CNS/ATM AVIONICS ARCHITECTURES SUPPORTING NEXTGEN / SESAR CONCEPTS

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PBN is a comprehensive airspace management approach that implements an operational concept based upon enhanced efficiency in all flight phases. The concept moves away from a single sensor-based focus to one based upon operational requirements and how that operation can be more efficiently executed relative to time, fuel expenditures, emissions, and other factors which make up the total cost of operation. PBN is a harmonized global approach to airspace operations in which performance requirements are identified in navigation specifications (see 2.1.1.2 below). The operator can then select the most efficient method of operating within the respective specification. System of systems requirements are defined relative to the respective navigation specification. A seamless function is made possible by harmonized contributions of communication, surveillance, air traffic management, and the navigation infrastructure. Aircraft systems are defined “in terms of the accuracy, integrity, availability, continuity and functionality, which are needed for the proposed operations in the context of a particular airspace concept.” Such terms emphasize the navigation accuracy for both the lateral and vertical flight plan. As a result, PBN incorporates both Area Navigation (RNAV) and Required Navigation Performance (RNP) operations but as operational requirements and airspace become more precise, the containment capability of RNP systems will dominate. PBN and the navigation specifications (RNAV and RNP) are defined along with implementation provisions in the ICAO Performance-based Navigation (PBN) Manual (Doc 9613 AN/937).

2.1.1.1 Airspace Concepts

2.1.1.1.1 Oceanic and Remote Domestic

Airspace over oceanic areas and domestic areas not covered by radar are dependent upon non-radar technologies for traffic control. The Air Traffic Services (ATS) Automatic Dependent Surveillance contract (ADS-C) provides aircraft position and limited trajectory information for traffic management. Future advancements in ATS data link technologies are expected to provide more precise trajectory intent information for enhanced controller awareness. The implementation of Automatic Dependent Surveillance broadcast (ADS-B) will provide for more efficient traffic control by providing real time aircraft position and velocity. As traffic density increases and efficient routes are in demand, separation will require the containment capability (expressed in nautical miles laterally left and right of the path) of RNP. RNP 10(NM) may accommodate lower density operations while RNP 4 (NM)will be required to ensure lower separations on the preferred routes.

2.1.1.1.2 Continental En-route

Domestic airspace with radar coverage will continue to utilize a mix of RNAV and RNP. The continued use of RNAV will depend upon the viability of the ground-based navaid infrastructure, particularly the Distance Measuring Equipment (DME). RNAV 5 (B-RNAV in Europe) or RNAV 2 (USA) (see 2.1.1.3 below for specification descriptions) may satisfy the operational requirements for domestic continental en route airspace in some states. However, the proliferation of GNSS-based aircraft navigation systems will enable a greater reliance on RNP and particularly for those states with high density traffic and/or those who choose to implement Automatic Dependent Surveillance-Broadcast (ADS-B) for traffic control.

2.1.1.1.3 Terminal - Departure and Arrival

Similar to domestic airspace, the terminal environment will also employ both RNAV and RNP for departure and arrival procedures. The use of RNAV will similarly depend upon the continued viability of the ground-based navaid infrastructure but also the requirements of the specific location. RNAV 1 may support those locations that do not require enhanced accuracy and lower separation levels. Those locations with higher density or terrain/ obstacle/ airspace/efficiency challenges will realize the benefits of RNP procedures. Airspace managers and procedure designers should consider the accuracy, predictability and repeatability of RNP designs for all new or updated procedures to enhance safety, relieve flight crew and controller workload, and address environmental concerns.

2.1.1.1.4 Approach

The approach environment (all approach segments and the missed approach) will increasingly require the accuracy of RNP, particularly for those runway ends not served by a precision guidance system. As ground-based systems such as ILS and MLS become more expensive to maintain, Localizer Performance with Vertical Guidance (LPV), GNSS Landing System (GLS) and RNP will become more prevalent. RNP will offer the added benefit of curved paths to the final approach segment (and in the missed approach) and may be adjoined to the straight-in segments of the precision final guidance systems. Regardless of system type, all runway ends will be enabled with accurate course guidance to the missed approach point. The precision guidance systems will provide Cat I/II/III minima and aircraft systems will further provide an option for autoland capability.

2.1.1.2 PBN Navigation Specifications

The navigation specification is described in the ICAO PBN Manual as a defined set of requirements upon which the flight crew must operate within a defined airspace. The two categories are RNAV and RNP with subcategories of each (RNAV 5, RNAV 2, RNAV 1; RNP 10, 4, 2, 1, ADV, APCH, AR). The numerical values reference lateral cross-track distance in nautical miles from the computed path. RNP Advanced (ADV), Approach (APCH) and Authorization Required (AR) specify a specific navigation application within a defined airspace concept. The respective specification is applied dependent upon the operational requirements of the respective airspace. For example, when terrain, obstacles or airspace operations require strict path compliance, RNP would be specified and the level determined by the allowable margin to the controlling constraint as defined in the respective regulatory design guidance (PANS OPS, FAA ORDERs). As capacities increase to the levels expected for the far term and the respective airspaces are redesigned to enhance efficiency, RNP will be required for most operations.

2.1.1.2.1 RNAV

Future navigation operations will be conducted based upon geographical references. Those references or “waypoints” could be ground-based navaids or latitude/longitude fixes over the ground, the latter of which will dominate future operations. As a result, instrument procedures will not be bound to ground-based navaids for guidance to the final approach segment. Aircraft RNAV navigation systems will use the reference data and navigation position data from sensors to compute a repeatable and predictable lateral (and vertical if appropriately equipped) flight plan path definition. In addition to flight plan management, the aircraft RNAV systems should also provide navigation positioning, guidance commands and display information, all of which are accomplished by integrating information from sensors, such as air data, inertial reference, radio navigation and satellite navigation, together with inputs from internal databases and data entered by the flight crew. RNAV 5 is implemented for en route airspace in areas controlled by Air Traffic Services (ATS) via voice control or data link. RNAV 1 and 2 may be applicable to en route or terminal airspace (departures and arrivals up to the final approach fix).

2.1.1.2.2 RNP

RNP is also an RNAV operation but with the addition of an internal performance monitoring and alerting capability to alert the flight crew when the navigation system no longer meets the respective performance requirement. Assurance of a reliable, repeatable and predictable flight path is fundamental to PBN. All RNAV systems are designed to provide an accurate path along the lateral and vertical axes. However, current and future PBN specifications require the enhanced performance of RNP to meet capacity and efficiency demands as well as flight paths along curved, fixed radius turns. RNP systems enhance the RNAV concept through position and containment integrity. Containment integrity is defined as the “measure of confidence in the estimated position, expressed as the probability that the system will detect and annunciate the condition where total system error (TSE) is greater than the cross-track containment limit. Containment integrity is specified by the maximum allowable probability for the event that TSE is greater than the containment limit and the condition has not been detected.” It is the lateral containment operation, at various RNP levels described in nautical miles (10, 4, 2, 1, 0.3, 0.1), that provides the path accuracy required for the respective PBN specifications. It is the operational requirements of the respective airspace concept (en route, terminal, approach) that determines the RNP levels of performance.

2.1.1.2.3 Multinational coordination for adjoining airspace

Although PBN is a global approach to airspace management, states may choose to implement the navigation specifications differently to suit the respective operational requirements. Since many terminal airspace segments border other states, coordination between states will be required to ensure the navigation specification is consistent so that the desired operational efficiencies can be realized.

2.1.1.2.4 WGS-84 Datum

A successful global implementation of PBN is dependent upon a consistent navigation reference in all regions. WGS-84 has been accepted by ICAO member states as the international navigation datum. The various components of the Global Navigation Satellite System (GNSS) will provide an accurate, reliable and seamless position capability. Reliable interoperability of the navigation system requires a fundamentally consistent datum upon which the GNSS systems can provide position. Subsequently, the ICAO PBN Manual notes that those states not already operating in the WGS-84 datum will be required to transition from the local datum to WGS-84 to participate in the global PBN network.

2.1.2 Trajectory Based Operations

Trajectory management is a key foundation of both NextGen and SESAR programs to reach the objectives which are set in terms of ATM improvement.

The SESAR ConOps establishes that :

“The future ATM system will be built around four main pillars: collaborative, layered planning; performance based; airspace organised around aircraft trajectories, and System-Wide Information Management (SWIM) with the focus on Trajectory Management. In doing so it has to demonstrate what the delivered benefits will be to the community at large in achieving the objectives of the four main Key Performance Areas (KPA), namely:

- Capacity: a 3-fold increase in capacity while reducing delays, both on the ground and in the air;
- Safety: to improve safety levels by ensuring that the numbers of ATM induced accidents and serious or risk bearing incidents decrease;
- Environment: to enable a 10% reduction in the effects flights have on the environment;
- Cost-effectiveness: halve the total direct European gate-to-gate ATM costs.”

“The Trajectory Management concept entails the systematic sharing of aircraft trajectories between various participants in the ATM process to ensure that all partners have a common view of a flight and have access to the most up to date data available to perform their tasks. This concept enables the dynamic adjustment of airspace characteristics to meet predicted demand with distortions to the business/mission trajectories kept to the absolute minimum.”

“Trajectory management is the process by which the Trajectory of the aircraft is planned, agreed, updated and revised. It is achieved through Collaborative Decision Making (CDM) processes between Airspace users (Aircraft Operators) and ATM Service Providers (ANSP, Airports, Network Manager) or directly between the Flight Crew and the Controller during the execution phase when time does not permit CDM. It includes both surface and airborne segments and is built from, and updated with the most timely and accurate data available."

The agreed trajectory is ideally designed for an optimised continuous climb, and cruise route of the aircraft. The descent profile of the trajectory is also ideally a Continuous Descent Approach based upon the most optimum engine and airframe settings possible, integrating a constrained time of arrival (CTA) allowing the ATC to manage the arrival sequences at the destination airport.

