAP AVI2:

DOMAIN: AVIONICS

COMPONENT(S): NAVIGATION



Roadmap AVI2 - in the Block 0 time frame

- FMS supporting PBN represents a flight management system supporting PBN, i.e. providing multi-sensor (GNSS, DME, etc.) navigation and area navigation, and qualified for RNAV-x and RNP-x operations.
- INS will continue to be used in conjunction with other navigation sources. Navigation will be underpinned by the capability to merge and manage navigation data from various sources.

Roadmap AVI2 - in the Blocks 1 and 2 time frame

- Airport navigation integration (via ATN B2) provides integration between the FMS and the airport navigation system function to among other things support the easy loading within the traffic computer of ATC taxi clearances transmitted by data link.
- Flight management system capability will be enhanced to support initial 4D capability.

interoperable satellite ranging sources will support the evolution of aircraft-based augmentation systems (ABAS, system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft) that could provide vertically guided approaches with minimal, or potentially no need for external augmentation signals. The availability of a second frequency will allow avionics to calculate ionospheric delay in real-time, effectively eliminating a major error source. The availability of multiple

- GNSS-based services today rely on a single constellation, the global positioning system (GPS), providing service on a single frequency. Other constellations, i.e., the GLObal NAvigation Satellite System (GLONASS), Galileo and BeiDou will be deployed. All constellations will eventually operate in multiple frequency bands. GNSS performance is sensitive to the number of satellites in view. Multi-constellation GNSS will substantially increase that number, improving the availability and continuity of service. Furthermore, availability of additional independent constellations will provide redundancy to mitigate the risk of service loss due to a major system failure within a core constellation, and will address the concerns of some States about reliance on a single GNSS constellation outside their operational control.
- The airborne MMR and FMS will have to gradually become compatible and interoperable with multi-constellation systems.

Roadmap AVI2 - in the Block 3 time frame and beyond
Flight management system capability will be enhanced to support the full 4D capability.

ROADMAP AVI3:

DOMAIN: AVIONICS
COMPONENT(S): AIRBORNE SAFETY NETS

ON-BOARD SYSTEMS

Roadmap AVI3 - in the Block 0 time frame

- ACAS II (TCAS Version 7.1) will be the main airborne safety net. This will continue through the Block 1 time frame.
- The ground proximity warning system (GPWS, a.k.a. TAWS) will also continue.
- Information display devices will become increasingly common in the cockpit. Care must be taken to ensure that the use of the displays and/or electronic flight bags is well-defined, that they have been certified for the functions supported, and approved for use.
- Airport moving maps and cockpit display of traffic information will be supported with technologies such as ADS-B.
- Enhanced vision systems (EVS) for aerodrome use will be available in the cockpit.

Roadmap AVI3 - in the Block 2 time frame

Synthetic vision systems (SVS) for aerodrome use will be available in the cockpit.

4.7.1.6 Automation

(a) The ICAO Global Air Navigation Plan does not yet provide any Technology Roadmap for the Automation System to support the harmonised implementation of the ICAO Aviation System Block Upgrade (ASBU) modules.

(b) However, some changes to the automation systems are already brought about by changes in the other ICAO technology roadmaps in Communication, Navigation, Surveillance and Information Management, as described below.

4.7.1.6.1 Communication

The changes expected in the Communication domain are described in Section 4.7.1.1 of this document. They will impact the ATC systems as follows:

(a) Migration from AFTN to AMHS for the exchange of ATS-related messages:

(1) Once the migration from AFTN to AMHS has been completed, the ATC systems will have to accommodate this change to cover all ATS-related messages exchanges.

(2) Additionally, the AMHS capability will provide enhanced services in support of the ATS operations; the ATC systems will therefore have to evolve to support the exchange of XML-based messages that will introduce significant operational improvements, such as OPMET, digital NOTAM and Flight Object.

(3) It is therefore important to anticipate and prepare for this evolution by identifying the type and format of data that will need to be exchanged using AMHS, and verifying that AMHS will actually support these data exchanges, including at the IP network level.

(b) Implementation of AIDC for flight coordination and transfer of flights between adjacent ATS Units:

(1) The ATS Interfacility Data Communication (AIDC) communication protocol will have to be implemented in the Flight Data Processing Systems (FDPS) of ATC systems.