The concept relies on 4 items which will be addressed independently in Section 4.2, when their impact on the avionics architecture will be considered :

- Continuous Climb Departure
- Continuous Climb Cruise
- Continuous Descent Approach
- 4D trajectory management

2.1.3 Approach and Landing

2.1.4 ATS Data Link

The NextGen/SESAR Air Traffic Control DataLink Communication Systems will be deployed to improve communication reliability and increase airspace capacity by reducing the overall workload on the tactical controller. By using predefined messages sets pilots and controllers can communicate quickly and clearly to improve efficiency as to just communicating over voice.

Air Traffic Service (ATS) Datalink comprises of three main functions:

- Context Management Application (CMA)/ATC Facilities Notification (AFN)
- Controller Pilot DataLink Communications (CPDLC)
- Automatic Dependent Surveillance – Contract (ADS-C)

These functions provide the following services:

CMA/AFN:

- Aircraft announces to ATC Facility readiness to begin data link communication
- Provides aircraft information and capability to ATC Facility
- Establishes Agreement on services, features, functions and requirements
- Facilitates ATS communication across FIR boundaries

CPDLC:

- Text messages that relay information/requests to and from pilots i.e. Confirm Assigned Level, Estimate Time Arrival (ETA), Descend to XXX FL. etc.
    - There additional services that CPDLC provides but these depend on whether or not an integrated FMS datalink system is used:
- ▪ Loading uplinks to FMS flight plan
- Routes and route modifications
- Direct clearances
- Offset clearances
- Crossing constraints
- ▪ Validation of data in requests
- Against route / navigation data base
- ▪ Validation of uplinks

- Against route / Navigation data base

ADS-C:

- Periodic Contracts
  - Interval—64 seconds to over an hour (1:08:16)
  - On-Request Groups
  - Included at specified reporting intervals
  - Each On-Request Group may be included at different intervals
  - Seven On-Request Groups
- Basic Group Content
  - Aircraft Current 4-D Position
  - Latitude, Longitude, Altitude, Time at which position was determined
  - Figure of Merit
  - Accuracy of position determination
  - Navigation Redundancy
  - TCAS Health
- Event Contracts
  - Waypoint Change
  - Altitude Range Change
  - Lateral Deviation
  - Vertical Rate Change

There are two different forms ATS datalink communication; integrated and non-integrated FMS communication systems. The difference between the systems is the ability to for CPDLC communications that contain navigation information to be automatically inserted in the FMC flight plan by the pilot’s action of accepting the datalink message.

ATS Message Protocols: FANS & ATN

Within the ATS datalink community there two different message protocols that are being deployed by NextGen and SESAR; the Future Air Navigation System (FANS) and Aeronautical Telecommunications Network (ATN). The message sets for FANS are defined in RCTA document DO-258A and ATN is defined in ICAO document 4444 Ed 15. Both FANS and ATN provide the standard ATS functions listed above but ATN delivers one extra function called Flight Information Services.

FIS function delivers the services of Datalink Automatic Terminal Information Service (D-ATIS) this service provides data that encompasses meteorological, and various other information which may affect the departure, approach and landing phases as well as surface operations. The function has three aspects:

- Demand contract
- Update contract
- Cancel contract

All three of these aspects deal with activating, updating, and canceling D-ATIS requests that the pilot makes during any phase of flight.

FANS was initially developed for use in remote/oceanic environments where as ATN was intended for use in enroute and terminal airspace as well. The FANS message set contains 183 defined uplink messages and 80 downlink messages while the ATN message set contains 233 uplink messages and 114 downlink messages; the chart below details additional application difference between FANS and ATN and what document defined the application:

ATS data link application	ACARS	FANS 1/A	ATN
Data link automated terminal information system (DATIS)	ED89 A623	N/A	D-ATIS (DO-280B)
Departure clearance (DCL) or predeparture clearance (PDC)	ED85 A623	CPDLC (DO-258A)	CPDLC (DO-280B)
Oceanic clearance (OCL)	ED106 A623	N/A	CPDLC (DO-280B)
FMS waypoint position reporting (WPR)	A?	ADS-C (DO-258A)	ADS-C (Annex 10)
Data link initiation capability (DLIC)	N/A	AFN (DO-258A)	CM (DO-280B)
Controller pilot data link communications (CPDLC)	N/A	CPDLC (DO-258A)	CPDLC (DO-280B)
Automatic dependent surveillance – contract (ADSC)	N/A	ADS-C (DO258A)	ADS-C (Annex 10)

NOTE: The column denoted FANS as "FANS 1/A" will be describe in section 4.5.1.

2.1.5 Surface Operations

[what part of Hugues' paper goes here?]

2.2 Delegated Separation

2.2.1 ADS-B Applications

2.3 Improved Safety and Environment

2.3.1 Traffic awareness

2.3.2 Enhanced Vision

2.3.3 Synthetic Vision

2.4 Airborne Information Management

Per ICAO Annex 15, Aeronautical Data is a representation of aeronautical facts, concepts, or instructions in a formalized manner suitable for communication, interpretation or processing. It further defines Aeronautical Information as information resulting from the assembly, analysis and formatting of Aeronautical Data. The management of aeronautical Information and Data became a key part in SESAR and NextGen. In this context mainly the ground infrastructure from generation down to distribution and release to the user has been the main focus. Essential enhancements in the field of :

1. Accuracy
2. Availability
3. Continuity
4. Completeness and
5. Integrity

have been targeted where the main focus is the integrity and quality control process.

Several work packages in SESAR have been assigned for this purpose that will most properly result in rulemaking efforts too. In SESAR and NextGen, the term SWIM (System Wide Information Management) has been established

Clear successes have already been accomplished in the field of formatting and structuring aeronautical data and information exchange on the ground by the AIXM format. IT style data formats in the XML format seem to be used throughout the distribution chain. Today, SWIM does not address the management of data and information in the Onboard Infrastructure.

AIXM should not be taken as is but reduced in content and format for embedded use.

Therefore it also appears logical that the onboard infrastructure employ some kind of information management that would, whenever practical, use the same quasi approach, thus continuing the data chain from the ground into the A/C avionics architecture.

The challenge is to provide a definition for this in the ARINC 660B Architecture that provides a clear way forward for new airplanes but still leaves room for updating the existing A/C. For existing airplanes it should be possible to get at least some advantage out of those architectural changes by punctual cost efficient modifications. At this point in time we see a rapid change in the avionics from analog data being provided from the aircraft sensors to that data being provided digitally, which has more resemblance to an IT oriented digital data world. This means that more advanced systems today will get more and more use out of digital data and information than from paper information or analog sensor data. Good examples are:

- new charting applications
- Airport moving map displays or
- EFB deployment.

Standards are being defined today that will increase the need for data and information. RTCA Special Committee 206 is defining standards for airborne applications to use Aeronautical Information Services (AIS) and Meteorological (MET) information. RTCA Special Committee 214 is defining applications that will use Air Traffic Services data uplinked to the aircraft via a datalink. Some examples of these applications are: D-TAXI, D-OTIS, D-RVR, 4DTRAD, D-HZWX, etc. These applications and services will be distributed amongst different avionics systems, but require some of the same data. Similarly, aircraft systems today have needs for the same data, but must use their own system resources to contain their own copy of that data, leading to inconsistencies between systems and potential discrepancies delivered to the pilot (i.e. FMS vs. EFB navigation or situational awareness information). Thus it makes sense that a single data and information management system would make the airplane operation more efficient and safe.

2.4.1 Metrological Data

2.4.2 NOTAMs

3.0 Avionics Reference Architectures

The avionics architectures considered in this document are those of aircraft equipped with FMS and EFIS, whether they are based on LRUs or IMA.

Classical aircraft are not considered in the document, as most of them will be ceasing operation in the time-frame of the emergence of NextGen and SESAR developments.

The allocation of the aircraft functions to the avionics systems is, to some extent the same on most of the aircraft types.

Nevertheless depending on the Airframe Manufacturers philosophies and on the aircraft types there are some differences in terms of avionics architecture.

The main differences are the following :

- The CPDLC function can be hosted in the CMU/ATSU or in the FMS
- Its human-machine interface can be supported by the MCDU, or by DCDU plus MCDU
- The Airport Navigation Function (ANF) can be hosted in a dedicated computer or in the Display System, or in an EFB. The Airport Moving Map can be displayed by the display system (EIS) or by an EFB.
- The CDTI can be hosted by the Display System or by an EFB
- ...

IMA : The Aircraft Manufacturer has a lot of freedom to allocate the avionics functions to the Core Processing Modules. No general rule can be formulated on how to organise the grouping of functions on IMA.

By the end, considering also the different updates which have occurred during the life of some aircraft types, there is a large lot of avionics architectures implemented today on aircraft in service and in production, whether they are Airbus, Boeing, Regional or Business aircraft.

As a consequence, it is very difficult to present in a single document how the different avionics architectures will be impacted by the new NextGen/SESAR concepts.

This is the reason why, it is proposed to identify the impact of the NextGen/SESAR concepts on the Aircraft Functions, which will be valid for all types of aircraft, and to document only some examples of impacts on the avionics systems, rather than to try to present how the avionics of all types of aircraft will be impacted.

<u>List of Aircraft Functions impacted by the NextGen/SESAR Concepts :</u>

- ADS-C (new surveillance contracts)
- AN : Airport Navigation (New Function)
- CPDLC : Controller Pilot Data-Link Communication (new clearances)
- Displays (Traffic, Airport Navigation for instance)
- FM : Flight Management (by TBO for example)
- ...

As a consequence:

- The “CNS/ATM Avionics Architectures Supporting NextGen/SESAR concepts” document will present the evolutions of the aircraft functions which will be necessary to support the NextGen and SESAR concepts.
- The current allocation of these functions to Avionics Systems defined for each Aircraft type will allow to identify which Avionics Systems will be impacted.