(2) In line with the approach recommended in the ASBU B0-FICE module, improvements in this area are key to increasing ground-ground integration, which is the enabler for an increased interoperability, improved efficiency and capacity.

(3) AIDC connections should be put into operation at the international level between ACC and the eight adjacent ACCs wherever possible.

(4) The implementation of these international connections will require bilateral initiatives between to operate AIDC between their ATS Units. However, these bilateral initiatives might have to face constraints at different levels:

(i) At the communication infrastructure level where the proper links will have to be available;

(ii) At the ATM system level where software upgrades may be required; and

(iii) At the legal/operational level where agreements need to be put in place for the exchange of AIDC data.

4.7.1.6.2 Navigation

(a) The changes expected in the Navigation domain are described in Section 4.7.1.2 of this document. The use of GNSS core constellation system together with a GNSS augmentation system will not impact the ATC systems. However, the Monitoring Aids functions of the ATC systems might have to be modified to adjust the deviation and separation tolerances for RNP aircraft capabilities.

4.7.1.6.3 Surveillance

The changes expected in the Surveillance domain are described in Section 4.7.1.3 of this document. They will impact on the ATC systems as follows:

(a) **Deployment of ADS-B ground stations:**

The AFI States should deploy ADS-B ground stations to provide full coverage above in the upper airspace. The ATC system deployed in the ACC will have to be upgraded as required to support this initiative.

A Multi-Sensor Data Fusion should be operationally deployed to integrate data from multiple sensors of various natures (PSR, MSSR, and ADS-B) to form a single track for each aircraft.

(b) **Satellite-based ADS-B:**

The use of satellite-based ADS-B is recommended for consideration in the long-term to improve the surveillance coverage at the lower levels.

As above, the ATC systems should be upgraded as required to support this initiative.

(c) **Surveillance data sharing**

Cross-boundary sharing of surveillance data is recommended to improve surveillance coverage or redundancy, and coordination, using the existing surveillance infrastructure and taking into account new surveillance means deployed.

The ATC systems should be upgraded as required to support any initiative related to surveillance data sharing.

4.7.1.6.4 Information Management

The changes expected in the Information Management domain are discussed in Section 4.7.1.4 of this document. They will impact on the ATC systems as follows:

(a) **SWIM**:

Initial SWIM deployment is likely to occur and the ATC systems will have to be upgraded to support SWIM exchanges using the latest data standard (FIXM, AIXM …).

(b) **AIS to AIM transition**:

The transition from AIS to AIM should progress and the ATC systems will have to be upgraded to support the integration with the AIM system using the latest AIXM standard.

(c) **Integration of MET information**:

The ATC systems will have to accommodate the integration of MET data to support THE planed automated decision processes or aids.

4.7.2 Prioritization of ASBU Block 0 Modules for The AFI Region

(a) The Table below provides the list of Block 0 modules with suggested allocated priority for implementation within the AFI Region. The allocation of priority is based on the following criteria. Priority 1 = immediate implementation; Priority 2 = recommended implementation. Although AFI region has categorized all 18 Block 0 Modules for its implementation, only 7 Modules will have priori 1 as it covers most of the AFI States. The remaining Modules are priority 2 and applies to only specific State (s) of the AFI region.

PIA	Module Description	Module	Priority
PIA 1	Improve Traffic flow through Runway Sequencing (AMAN/DMAN)	B0-15 RSEQ	2
	Optimization of Approach Procedures including vertical guidance	B0-65 APTA	1
	Increased Runway Throughput through optimized Wake Turbulence Separation	B0-70 WAKE	2
	Safety and Efficiency of Surface Operations (A-SMGCS Level 1-2)	B0-75 SURF	2
	Improved Airport Operations through Airport-CDM	B0-80 ACDM	1
PIA 2	Increased Interoperability, Efficiency and Capacity through Ground-Ground Integration	B0-25 FICE	1
	Service Improvement through Digital Aeronautical Information Management	B0-30 DAIM	1

PIA	Module Description	Module	Priority
	Meteorological information supporting enhanced operational efficiency and safety	B0-105 AMET	1
PIA 3	Improved Operations through Enhanced En-Route Trajectories	B0-10 FRTO	1
	Improved Flow Performance through Planning based on a Network-Wide view	B0-35 NOPS	2
	Initial capability for ground surveillance	B0-84 ASUR	2
	Air Traffic Situational Awareness (ATSA)	B0-85 ASEP	2
	Improved access to Optimum Flight Levels through Climb/Descent Procedures using ADS-B	B0-86 OPFL	2
	ACAS Improvements	B0-101 ACAS	1
	Increased Effectiveness of Ground-Based Safety Nets	B0-102 SNET	2
PIA 4	Improved Flexibility and Efficiency in Descent Profiles (CDO)	B0-05 CDO	1
	Improved Safety and Efficiency through the initial application of Data Link En-Route	B0-40 TBO	2
	Improved Flexibility and Efficiency Departure Profiles - Continuous Climb Operations (CCO)	B0-20 CCO	1

4.7.3 Airport Operations

B0-ACDM Improved Airport Operations through Airport-CDM:

It is recommended that the AFI States implement A-CDM at all international airports. Airport Collaborative Decision-Making (A-CDM) does not require specific new functionalities as such. The local ATC systems will have mainly to be upgraded to support interconnection with the ground systems of the other airport stakeholders (airport operator, ground handlers and airlines).

PART V

TRAINING RECRUITING AND HUMAN PERFORMANCE CONSIDERATIONS

5.1 Introduction

(a) Aviation professionals have an essential role in the transition to, and successful implementation of the AFI ATM Master Plan. The system changes will affect the work of many skilled personnel in the air and on the ground, potentially changing their roles and interactions and even requiring new proficiencies to be developed. Furthermore, with the expected growth of aviation, it is critical that enough qualified and competent personnel are available to ensure a safe and efficient aviation system.

(b) It is therefore critical that the concepts being developed within the GANP take into account the strengths and weaknesses of existing and future skilled personnel at every juncture. All actors with a stake in a safe air transportation system will need to intensify efforts to manage risks associated with human performance and the sector will need to proactively anticipate interface and workstation design, training needs and operational procedures while promulgating best practices. In support of this, the AFI region will work with key stakeholders ensure that personnel are trained utilizing competency-based training methods found in the manuals developed for Air Traffic Controllers (ATCOs) and Air Traffic Safety Electronics Personnel (ATSEPs).

(c) The AFI region has recognized these factors, and thus the consideration of human performance in the context of the Block Upgrades requirements will continue to evolve through State Safety Programme (SSP) and Industry Safety Management Systems (SMS) approaches.

(d) Amongst other priorities, the management of change pertinent to the Block Upgrades evolution should include human performance-related considerations in the following areas:

(1) Initial training, competence and/or adaptation of new/ active operational staff;

(2) New roles and responsibilities and tasks to be defined and implemented;

(3) Social factors and management of the cultural changes linked to increased automation.

(e) Human performance needs to be embedded both in the planning and design phases of new systems and technologies as well as during implementation. Early involvement of operational personnel is also essential.

(f) Sharing of information regarding the various aspects of human performance and the identification of human performance risk management approaches will be a prerequisite for improving safety outcomes. This is particularly true in today's aviation operational context and the successful implementation of the Block Upgrades and other new systems into the future.

(g) Widespread and effective management of human performance risks within an operational context cannot be achieved without a coordinated effort from regulators, industry service providers, and operational personnel representing all disciplines.

5.2 Training Areas

(a) The following training areas have been identified to support seamless operations in the AFI region:

(1) Aeronautical Information Management (AIM)
(2) Air Traffic Flow Management (ATFM)
(3) Airspace Design
(4) Airspace Management
(5) Automation Systems
(6) Aviation and Environment
(7) Awareness raising on the project
(8) CNS/ATM
(9) Collaborative Decision Making (CDM)
(10) Communication
(11) English Proficiency
(12) Flexible Use of Airspace (FUA)
(13) Navigation
(14) Operational Procedures
(15) Safety
(16) Search & Rescue (SAR)
(17) Security of ATM/CNS systems
(18) Surveillance

PART VI

COST-BENEFIT ANALYSIS

6.1 Introduction

(a) As a general rule, prior to any significant system change, a cost/benefit analysis (CBA) would be conducted to demonstrate the value, negative or positive, of the projected change.

(b) A CBA of the transition to an AFI Seamless ANS environment will be developed when the Seamless ANS Plan has been accepted by APIRG on behalf of all African States. Although each State retains responsibility for their sovereign airspace, acceptance of the Seamless ANS Plan by APIRG, on behalf of all States, creates an obligation on each State, as far as practicable, to follow the agreed upgrade path.