The following table gives some examples how aircraft functions are implemented on some types of aircraft :

Functions	Airbus A320, A330/A340	Airbus A380, A350	Boeing B737	Boeing B777	Boeing B787
ADS-C	ATSU	ADS-C/CPIOM			
AN	OANC	OANC/CDS			CDS
CPDLC	ATSU, DCDU/MCDU	ATC/CPIOM CDS	CMU	FMS	FMS
COM ROUTER	ATSU	ACR/CPIOM	CMU	CMU	CMU
FM	FMGC/FMGEC	FM CPM		AIMS	
FM - CDU	MCDU	MFD	MCDU	MCDU	MFD
TC	TCAS	ISS			
...					

Example: if NextGen and SESAR concepts require new CPDLC messages, modification of the CMU/ATSU will be required for aircraft types for which CPDLC is implemented in the CMU/ATSU. For other aircraft for which CPDLC is implemented in the FMS, the FMS will require a modification.

3.1 Classical

3.2 Modern (FM/EFIS) with variants

3.3 IMA based

4.0 Avionics architecture evolutions by Domains

4.1 Performance Based Navigation

4.1.1 NextGen/SESAR concept description

PBN is a framework for defining a navigation performance specification along a route, during a procedure, or in airspace within which an aircraft must comply with specified operational performance requirements. It provides a simple basis for the design and implementation of automated flight paths and for airspace design, aircraft separation, and obstacle clearance. It also offers a straightforward means to communicate the performance and operational capabilities necessary for the utilization of such paths and airspace. Once the performance level (i.e., the accuracy value) is established on the basis of operational needs, the aircraft's own capability determines whether the aircraft can safely achieve the specified performance and thus qualify for the operation.

From an aircraft and aircrew perspective, PBN provides a uniform structure of requirements for airworthiness and operational approval for area navigation systems in airspace implementations. PBN implementation in Europe will introduce future navigation specifications (Advanced RNP, RNP APCH (LPV) , RNP AR APCH) which are one enabler; the second is the ground and space navaid infrastructure of the area navigation application. Performance-based applications will gradually be used as the nominal mode of operation for all phases of flight while the sensor specific applications will become the reversionary modes. PBN is a pillar of the NextGen and SESAR ATM target concepts. Moving from airspace to trajectory based operations in association with other ATC best practices, it allows an aircrew to determine whether they can achieve the specified performance with additional benefits in terms of fuel efficiency , airspace capacity, predictability and Air Navigation Services (ANS) cost reduction.

4.1.1.1 Curved Path Operations

A combination of increased capacity and environmentally sensitive area encroachment on airports has created the requirement for creative flight path management in the terminal area for both departures and arrivals. RNP has provided an accurate, predictable and repeatable track and the “Constant Radius ARC to a Fix” (RF) navigation leg type provides that same accuracy for a fixed radius curved path. The RF leg has been efficiently utilized in terminal area procedures that are constrained by airspace, terrain, or environmentally sensitive areas. Further exploitation of the this navigation leg type should be considered to shorten procedures (reduce track miles) and reduce fuel burn and hence emissions. The RF leg should also be considered as an intermediate segment to an approach procedure design that intercepts a precision straight-in final segment (ILS, MLS, GLS, LPV) as well as in Segment 1 of the missed approach to accommodate parallel operations or other constraints.

4.1.1.2 Low Visibility Operations

Access to airports during periods of low visibility continues to be a priority to ensure access and capacity. Precision guidance systems continue to provide safe operations for Category II/III minima, but additional technologies will be required for those runways not served with precision guidance. Enhanced Flight Vision Systems (EFVS) will provide enhanced awareness of the landing environment enabling lower approach minima regardless of the airport infrastructure. Heads-up Display (HUD) systems will provide an approach capability to lower minima on some precision approach categories.

Ground-based precision approach guidance will continue to be provided by ILS, MLS and GLS. GLS will be an enabler for precision guidance to all runway ends with the added benefit of autoland capability (if the aircraft is appropriately equipped) and accurate position for taxi guidance in very low visibility conditions.

Precision approaches with vertical guidance using SBAS or GNSS approaches with baro/VNAV vertical guidance will continue to provide accurate path guidance to runways not served by ground-based facilities. These approach types are onboard-based systems (do not require ground facilities) and can be implemented quickly and at lower cost than ILS. These approach types increase the level of safety and therefore should replace existing non-precision approach types such as VOR, NDB, LOC-only, SDF etc.

4.1.1.2.1 Parallel Runway Operations

Both capacity and efficiency are significantly impacted when operating to closely spaced parallel runways (CSPR) in low visibility conditions. As traffic levels continue to increase, the effect on operations will become even more significant. Early considerations are being given to runway separation standards and procedures to increase capacity. However, further strides in safety and capacity will be dependent upon additional research in multiple areas such as wake analysis, deviations during simultaneous independent approaches, data collection and analysis ("blunder" analysis), PBN, enhanced surveillance (both air and ground), advanced avionics, and new procedures (based upon PBN, surveillance and avionics enablers).

4.1.2 Requirements for the onboard avionics

4.1.2.1 Path Definition and Flight Planning-RNP

4.1.2.2 Airspace Containment-RNP

4.1.2.4 Navigation Database (NDB)

Many current aircraft navigation systems are equipped with a world-wide navigation database containing data sufficient for most operations. However, the available data for both domestic and international operations is quickly exceeding the memory capability of those database systems. New flight management systems and updates to current systems must expand the NDB capability to meet the requirements of new navigation schemes such as the US National Reference System and the increased number of instrument procedures. Such advances should be included for future aircraft information management systems.

Concurrently, NDB providers and operators must ensure the validity of the NDB. Current methods of validating the data are cumbersome and expensive and therefore require a new concept of NDB validation that reduces expenditures while ensuring the quality of the data.

4.1.2.5 System Onboard Performance and Monitoring

RNP systems must have total system error components in the cross-track and along-track directions that are less than the RNP value 95 % of the flying time. Should the total system error exceed the containment limit for the respective airspace operation, an annunciation must be presented to inform the flight crew of the degradation of the navigation system. System degradation can be the result of sensor failures, degraded modes, hardware component failures among others. Annunciation of a containment limit exceedance must be presented in the flight crew's forward field of view.

4.1.2.6 Cross Track Deviation Monitoring

Display of path steering error (flight technical error plus display error) relative to the desired flight path enhances flight crew awareness of path tracking accuracy. Although not required for larger RNP values, instrumentation that depicts cross track deviation (course deviation indicator, e.g.) and alerts the flight crew of excessive lateral deviations should be provided for RNP values of 0.3 NM and lower.

4.1.2.7 RNP Performance Prediction

The operator must ensure that sufficient RNP capability is available for the time and location of the desired operation. Requirements for the predictive tools are specified in the respective region's regulatory guidance and can be accomplished by either airborne or ground-based equipment. The addition of duplicative satellite systems, or operational enhancements to current systems, may provide sufficient operational capability (enhanced availability) such that regulators may provide relief for a performance prediction requirement. Relief for the operator would be based upon appropriate equipage to utilize the additional sensors, demonstrated RNP performance utilizing the available sensors, and a robust procedure to respond to system outages.

4.1.2.8 GNSS

4.1.2.9 Multiple Sensor Receiver

As additional GNSS and SBAS systems come on line, interoperability and therefore usability will be critical. As RNP and precision positioning become more essential in airspace operations, aircraft flight management and navigation systems must have continuous availability of a reliable navigation sensor or group of sensors. To provide continuous availability to ensure signal coverage at all locations such that a performance prediction is no longer required, on-board receivers should therefore be capable of receiving and computing position data from multiple space-based and ground-based sensor systems. As the Minimum Operational Performance Standards (MOPS) and Minimum Aviation System Performance Standards (MASPS) are developed, consideration should be given to the number of satellite systems interrogated such that integrity of the navigation position performance is the primary focus.

4.1.2.10 Alternative Position Sources

Similar to any signal in space, satellite systems are susceptible to interference by intentional or unintended sources. A dedicated alternate position-navigation-time (APNT) system is therefore required to provide an alternative position source when satellite signal interruptions or outages are experienced. The APNT system should be robust and provide sufficient navigation data for all flight phases with sufficient coverage to allow an instrument approach can be flown to a point where a visual landing can be accomplished.

4.1.2.11 Required Time of Arrival (RTA)

PBN operations are not only dependent upon aircraft equipage but also on ground-based systems capable of traffic flow management. However, the success of effective traffic management in a trajectory-based operations (TBO) environment requires the aircraft to be capable of accepting an RTA at a specific location and then computing the performance required to meet the time clearance.

4.1.3 High-level functional break-down

4.1.4 Proposed Allocation for Avionics Reference Architectures

Function	Impacted System																		
	Air Data/ Inertial	ATC/ Xpndr	Audio System	Braking Systems	Comm UHF/ VFH/HF/ SATCOM	Controls Interface	Data Comm	Data Recorder	DB Server	Display PFD/ ND/ MFD/ DCDU	EFB	Engine /FADEC	Flight Controls FCC / AT	FMS/ MCDU	HUD	Nav Sensors ILS/MLS /GLS/ GPS/ SBAS	Surface Moving map system	TAWS	TCAS/ Tfc Comp

4.2 Trajectory Based Operations

4.2.1 Continuous Climb Departure

4.2.1.1 NextGen/SESAR concept description

There is no concept really detailed in the frame of NextGen and SESAR projects.

A Continuous Climb Departure (CCD) is often desired whereby level segments are eliminated as much as possible. This gets aircraft as high as possible as quickly as possible, reducing noise and local air quality impacts on the ground, and getting the aircraft to the more fuel efficient cruise altitudes earlier.

Level segments are defined by altitude constraints set by the ATC, at which the aircraft must level off, waiting for a clearance to continue to climb.

Some experiments of CCD have been conducted in the frame of AIRE initiatives with positive benefits in terms of noise and fuel consumption reduction.

4.2.1.2 Requirements for the onboard avionics

The requirements for the avionics are to be able to fly a departure procedure with no altitude constraint.

Current FMS have such a capability: they can fly a continuous departure and climb, while optimizing the speed profile, considering the cost index optimisation factor.