(c) Although a CBA for the region would not be possible due to the complexity of the task, it was felt necessary to demonstrate, at a high level, the benefits of the proposed Seamless ANS Plan as presented in the following sections.

6.2 Cost Benefit Analysis - Generalities

(a) The programmes related to the AFI ATM Master Plan implementation involve a combination of capital investment in new infrastructures, operating expenditure and the creation of working groups to define new operational procedures and ensure the coordination and convergence of ATM provision among Member States.

(b) The CBA focusses on comparing the financial costs and benefits of the implementation of the ATM Master plan project and does not discuss non-monetary benefits such as safety gains, reduced environmental impact and indirect induced economic growth.

(c) Consistent with the investment, operational and organisational recommendations developed within this report, each programme has been broken down into a number of underlying activities at which level the cost estimation has been undertaken.

(d) The overall projects generate benefits from productivity enhancements and cost-efficiencies, as well as safety and environmental gains.

6.3 ANSPs

(a) As providers of Air Navigation Services (ANS), ANSPs bear the biggest part of the initial costs of putting in place new infrastructures and defining new operational structures and institutions. This analysis is based on the understanding that most costs are financed by ANSPs, and can subsequently be recovered through improved cost-efficiencies as well as through ANS charges, which are collected from airspace users.

(b) The financial impact on ANSPs is ideally zero, determined by the combination of capital and operating expenditure incurred, and by the cost recovery mechanism through which ANS charges are collected from airspace users:

(1) Capital expenditure related to programs involving infrastructures investment. Capital expenditure is annualised linearly over an average economic lifetime of 10 years, beginning when the program becomes operational. For the purpose of the business case, it assumed that capital investment items will be replaced at the end of their economic lifetime, at the same cost and cost of capital as initially assumed. This leads to a continuous capital expenditure/depreciation cost from entry into operation until the end of the project horizon, unless otherwise specified.

The CBA considers the incremental effect of the investment, which means that investment is considered in isolation. This is necessary because the cost for each individual ANSP of maintaining and upgrading existing infrastructure, existing capital expenditure plans and depreciation schedules are not known.

(2) It must be noted that the cost estimates for ATM and communication related investment are specific to the conditions of each country, depending on existing installations and communications infrastructures that could be upgraded, different technologies and solutions that can achieve the same objective, commercial negations with providers, potential collaborations between countries, etc.

(3) Operating expenditure refer to the costs of implementing, operating and maintaining new equipment. The actual expenditures incurred by each ANSP are likely to vary significantly, depending on today's cost and personnel structure of ANSPs, equipment to be replaced, traffic growth, etc. ANSPs in the AFI region are likely to operate on different cost curves or on different segments of the same cost curve. For example, with a given ATCO productivity and workload, an ANSP might be able to accommodate some amount of additional movements, or none at all.

(4) In addition to the operating expenditure impact of specific programs, the CBA considers global costs of ANS provision to increase with traffic growth at an elasticity of 0.75 – this figure considers that infrastructure costs increase at a factor

<1 as traffic grows. On the other hand, staff costs, which constitute about half of ANSP costs, grow at almost the same rate as traffic.

(5) The CBA assumes the investment case to yield cost-efficiency gains of 2% per year as new technologies, procedures and economic regulations are deployed. This is slightly higher than cost-efficiency gains currently achieved in the context of the Single European Sky and reflects the opportunity for efficiency improvements in less mature ANSPs.

(c) Working groups: Programmes require extensive preparation and coordination within and among Member States in the AFI region and other stakeholders. The staff requirements associated to this effort is assumed to be supported from current ANSP, CAA, and military and government structures, without the need for hiring or committing additional human resources. However, it is assumed that ANSP staff needs to participate in specific IATA and ICAO compliant training programs and dedicated meetings in addition to existing training and meeting formats. This assumption has been made under the presumption to minimise the additional effort generated by the project and to make best use of existing staff, meeting formats, training programs and existing ICAO collaborations for the provision of consultancy and expertise. Still an assumption has been made about the likely incremental cost impact for ANSPs of participating in additional training and meetings.

(d) Interests: Costs are recovered from airspace users deferred by two years, consistent with the ANS charges regimes applicable in many advanced economic ANS regulations. In order to avoid cash flow issues, this interim period of two years needs to be bridged by finance. Annualization of capital costs also leads to financing arrangements that are assumed to be provided at an interest rate of 8.7%, based on an average for several AFI Member States and as provided by the World Bank.