As soon as the ATC will define no altitude constraint, FMS equipped aircraft are able to fly an optimized Continuous Climb Departure.

There is no avionics modification required. CCD procedure only need to be defined in the FMS navigation data base.

More information will be provided, when the concept will be described in more details in the frame of the NextGen and SESAR projects.

4.2.2 Continuous Climb Cruise

4.2.2.1 NextGen/SESAR concept description

There is no concept really detailed in the frame of NextGen and SESAR projects. Nevertheless SESAR 9.39 project is addressing the concept, but it is not yet mature.

Step climbs may be accepted by the ATC to allow aircraft to fly at a more optimised cruise altitude. These step climbs are performed in a short period of time by the aircraft, to free rapidly their flight level and join their new flight altitude.

The principle of the Continuous Climb Cruise (CCC) enables aircraft to perform an optimized cruise climb manoeuvre which can take time (low vertical rates), compared to a step climb concept.

Some experiments of CCC have been conducted in the frame of AIRE initiatives with positive benefits in terms of fuel saving.

4.2.2.2 Requirements for the onboard avionics

It is not possible to identify requirements for the onboard avionics, as the concept for CCC is not enough defined.

The FMS will probably be impacted by the concept, but it is too early to detail these impacts.

More information will be provided, when the concept will be described in more details in the frame of the NextGen and SESAR projects.

4.2.3 Continuous Descent Approach

4.2.3.1 NextGen/SESAR concept description

The Continuous Descent Approach (CDA) is considered in both NextGen and SESAR projects.

One major problem for airports today is the noise and environmental effects of step-down arrival/approach procedures. Step-down approach procedures, for example, often lead aircraft to descend to intermediate altitudes on the order of 2.000 to 3.000 feet AGL, before transitioning onto the final approach path and final descent to the runway. The consequences of such procedures are the spread of noise and aircraft emissions onto nearby towns and cities, sometimes as far away as 30 NM from the runway threshold.

Continuous Descent Approach (CDA) procedures have been proposed to reduce noise and emissions. The principle is (1) to delay descent beyond the ‘regular’ Top Of Descent (TOD), and (2) to descent at idle or near idle thrust, while decelerating from the descent speed to the final approach speed, and without flying level.

Continuous Descent Approach is an aircraft operating technique in which an arriving aircraft descends from an optimal position with minimum thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions. The concept is described in ICAO doc 9931.

CDA procedures are now regularly flown at London Heathrow using altitude and speed clearances and manual autopilot parameter selections. These manual procedures are intensive in terms of workload and occasionally result in undesirable vertical profiles, e.g. a level off at intermediate altitude may be required. In order to reduce pilot and controller workload, FMS based CDA procedures were used at Amsterdam (Schiphol) and at some other airports to reduce noise during night-time operations. However, due to uncertainty in the velocity profile and time of arrival at an appropriate Final Approach Fix (FAF), the current FMS procedures require substantially greater separations than for peak operations. Advanced CDA operation could be considered based on appropriate ATC practices (CDA trajectories definition) and aircraft avionics modification, to allow achieving the noise reduction benefit of an idle descent while maintaining traffic at high throughput rates during both daily peak and low density night-time operations.

4.2.3.2 Requirements for the onboard avionics

Assuming that CDA trajectories can be defined with the ATC, based on airspeed profile from CDA deceleration point to the FAF, the requirements for the aircraft to support an advanced CDA function would be:

(1) to plan a vertical path profile from CDA Deceleration point to the FAF such that the airspeed profile follows a known, predictable deceleration from the initial descent speed to a desired final approach speed,

(2) to monitor the vertical path versus the vertical profile, so that arrival at the FAF is at the right altitude,

(3) to provide energy management advisories to the crew for achieving the desired airspeed profile, and providing path, speed and energy cues for pilot loop closure in achieving the desired flight objectives in the presence of unknown winds and other error sources.

4.2.3.3 High-level functional break-down

The advanced CDA aircraft function can be broken down as follows :

- Select/Deselect CDA function
- Build up CDA vertical profile
- Detect high energy situations versus CDA profile
- Display CDA related information
- Guide the aircraft.

4.2.3.4 Proposed Allocation for Avionics Reference Architectures

The following table proposes an allocation of the CDA sub-functions to the aircraft functions :

	Impacted Functions				
	FM-CDU	FM	FG	Display	Warning
Select/Deselect CDA function	X				
Build up CDA vertical profile		X			
Detect high energy situations versus CDA profile		X			
Display CDA related information	X			X	X
Guide the aircraft			X		

4.2.4 4D trajectory Management

4.2.4.1 NextGen/SESAR concept description

This part is addressing TBO foreseen in the short-term, 2013 - 2017 by the NextGen and SESAR programs.

Longer term TBO operations will be described in additional parts.

<u>NextGen and SESAR concepts</u>

NextGen Concept

TBD (Addressed by RTCA Tops Group ?)

SESAR Concept

SESAR concept is defined in B.04.02 : “SESAR Trajectory Management Document”.

“This document provides a high level description of Trajectory Management in SESAR with the purpose to bring about a better understanding of Trajectory Management focusing in concept story board step 1. It aims to describe the high level aspects of TM, relating them to the SESAR Story Board steps and their target times. It also offers clarifications to some matters dealt with during the SESAR definition work which when put in writing (ConOps) did not become clear enough. The document also describes the technology needed to realise the concept. »

The document gives a high-level description of trajectory management by 2020, together with an operational scenario. As well, it describes and gives scenarios for the intermediate steps : Step 1, 2013 Time Based Operation, and Step 2, 2017 Trajectory Based Operation.

For each step, the document starts with the long-term planning, when the Aircraft Operator is planning its flights and negotiating departure and arrival slots with the Airports Operators, then covers medium-term planning whose aim is to detail the flight plans, and after describes the different phases of the flight, from pre-departure to landing and Taxi.

For Step 1, 2013 Time Based Operation, the following extract can be made regarding TBO during the flight phase.

Glossary : TMR : Trajectory Management Requirement , NOP : Network Operations Plan, ADS-C EPP : Extended Projected Profile, RBT/SBT : Required/Shared Business Trajectory, RMT/SMT : Required/Shared Mission Trajectory

“At AMAN horizon, before TOD, the Flight crew prepares the descent and logs on Flight Information Services to get the last up to date parameters using e.g. D-OTIS (runway in use, QNH, weather warning, NOTAM etc) and he requests the last up to date winds and temperatures on the arrival profile.

Before beginning the descent (to avoid busy approach phases), the Flight crew agrees with ATC on the runway exit and receives the taxi route information via data link (e.g. CPDLC). After updating wind/temperature data in the aircraft system, the 3D profile may now be deviating from the previously shared profile more than the delta pre defined by ATC (TMR), the downlink of the trajectory predictions computed onboard is therefore automatically triggered to update the NOP (e.g ADS-C EPP).

Taking into account the ETA min/max report automatically provided by the aircraft system on ATC request specifying the metering point, the AMAN system calculates a CTA based on the position of the aircraft in the current optimized sequence. Additionally the AMAN computes a prediction of the modified trajectory, should the CTA be implemented. Through SWIM, all concerned Air Traffic Service Units (ATSU) are made aware of the potential effect in their airspace. Once coordinated with them the CTA is transmitted to the Flight Crew who loads the CTA within the aircraft system to check its feasibility using the RTA function and if acceptable, activates the resulting trajectory onboard leading to a revision followed by an automatic update of the RBT shared through data link and SWIM to the NOP. Consecutively to CTA allocation, the Flight crew confirms the runway exit previously agreed.

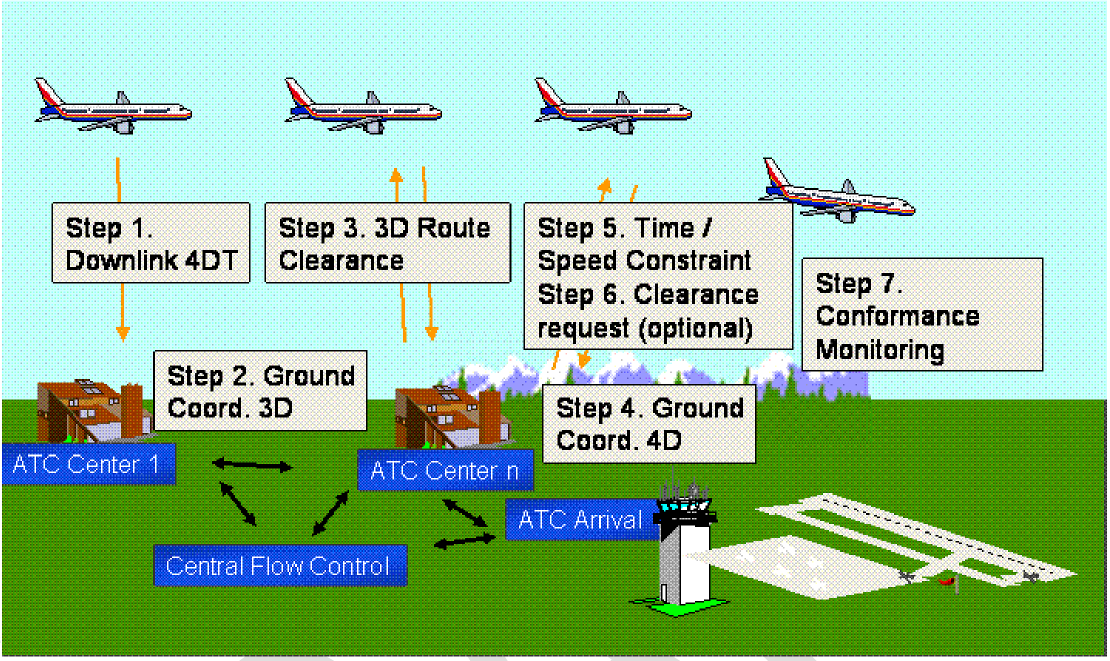
Just before Top of Descent, the Flight crew requests clearance to start descent and flies the descent profile of the RBT which ideally is a Continuous Descent Approach based upon the most optimum engine and airframe settings possible integrating the CTA. The aircraft system continuously monitors the compliance to the RBT, providing speed adjustments to meet the CTA with the required precision.