(e) Airspace user revenues are a function of traffic volumes and ANS unit charges. Traffic volumes are considered as an exogenous factor in this CBA. One of the aims of the AFI Master Plan is to reduce the overall distance flown by airspace users, leading to a reduction in the number of service units and negatively affecting the overall revenue from ANS charges. ANS unit charges are determined by dividing an ANSP’s planned cost base by the forecasted number of service units. Therefore, both, traffic volumes and cost base affect ANS unit charges, which in turn affect overall ANSP revenues.

(f) The CBA considers traffic in accordance with the traffic forecast presented in Section 2 of this report. The expected increase of traffic (in movements) of 5.6 % annually will therefore distribute the increasing cost base of AFI ANSPs across a growing number of service units, ideally offsetting the rise in cost bases and stabilising ANS charges.

6.4 Airspace users

(a) Airspace users represent a key stakeholder group in the context of this project, given that airspace users rely on and largely finance the effective provision of ANS. When undertaking new investment in new infrastructure, and operational procedures and institutional change, ANSPs and CAAs have to assess how far this will benefit airspace users. They need to assess if the benefits for commercial and private aviation justify the costs incurred, and if costs can be recovered without unrealistically inflating unit rates. The focus of this CBA is on civilian airspace users and commercial airlines, which are the main beneficiaries of this project and are impacted by variations in unit rates.

The financial impact on Airspace Users is determined by the balance of financial savings derived from operational benefits generated by seamless operations, and financial costs from growing unit rates and potential investment in airborne navigation and communication equipment:

(1) Distance flown by airspace users is expected to be reduced as a result of improved airspace structure and operation. This does not only lead to a reduction in fuel burn, but also in-flight time, affecting direct operating costs such as fuel costs, crew costs, aircraft and engine operating hours, and ANS costs. The CBA quantifies fuel cost savings and overall ANS charges.

(2) Flight deck workload can be significantly reduced by some of the projects, for example related to communication and the transmission of data from the ANS provider to the aircraft and vice-versa. Flight planning will become less complex for both flight deck and back-office staff. The CBA does not assign any monetary value to this benefit, which is mainly related to safety.

(3) Disruption incidents and delays have been known to be reduced by improved design and operational procedures in highly congested areas and at the interface between upper and lower airspace. While these types of improvement can be economically and reputationally beneficial for airspace users, they are of marginal economic importance for the upper airspace, especially when considering the vastness of the airspace over the AFI States.

(4) The ATM Master Plan initiatives have been identified with the aim of modernising ATM and CNS infrastructure and enabling traffic growth, in accordance with the forecasts presented in Section 2 of this report. As a result, one of the main benefits for commercial airlines is being able to grow their business in line with the long-term market potential. It is clear that the resulting increase in revenue and profits is dependent on a multitude of factors in the management of these airlines. The CBA does therefore not quantify the financial impact of market growth on airspace users.

(5) It is worth noting that high rates in traffic growth make most of the investments proposed under this project mandatory – without investment, safe and efficient ANS provision could not be guaranteed and would in fact become incompliant with ICAO ASBU blocks. This will generally lead to declining unit rates as traffic increases, but will also be affected by the investment scenario and other factors.

(6) Capital expenditure/ Equipage costs may be incurred by aircraft operators that need to upgrade airborne navigation and communication equipment to comply with the standards proposed under this project. Such costs can be considerable for a specific aircraft when retrofitted. It must be noted however, that the AFI Master Plan project aligns with the requirements of ICAO ASBU Blocks, meaning that aircraft operating beyond the confines of the AFI States would in most cases need to abide by these requirements even without this project. Furthermore, with most commercial airlines having a useful life of 25 to 30 years, we expect that most aircraft will have the required equipage level by default at the time that new requirements apply. However, operators of regional aircraft, where equipage could be optional, might be forced to upgrade old fleets.

6.5 States

(a) States, including CAAs, government organisations and military, play a critical role in the implementation of the project through their contribution to working groups aimed at defining new structures and procedures. It is assumed that the effort related to the project is supported by existing staff and meeting structures. Therefore, there is no incremental cost involved for the State.

Also, there are no direct monetary benefits for the oversight and regulation activities of CAAs. Nonetheless, States in general are expected to enjoy indirect and induced economic benefits from the implementation of the project. These benefits include:

(1) Safety impacts: Implementing the projects proposed in the ATM Master Plan initiative contributes to greater safety for operating airlines, passengers and airport employees.

(2) Environmental impacts: By optimising airspace design and putting in place improved operational measures, the average distance flown by airspace users can be reduced by at least 1.4% on international flights. This leads to a reduction in fuel-burn and CO_2 emissions.

(b) Other societal factors: By enhancing ATM capabilities, capacities in the upper airspace will be enhanced, local bottlenecks in the interface with lower airspace and approaches to major airports and metropolitan areas will be removed, and operating costs for airlines reduced. This enables growth opportunities for airlines – particularly in the budget airline sector - and ultimately contributes to the affordability of air travel and mobility.

PART VII

SAFETY PLAN

7.1 The GASP

(a) The Global Aviation Safety Plan (ICAO Doc. 10004) is an ICAO initiative aiming at a continuous improvement in global aviation safety, stated a fundamental to ensuring air transport continues to play a major role in driving sustainable economic and social development around the world.

(b) The GASP has undergone significant change, driven mainly by its strengthened role as a high-level policy, planning and implementation document guiding complementary and sector-wide air transport progress in conjunction with the ICAO Global Air Navigation Plan (GANP). The Global Plans define the means and targets by which ICAO, States and aviation stakeholders can anticipate and efficiently manage air traffic growth while proactively maintaining or increasing safety. The GASP and its amendments are therefore approved by the Council prior to eventual budget-related developments and endorsement by the Assembly.

In the nutshell, the GASP purposes are:

(1) Sets global safety objectives including specific milestones and priorities;

(2) Provides a familiar planning framework to make safety improvements through the use of the four Safety Performance Enablers: standardization, collaboration, resources and safety information exchange.

(3) Outlines implementation strategies and best practice guidance material to tailor State and regional solutions for addressing global objectives and priorities.

The GASP policy principles aim at the following commitments:

(1) The implementation of ICAO's Strategic Objectives;

(2) Aviation safety is the highest priority;

(3) A tiered approach to safety planning is carried out;

(4) State Safety Programme and Safety Management Systems implementation;

(5) Global aviation safety priorities are defined;

(6) Regional and State air safety priorities are defined;

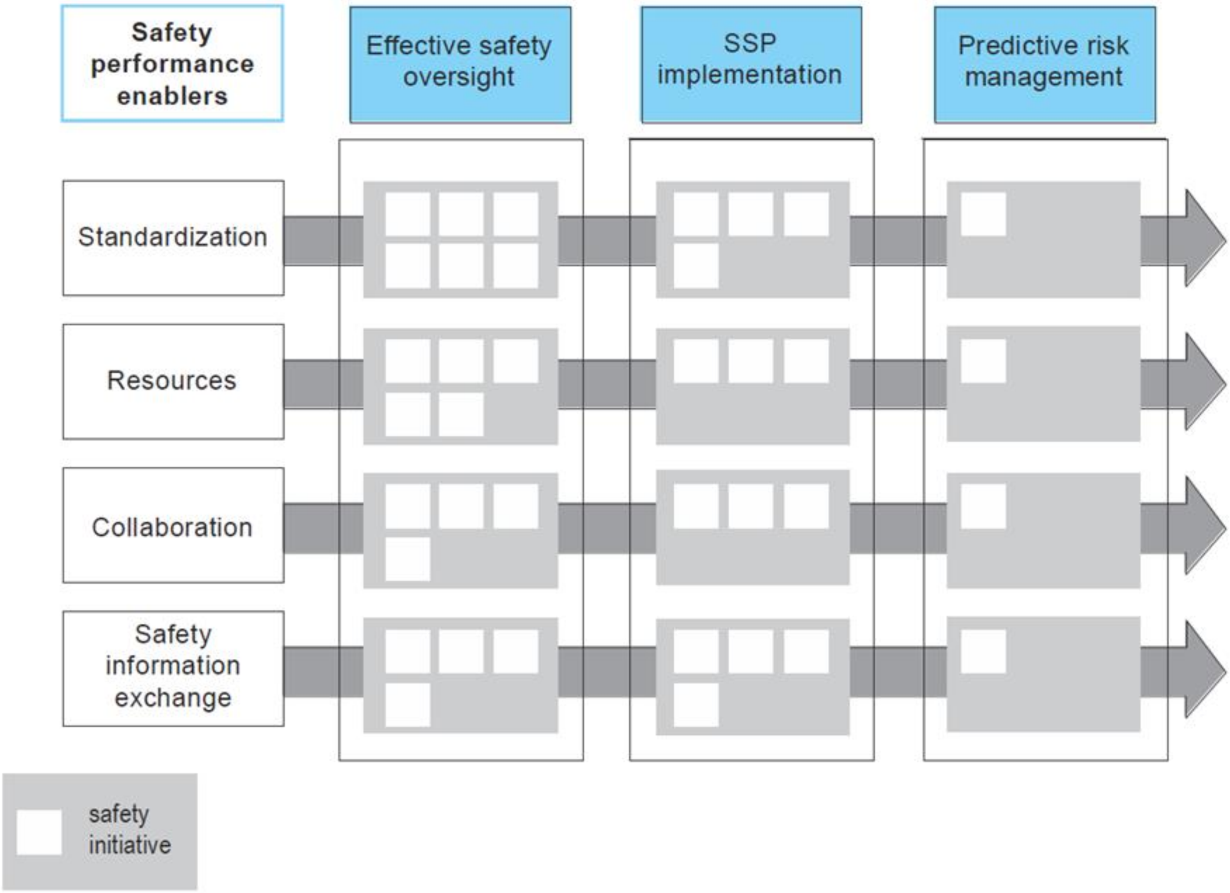
(7) GASP objectives and Safety Performance Enablers are identified;