To synchronise all inbound flights the ATM Ground system at the destination airport builds and tactically updates a common sequence of arrivals and departures integrating data from all relevant SBT/RBT, SMT/RMT and taking into account airport configuration, taxi route and other constraints.”

4.2.4.2 Requirements for the onboard avionics

RTCA SC214 / EUROCAE WG 78 have developed an SPR for the 4DTRAD service. SPR H Part 6 gives a detailed description of the service, including the technologies necessary to support it.

“



Step 1

The 4DTRAD service starts with the downlink of the aircraft’s 4D trajectory.

Step 2

The second step in the 4DTRAD service involves the ground-ground co-ordination of the route with expected vertical constraints. This step is aimed at ensuring that the ground systems have a consistent view on the route and profile of the flight and will use as a basis for the initiation of co-ordination the downlinked trajectory. For a majority of flights this co-ordination will result in a reconfirmation of the FPL trajectory. Remaining planned trajectory discrepancies between ground systems need to be solved at this stage in order to propose to the aircraft a trajectory that can be then respected by all ground actors.

Step 3

The third step of the service consists in a negotiation of the route with expected vertical constraints between ground and air. At this stage the ground agreed 3D route will be uplinked to the aircraft. The flight crew will analyse (by the means of a flight plan trial function) the implications of the ground proposed trajectory and will either accept or reject it. In case of a rejection the negotiation is terminated and the flight will progress as per today. In this case the trajectory discrepancies will be solved between air and ground using voice communications and tactical control instructions.

It is anticipated that in most cases trajectory changes proposed by the ground systems will be minor and acceptable to the flight crew. In this case the flight crew will acknowledge the trajectory and the aircraft will downlink the estimated min/max times for select waypoints along the agreed route. The estimated times will enable the ground systems to negotiate a constraint that is achievable by the flight.

Step 4

Starting from the estimated times downlinked by the aircraft the ground systems will negotiate a waypoint and an associated constraint. The constraint may be sourced from a range of tools (e.g. AMAN, complexity manager, ETFMS, etc.) and might have various operational purposes (e.g. sequencing at the arrival aerodrome, sequencing in en-route for reduction of traffic complexity, etc.). For arriving at complex TMAs, the constraint waypoint may be an en-route waypoint shortly before or at the top of descent, a waypoint that serves as a gate for merging and sequencing or the point at which the aircraft begins its instrument approach procedure (i.e. IAF or FAF) or at the destination. The constraint waypoint is expected to be determined and used by the AMAN tool.

As for the planned timescale the avionics will not be able to support multiple cleared time constraints at the same time it is anticipated that the ground component of the 4DTRAD service will need to propose one cleared time constraint that has the maximum benefit from a network perspective.

Step 5

At this stage the ground system negotiates the time constraint with the aircraft. Because the constraint derivation is based on the aircraft estimated times calculated based on the synchronised 3D trajectory (Step 3), it is anticipated that in most cases the constraint will be accepted by the flight crew. In case the time constraint cannot be accepted, the ground will try to negotiate another time constraint or the service will be terminated.

Step 6 (Optional)

For different operationally significant reasons, flight crew can request a full route clearance indicating the preferred route and constraints.

Step 7

The flight continues its progression in accordance with the agreed 4D trajectory. ATC will uplink clearances for its Area of Responsibility in accordance with the agreed 4D trajectory and try as far as possible to limit tactical interventions. In some cases (for separation assurance or due to weather) the aircraft trajectory will need to be modified in comparison to the plan. In this case, if the aircraft can still meet the cleared constraint, 4DTRAD is continued seamlessly. In case the tactical intervention results in the aircraft not being able to meet the cleared constraint a warning will be presented both to the flight crew and the controller, a new 4D trajectory is downlinked and a new negotiation of a time constraint might be required.

Step 8

At this stage the aircraft reaches the waypoint for which a time constraint was agreed. This results either in the termination of the service, or in a new process aimed at setting a new time constraint in case it is required.”

4.2.4.3 High-level functional break-down

RTCA SC214 / EUROCAE WG 78 have developed requirements for 4DTRAD

- CPDLC to support the uplink or requests from the Controller to the Aircraft

- ADS-C to downlink 4D trajectory and ETA Min/ETA Max reports

The following flow of actions/information can be identified :

Aircraft Role	Action/information flow
Step 1 : The 4DTRAD service starts with the downlink of the aircraft 4D trajectory	ADS-C contract received from the ground FM to generate the data, ADS-C EPP sent
Step 3 : Uplink of 3D Trajectory Load in The FMS Request for updated wind/temperature Downlink of the aircraft 4D trajectory And ETA Min/ETA Max	*ATC UL (capability already existing today)* *FM (capability already existing today)* *New AOC to get more accurate Met data* *ADS-C EPP sent* FM to generate the data, ADS-C ETA Min / ETA Max
Step 5 : Uplink of a CTA constraint Load in the FMS, manage CTA	ATC UL Load in FM, FM update to ensure RTA with enhanced accuracy and tolerance through lateral and vertical guidance
Step 7 : Monitoring of the CTA On-Board the aircraft by FM and annunciation to the crew By the ground through aircraft 4D trajectory downlink	FM to monitor CTA execution and to send data to Displays and Warning ADS-C EPP sent

4.2.4.4 Proposed Allocation for Avionics Reference Architectures

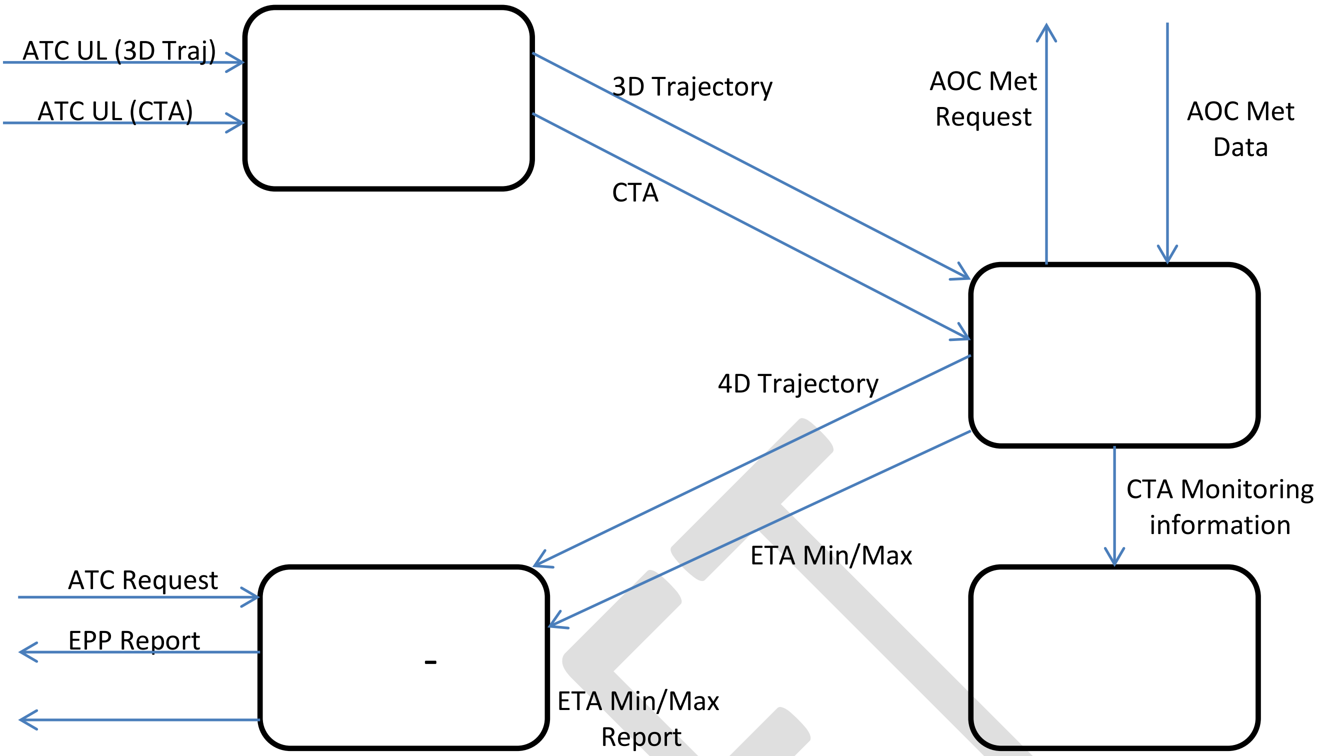
The following table proposes an allocation of the I4D - 4DTRAD sub-functions to the aircraft functions :

I4D – 4DTRAD	Impacted Functions				
	FM	CPDLC	ADS-C	Display	Warning
ATC uplink message to initiate 4DTRAD		X			
ADS-C contract received from the ground	X		X		
4D trajectory generation in FMS	X				
ADS-C Extended projected Profile = 4D traj downlink	X		X		
ATC uplink of 3D trajectory (FPLN) (already existing for FMS FANS FPLN uplink)		X			
Loading FPLN in FMS (already existing for FMS capable of Loading FANS FPLN)	X				
FM to send AOC request for getting more accurate MET data	X				
Downlink of the 4D trajectory (ADS-C Extended projected Profile)	X		X		
ADS-C request for RTA window	X		X		
ETA min/max Generation in FMS	X				
ADS-C ETA Min/Max => ADS-C	X		X		
ADS-C MET reports	X		X		
ATC uplink of CTA constraint		X			
Load in FMS the CTA	X				
Manage Enhanced RTA	X				
Monitor CTA compliance	X				
Monitoring information sent to displays and warning	X			X	X
Downlink of the 4D trajectory (ADS-C Extended projected Profile)	X		X		

The following table presents the new features which must be added to the aircraft functions to support the I4D - 4DTRAD service:

Function	Impact of I4D - 4DTRAD
ADS-C	New reports : - 4D trajectory EPP - ETA Min / ETA Max
FM	New AOC capability to upload more accurate wind and temperature data Generation of 4D trajectory data Output of 4D trajectory data sent to ADS-C Generation of ETA Min/ETA Max Output of ETA Min/ETA Max sent to ADS-C Management of CTA (Enhanced RTAs) : input, modification of algorithms to manage CTA with associated accuracy and tolerance, need for having and to manage a more accurate wind and temperature model to have more accurate predictions to satisfy the CTA requirement Monitoring of CTA execution, output of data sent to Displays and Warning to help the crew monitor the CTA
Displays – Warning	Display of information associated to CTA monitoring, and associated warnings
CPDLC	New clearances to initiate 4DTRAD, to send CTA with accuracy, use of existing clearance to up-load a flight plan

The following diagram gives a description of the functions and of the data flows of I4D – 4DTRAD:


ATC UL (3D Traj)
ATC UL (CTA)
3D Trajectory
CTA
AOC Met Request
AOC Met Data
4D Trajectory
CTA Monitoring information
ETA Min/Max
ATC Request
EPP Report
ETA Min/Max Report

4.3 Approach and Landing

4.3.1 NextGen/SESAR concept description

4.3.2 Requirements for the onboard avionics

4.3.3 High-level functional break-down

4.3.4 Proposed Allocation for Avionics Reference Architectures

4.4 Surface Operations

4.4.1 NextGen/SESAR concept description

Within NextGen/SESAR plans and roadmaps efficiency and safety of surface traffic management will be improved, with corresponding reduction of environmental impacts, through the use of improved surveillance, automation, on-board displays, data link of taxi instructions and extension of the Trajectory Based Operations to the ground part (ground TBO).

It is based on the hypothesis that the responsibilities between aircraft crew and Air Traffic Control (ATC) remains roughly the same as today for operations on the airport surface, i.e. Ground ATC defines and decides the taxi route that the aircraft should follow and provides, accordingly, the aircraft crew with clearances along this path, whereas the aircraft crew has to execute the taxiing according to the received clearances. The crew is responsible for their own compliance and monitoring runway incursion potential. It also assumes that there will be full data link communication used to reduce voice communication and enable more complex clearances with less confusion in the prescribed taxi route.

For the time being the aircraft crew has few specific avionics means to facilitate its surface operations, and though significant improvements at ground ANSP level, new avionics means will become available in the mid to far-term for improving efficiency, predictability and safety of approach/departure and taxing operations, in, addition to upcoming ground ANSP means. .

This is expected to benefit aircraft operators and controllers by enabling more effective and safer airport operations, due to the improved ability to track manage ground trajectories and associated traffic conflicts.

Safety enhancements and hazard mitigation & avoidance

Surface moving maps with overlaid “own ship” position information will improve flight crew situational awareness in ramp areas, taxiways and runways helping to reduce taxiway and runway incursions and confusion.

Own Ship Surface Relative Position capability will aid flight crews by providing better situational awareness of their own position relative to the locations of runways along their route of taxi, resulting in greatly reduced occurrences of taxiway and runway incursions and confusions. This is expected to be complemented by incorporating the following capabilities in the system:

1. **Own-ship surface movement alerting** significantly helps in reducing runway excursions of its own-ship aircraft, by providing timely indications and alerting to the aircraft crew of unsafe situations, including :

a. Indication of Runway Identifier Toward Which the Aircraft is Approaching

This capability aids both when flying an approach and when taxing on the airport surface in positive runway identification to eliminate confusion as to the aircraft location with respect to active runways.

This function may also be used to provide positive verification of the assigned departure or landing runway

b. Insufficient Runway Length and Alerting

This capability improves crew awareness of runway distance at the start of the takeoff roll and provides remaining runway distance during the landing roll. It will provide an alert when there is insufficient runway distance required to complete the takeoff or landing maneuver. During the landing maneuver, this aids the decision process for the crew to determine if additional deceleration is necessary to stop within the remaining runway distance or to perform a missed approach.

2. **On-board runway incursion alerting** significantly helps in reducing runway incursions from its own-ship aircraft, by providing timely alerting whatever the visibility level to the aircraft crew of unsafe situations, including :

a. Indication and alerting of an Imminent Runway Crossing,

Such indication is provided when the aircraft moving on the airport surface is close to enter a runway, thus requiring an immediate stop to avoid a runway incursion situation.

Advantageously, such indication is provided when the aircraft moving on the airport surface is close to enter an occupied runway by another aircraft already on the runway or in approach for landing

b. Final Approach Runway Occupancy Alerting (FAROA),

This capability provides an alert to a landing aircraft on final approach when the runway is occupied by another aircraft or vehicle. While not a surface movement capability per se, it does provide situational awareness to an aircraft on final approach by providing it with information about aircraft on the runway or approaching the runway. This significantly reduces the potential for error, especially in low visibility conditions, for issuance of a landing clearance with another aircraft on or moving onto the landing runway.

c. Approaching Runway alerting without line-up clearance,

Such alert is provided when the aircraft moving on the airport surface is close to enter a runway without a “line-up” clearance to do it, whatever the runway is occupied (by an another aircraft on the runway or in approach) or not, thus requiring an immediate stop to avoid a runway incursion situation.

3. **Surrounding traffic awareness** improves aircraft crew situation awareness on the relative position of its aircraft with regard to other surrounding traffics maneuvering on the airport surface (typically in higher density situations), as well as a better identification of those other traffic when they are addressed in an ATC message or clearance. This capability shows the relative locations of other aircraft/vehicles in reasonable proximity of its own ship overlaid over the airport moving map. Information on other traffic over the airport surface is obtained from ADS-B “in” and/or TIS-B.

Additionally some **Traffic alerting** may be provided as a safety net complementing the nominal ATC traffic surveillance to alleviate potential collision with other aircraft maneuvering on the airport surface.

Such indications and alerts as well as surrounding traffics are advantageously overlaid on the displayed airport moving maps. Alerts are also provided by characteristics aural messages and tones.

Early implementation includes basic surface movement indication and alerting functions. The more advanced applications are expected to become available in the late mid-term or far-term periods and will first appear in new aircraft designs and then be offered as retrofit packages to existing aircraft.

Improved efficiency of taxiing operations

During periods of high traffic density and poor visibility, the following on-board aircraft capabilities will allow for less dependence on costly ground infrastructure :

1. **Display of Taxi Route Clearances** improves aircraft crew situation awareness on the effective path to follow during their taxiing operation, allowing to minimize crew hesitations and potential path errors.

This capability, toward the end of the midterm and early far term will be automatically uploaded and overlaid on the moving map display. In the far term, additional capability may come in the form of taxi clearances that include a time element from first movement off the gate/parking spot to the end of the runway.

2. **Runway exit indication,**

This capability provides situational awareness on the predicted runway exit where its aircraft will most likely exit the runway. This will allow the flight crew to adjust the braking intensity to optimize the deceleration rate of the aircraft and to determine if additional thrust is required to taxi up to a runway turnoff.

3. **Surface Guidance,**

is an additional capability allowing the aircraft crew to expedite more quickly and safely its taxing typically in bad weather conditions, with less interpretation errors on which taxiway to take and the holding point where to stop,. Typically steering directions with possibly lateral path deviation indications are provided.

4. **Automated Surface Guidance,**

In the far-term automated surface guidance may be considered for taxing automation accordingly to a prescribed clearance, in order the aircraft crew expedites the execution of its aircraft taxiing, thus allowing significant of surface operations efficiency.

Gate-to-Gate Trajectory Based Operations (TBO)

In the Far-term TBO migrates from limited trajectory operations in en route cruise through arrivals, linking en route trajectories to TOD, and then through OPDs to approach and landing. Additionally Ground 3DT (lateral, longitudinal, and time) are used in surface movement with introduction at ANSP level of surface movement management tools for sequencing aircraft for departures with consideration to arrival flows.

The concept of Ground TBO is from gate-to-gate, not just today's ANSP-defined movement area beyond the gate and parking area. In the mid-term, this surface movement will be largely the responsibility of the operator and the ground controller. The intent is to reduce variability in surface movement by using trajectories with a single takeoff time performance working back to pushback or start of taxi from a hardstand or gate. This expected takeoff time for surface movement extends the TBO concept into flight with the actual takeoff time resetting the flight 4DT.

Surface operations are a closed trajectory – a defined taxi route to take the aircraft from and to the gate to and from the runway. On takeoff, the aircraft starts another closed trajectory representing the flight 4DT that was selected by the operator of the aircraft as part of flight planning and updated with the actual takeoff time.

A comprehensive view of aggregate traffic flows enables the ANSP to project demand, predict, plan, and manage surface movements, and balance runway assignments. This facilitates more efficient surface movement and arrival/departure flows. Automation monitors conformance of surface operations and updates the estimated departure clearance times to renegotiate the 4DT. Surface optimization automation at ANSP level includes activities such as snow effect prediction, runway snow removal, aircraft deicing, braking action, and runway configuration, as well as flight arrivals.

4.4.2 Requirements for the onboard avionics

1. Surface Moving map display

There are various display requirements that must be met based on the level of capability being displayed. These can be met in various ways but may impact the display/instrument system installed on the aircraft. Typically such moving maps may be presented on electronic flight bags (EFBs) or preferably on Navigation Displays specifically when other surface applications are also made available.

Graphical qualities, modes, and ranges, as well as Human Machine Interface (e.g. interactive) depend on the specific installation.

2. Airport map databases

Surface moving maps are built from airport map databases. A database incorporating essential surface data (runways, taxiways, ramps, etc.) will be needed to support the surface movement applications. As these capabilities evolve, the level of integrity and accuracy of the information will have to increase to support the more critical operations.

Existing Airport Map Databases are suitable for short-term surface functionalities which are basically advisory and situation awareness capabilities, mainly focused on displaying airport features or layout.