(8) Use of objectives and Safety Performance Enablers are defined;

(9) Cost benefit and financial issues are analysed;

(10) Review and evaluation of aviation safety planning are regularly carried out.

Like for the ASBU concept definition, the GASP safety initiatives are categorized according to the maturity level and corresponding Safety Performance Enabler. Each square in Figure xxx represents an individual safety initiative.



7.2 GASP framework

(a) ICAO and the RASGs publish annual safety reports to provide regular updates on the level of progress achieved with respect to the GASP objectives through measurement of reactive, proactive and predictive safety indicators.

(b) Moreover, each annual Safety Report (the first edition for the RASG-AFI, reporting year 2014, has been issued in May 2015) includes analysis of a number of key safety metrics including statistics on accidents and related fatalities, States' compliance with

ICAO requirements as well as information related to global traffic volume and traffic growth.

(c) An analysis of multiple safety indicators is essential to assess safety performance globally as well as at the regional levels.

PART VIII

IMPLEMENTATION ROAD MAP

PART IX

CONCLUSIONS AND RECOMMENDATIONS

REFERENCES

Doc 9750 Global Air Navigation Plan

Doc 9854 Global Air Traffic Management Operational Concept

Doc 10004 Global Aviation Safety Plan

Annex 10 Aeronautical Telecommunications

Annex 11 Air Traffic Services (particularly Chapter 2 [2.1 and 2.30], and Attachment C)

ASBU Document

Doc 4444 Procedures for Air Navigation Services Air Traffic Management (PANS ATM)

Doc 8071 Manual on Testing of Radio Navigation Aids Volume 2

Doc 9613 Performance-based Navigation Manual

Doc 9882 Manual on ATM System Requirements

Doc 9883 Manual on Global Performance of the Air Navigation System

Doc 9906 Quality Assurance Manual for flight Procedure Design Volume 5

Doc 9971 Manual on Collaborative Air Traffic Flow Management

Annex 6 Operation of Aircraft

Doc 8168 Procedure for Air Navigation Service Aircraft Operations Volume I Flight Procedures

Doc 8168 Procedure for Air Navigation Service Aircraft Operations Volume II Flight Procedures

Doc 9931 Continuous Descent Operations (CDO) Manual

Doc 9993 Continuous Climb Operations (CCO) Manual

Annex 1 Personnel Licensing

Circular 214 Fundamentals on Human Factors

Circular 227 Training of Operational Personnel on Human Factors

Circular 241 Human Factors in ATC

Circular 249 Human Factors in CNS and ATM Systems

Circular 318 Language Testing Criteria for Global Harmonization

Circular 323 Guidelines for Aviation English Training Programmes

Doc 9835 Manual on the Implementation of ICAO Language Proficiency Requirements

Doc 9966 Fatigue Risk Management Systems