However for more advanced surface functionalities for the mid-term and the far-term, Airport Moving Map Databases will need higher assurance level development standards, so as ensuring data criticality for those upcoming new surface functionalities, typically in terms of accuracy, but also in terms of integrity, completeness and timeliness.

Additionally Airport Moving Map Databases, which are nowadays mainly a graphical depiction of the airport elements, will be complemented by connectivity data linking the different airport elements, as required by those upcoming new surface functionalities.

In the far-term, it could be expected that the Airport Map data elements will be uplinked to the aircraft through a defined network in order to ensure consistency of the Airport Map data elements displayed and/or used by the aircraft crew and the airport ATC .

3. Aircraft positioning

This capability will rely on augmented Global Navigation Satellite Systems (like WAAS) position information (in order to ensure that the own-ship symbol is properly displayed on the moving map, as non-augmented position information is not sufficient alone) and will be suitable for most of the mid to far-term surface functionalities.

However, accuracy and integrity improvements may be required for more advanced surface functionalities in the far-term (e.g. automatic guidance).

4. Alerting

Alerts will be provided whether by specific display symbols and/or by characteristic aural messages and tones.

5. CPDLC interface

Some foreseen capabilities rely on taxi route clearances. In the far-term those taxi route clearances will be received by CPDLC, with the appropriate messages for ground operations (e.g. digital taxi clearances). This enabler not only involve the airborne side but also require the ground to provide such capability.

Additionally, CMU will be used for Ground TBO exchanges between the Ground ATC and the aircraft.

6. Traffic information

A Traffic Computer receiving inputs from Automatic Dependent Surveillance-Broadcast (ADS-B) In and/or Traffic Information Services-Broadcast (TIS-B) will be necessary to support all traffic related surface functionalities. ADS-B “in” aircraft position on the airport surface will comply with the specific accuracy and integrity requirements for such surface functionalities.

7. Trajectory and performances computation

Introduction of Ground TBO will impact existing flight management computers (FMC).

New algorithms will also be required to compute takeoff and landing performance

8. Guidance symbology

Guidance symbology used for path steering will be advantageously displayed on the HUD as Surface Guidance System (SGS) capability in combination with Enhanced Vision Systems (EVS).

As a summary, involved on-board systems are composed of all or a part of the following :

- Airport Moving Map systems
- Cockpit Displays & Controls
- Traffic computer with ADS-B and/or TIS-B capability
- Enhanced Vision (HUD/SGS, EVS)
- Communication Management (CMU)
- Flight Management Systems
- Potential Database Server
- Braking Systems
- Flight Controls and Auto-throttle

4.4.3 High-level functional break-down

The functional requirements necessary to achieve the various Surface capabilities vary depending on the level of performance that is sought. Because of this the functional breakdown represents a superset to support the highest levels of performance, lower levels of performance may not require all functional areas or less stringent requirements within a functional area. A proposed functional breakdown is :

- Moving map display
- Airport Map Database management
- Ground aircraft position Estimation (accuracy, continuity, integrity)
- Alerting logics
- Take-off & landing performance estimation
- Runway exit determination
- Runway overrun prediction and alerting
- Braking guidance
- Path Definition
- Path Steering guidance
- Taxi Clearance uplink
- Taxi Clearance display
- Traffic environment acquisition
- Traffic display
- Traffic alerting
- Automated guidance
- Ground TBO communications (uplink/downlink)
- Ground TBO conformance monitoring
- Estimated time of arrival

- Time Control
- User Interface

4.4.4 Proposed Allocation for Avionics Reference Architectures

Based on the high level functional breakdown the following system allocation of the functions is proposed.

Function	Impacted System																		
	Air Data/ Inertial	ATC/ Xpndr	Audio System	Braking Systems	CMU/ ATSU	Comm UHF/ VFH/HF/ SATCOM	Controls Interface	Data Comm	DB Server	Display PFD/ND /MFD/ DCDU	EFB	Engine	Flight Controls FCC / AT	FMS/ MCDU	HUD	Nav Sensors ILS/MLS /GLS/ GPS/ SBAS	Surface Moving map system	TAWS	TCAS/ Tfc Comp
Moving map display										√	√						√		
Database Management									√								√		
Ground position Estimation														√		√	√		
Alerting logics			√							√							√		
Performance estimation														√			√		
Runway exit determination										√							√		
Runway overrun alerting			√							√							√		
Braking guidance				√						√							√		
Path Definition														√			√		
Path Steering										√					√		√		
Taxi clearance uplink					√														
Taxi clearance display										√									
Traffic acquisition																			√
Traffic display										√									
Traffic alerting										√							√		√

Function	Impacted System																		
	Air Data/ Inertial	ATC/ Xpndr	Audio System	Braking Systems	CMU/ ATSU	Comm UHF/ VFH/HF/ SATCOM	Controls Interface	Data Comm	DB Server	Display PFD/ND /MFD/ DCDU	EFB	Engine	Flight Controls FCC / AT	FMS/ MCDU	HUD	Nav Sensors ILS/MLS /GLS/ GPS/ SBAS	Surface Moving map system	TAWS	TCAS/ Tfc Comp
Automated guidance				√									√				√		
Ground TBO comm					√														
Ground TBO monitoring														√					
Estimated Time of Arrival														√			√		
Time Control														√			√		
User Interface										√	√		√						

4.5 ATS Data Link

4.5.1 NextGen/SESAR concept description

Currently SESAR and the NextGen data communication system use a combination of two different message protocols, they are Future Air Navigation System (FANS) and Aeronautical Telecommunications Network (ATN). Both have basic messages sets used for oceanic, remote, and en-route operations.

SESAR PROGRAM

The SESAR datalink program begins with the Link 2000+ mandates that all aircraft by February 2015 must have ATN baseline 1 ATS functionality to fly above flight level 285. There is an exception for FANS equipped aircraft to fly above flight level 285 as long as the aircraft is equipped and the airline is authorized to use FANS CPDLC by January 2014.

The Link 2000+ uses a sub section of the ATN protocol message sets known as ATN baseline 1. The messages sets and applications are defined in RTCA documents DO-258A. The functions that will be implemented in Link 2000+ are the following:

- Context Management - Data Link Initiation Capability
    - Provides the necessary information to establish a connection and enable CPDLC
- ATC Communication Management (ACM)
    - Provides automated assistance to the aircrew and controllers for transferring ATC communications from one sector to another
- ATC Clearances (ACL)
    - Enables the controller to send ‘strategic’ en-route clearances for altitude, heading, speed, direct route, and rate of climb
    - Provides the crew with the capability of requesting deviations in altitude, heading, speed
- ATC Microphone Check (AMC)
    - Provides controllers with the capability to uplink an instruction to the aircraft to check that they are not inadvertently blocking a given voice channel.
- FIS applications for ATIS information regarding weather.

It should be noted that all Air Navigation Service Providers (ANSP) will be able to support FANS 1/A+ aircraft since the European mandate does not force members to equip to do so. If a ANSP is not equipped to support FANS 1/A+ aircraft voice communications will be utilized to support the aircraft in the terminal and en-route environments.

NEXTGEN PROGRAM

The NextGen Data Communications program plans to implement datalink functionality over time to different airspaces gradually building up similar capabilities to SESAR and expanding/continuing current datalink programs to integrate them seamlessly.

- The first step will be the Tower airspace environment to enable pre departure clearances via CPDLC starting in 2015 and rolling out to 30 core airports across the USA by 2017.
  - The initial network will be setup to accommodate FANS 1/A+ aircraft
  - Currently the FAA is not planning to support ATN Baseline 1 aircraft.
  - These pre departure clearances will also contain oceanic clearances
- The second step will deploy CPDLC datalink functionality to the en-route domain starting in 2018 and being fully available across the USA by 2022. The following functions will be utilized by ATC:
  - Enable controllers to send 'strategic' en-route clearances for altitude, heading, speed, direct route, and rate of climb
  - Provide crews with the capability of requesting deviations in altitude, heading, speed
  - Again ATN Baseline 1 equipped aircraft will not be supported in this environment.
- Currently the use of FANS 1/A+ as defined in DO-258A is being utilized in oceanic environments to allow crews communicate with ATC for requests and position reporting via ADS-C. The NextGen DataComm program will continue to support this along with the addition of support ATN Baseline 2 aircraft for oceanic airspace.

4.5.2 Requirements for the onboard avionics

The equipment required to use the ATS functions for CPDLC and ADS-C are different depending upon which architecture the aircraft utilizes for either FANS or ATN systems. There also different requirements for data transmission depending whether you are flying in NextGen or SESAR airspace and whether or not you are using ATN or FANS ATS functions.

SESAR LINK 2000+ MANDATE MINIMUM EQUIPMENT:

- VDL Mode 2 VHF Radios
- Protected Mode CPDLC
- DO-178B Level C software

For aircraft flying in SESAR airspace and using the FANS exemption the systems only needs to be compliant with EUROCAE documents ED-100 & ED-100A or RTCA equivalent of DO-258A.

- There is no requirement for VDL Mode 2 VHF Radios
- The operator must have operational approval to use FANS CDPLC prior to January 1st, 2014 to gain the exemption.

NEXTGEN DATALINK PROGRAM MINIMUM EQUIPMENT:

- An ARINC 750 compliant radio with VDL-2 communications capability supporting the VDL Mode 2 auto-tune function as specified in ARINC 631-5 plus errata (VHF Digital Link (VDL) Mode 2 implementation provisions, which allows operation when system capacity demand requires the use of several VDL Mode 2 frequency channels. Capability supporting the VDL Mode 2 auto-tune function as specified in ARINC 631-5 plus errata.

- FANS 1/A+ AFN and CPDLC application capability in accordance with DO-258A.

4.5.3 High-level functional break-down

The three main functions of ATS datalink communications are CMA, CPDLC & ADS-C these functions are serve different purposes. Depending on whether one is using FANS or ATN ATS datalink impacts where functions reside in different aircraft computers. Regardless of the aircraft avionics architecture, these can be general be broken down into three categories:

1. FMS is the ATS and application end system, and the Communications Management Unit (CMU) is an ATS router. The ARINC 656 FMS/CMU interface is used.
2. FMS is the application end system. The CMU is the ATS end system and gateway to the FMS using the ARINC 656 remote stack interface.
3. CMU is the ATS and application end system, i.e., single end system. The FMS supports the ARINC 656 interface as required.

FANS equipped aircraft utilize integrated FMS system where CPDLC messages that contain flight plan alerting instructions are automatically inserted into the flight plan with just the pilot accepting the CPDLC message. In this case the architectures 1 and 2 can both be used since the FMC needs to be the host of the ATS application in order for it to transfer data received via CDPLC messages.

ATN baseline 1 equipped aircraft must utilize the third architecture since ATN ATS functions are hosted in a CMU is the application end system.

4.5.4 Proposed Allocation for Avionics Reference Architectures

4.6 ADS-B Applications

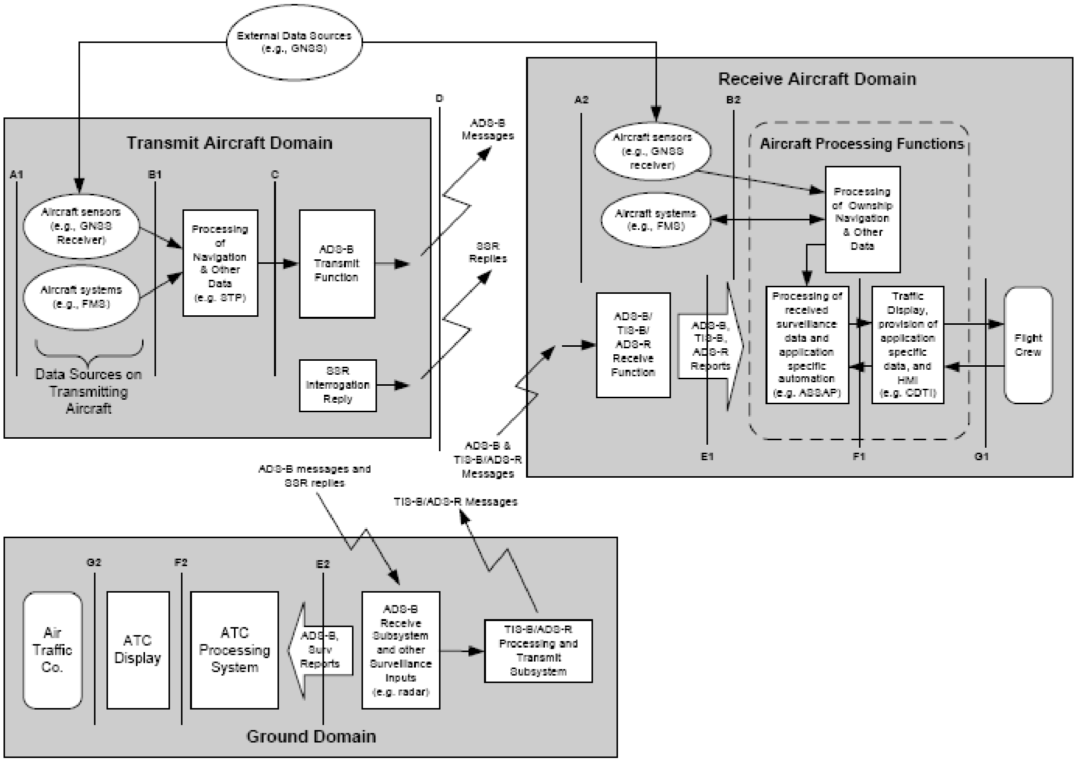
4.6.1 ADS-B Applications - General

RTCA and EUROCAE have developed documents describing the different ADS-B applications:

- Operational concepts
- OSED
- INTEROP
- SPR

In addition RTCA DO-317 is defining MOPS for the ASA (Airborne Surveillance Applications) system.

The document presents a high level architecture of the ADS-B functions, whether they are ADS-B In or Out of the aircraft, or related to ground ADS-B functions.



This frame will be considered in the on-board avionics architecture impact studies, performed in the next paragraphs.

4.6.2 ATSA - AIRB

4.6.2.1 NextGen/SESAR concept description

The ATSA – AIRB application (Airborne) is described in RTCA DO-319 document.

“During flight operations, flight crews should, to the greatest extent possible, maintain a general awareness of the environment in which they are operating. In particular, flight crews must attempt to maintain traffic situational awareness.

Traffic situational awareness is an asset in terms of safety and flight efficiency. During flight operations, flight crews use all available sources of information to build their mental traffic picture by scanning for traffic out the window and listening to radio communications. However, these sources may present some limitations. Visual acquisition of surrounding traffic is not usually possible in reduced visibility and can be difficult even in good conditions. Radio communications may only provide a partial picture (e.g. different VHF frequencies used in the same airspace for departures and arrivals in TMA, information about traffic only provided when the controller has time available to make non-mandatory transmissions for instance between IF (Instrument Flight Rules) flights in class A airspace).

The ATSA – AIRB application aims at enhancing flight crews’ traffic situational awareness through the provision of an appropriate on-board graphical display of airborne surrounding traffic transmitting ADS-B data relative to their aircraft together with supporting information on that traffic. It is expected that this enhanced traffic situational awareness will contribute to improve flight safety and flight operations.

The ATSA - AIRB application will supplement the other available sources of information (i.e. out of the window and/or radio communications) and should support the rapid and accurate mental integration of out of the window and radio communication information (i.e. the display of Aircraft Identification in conjunction with the voice communications party-line effect helps the flight crew in building their mental traffic picture) and help the flight crew to address the limitations of these sources (e.g. identification of the presence of a traffic of interest that cannot be visually acquired for instance due to limited visibility conditions or aircraft being out of the field of vision).

The ATSA – AIRB application can be used anytime the aircraft is airborne, i.e. from the runway departure on take-off, through in-flight operations, and during approach in touchdown, in all classes of airspace, in both IMC and VMC, by aircraft operating under IFR and VFR and by all types of aircraft, from large commercial jets to small General Aviation aircraft. The actual expected benefits will vary depending on the airspace and operational flight rules.

4.6.2.2 Requirements for the onboard avionics

The ATSA – AIRB application is an airborne only application.

The on-board avionics will have to support the following requirements :

- to be able to receive ADS-B messages sent by the surrounding traffic
- to extract the associated ADS-B traffic information
- to manage the ADS-B and TCAS traffic information
- to display the traffic information to the flight crew :
- both TCAS and ADS-B traffic information, merged when they correspond to the same traffic
- detailed information on ADS-B traffic
- to alert the flight crew in case of ATSA – AIRB failures

4.6.2.3 High-level functional break-down

The ATSA – AIRB application can be broken down in the following sub-functions :

- receive ADS-B messages from the surrounding traffic
- manage the ADS-B traffic information together with the TCAS information
- display the ADS-B and TCAS traffic information to the flight crew
- monitor and display to the flight crew the ATSA – AIRB function status

It is proposed to define a new function called “Traffic Computing” function, which will manage the different sources of traffic information available on-board the aircraft, whether they come from ADS-B, TIS-B or TCAS. The TCAS functions will remain independent and kept unchanged in terms of alerting the crew on risks due to the surrounding traffic. Traffic information generated by TCAS will be made available to the TC function.

4.6.2.4 Proposed Allocation for Avionics Reference Architectures

TCAS is working in a frequency band compatible with ADS-B messages. It is the appropriate system to host the "receive ADS-B messages function".

As well TCAS is monitoring the surrounding traffic and preparing traffic information which are displayed to the crew on the Navigation Display (ND) : TCAS function is also appropriate to manage ADS-B traffic together with TCAS traffic.

As a consequence, it is proposed to group TCAS and TC in the same avionics system, while keeping TCAS independent to maintain its safety role.

ND is a natural means to display ADS-B traffic information, together with TCAS traffic information.

But ND, is not adapted to the display of detailed information which are available for the ADS-B traffic (number of traffic, range of detection). Another means of human-machine interface must be considered, as the MCDU for instance.

	Impacted Functions			
	TC	Display - ND	TC - MCDU	Warning
Receive ADS-B messages	X			
Manage ADS-B traffic information together with TCAS information	X			
Display ADS-B and TCAS traffic information to the flight crew	X	X	X	
Monitor and display the ATSA – AIRB function status to the flight crew	X	X	X	X

4.6.3 ATSA - VSA

4.6.3.1 NextGen/SESAR concept description

The ATSA – VSA application (Visual Application in Approach) is described in RTCA DO-314 document.

"The current own visual separation procedure is comprised of four successive phases:

- Visual Acquisition;
- Clearance for Maintaining Own Visual Separation;
- Maintaining Own Visual Separation on the Approach; and
- Termination.

Visual Acquisition phase

The objective of this phase is that, at the end:

- the flight crew of the Succeeding Aircraft has:
- detected the Preceding Aircraft on the Traffic Display;
- visually acquired the Preceding Aircraft and visual contact can be maintained;
- checked consistency of the Traffic Display, out the window and controller information; and
- reported visual contact on the Preceding Aircraft to the controller;
- the controller has assessed the applicability of providing a clearance for maintaining own visual separation. This phase includes two procedures.
- The “Basic Procedure” is based on current ATC procedures. Flight crew’s procedures are only changed to include the use of the Traffic Display.
- The “Advanced Procedure” defines, in addition, new procedures for both the controller and the flight crew of the Succeeding Aircraft related to the use of the aircraft identification of the Preceding Aircraft by the flight crew using a modified phraseology.

Clearance phase

After the flight crew of the Succeeding Aircraft has explicitly reported having the Preceding Aircraft in sight, the controller provides the flight crew with the clearance to maintain own visual separation from the Preceding Aircraft. The flight crew decides to either accept or refuse this clearance and reports the decision to the controller. If the clearance is accepted, the ATSA-VSA application moves to the maintaining phase. If it is not, the controller continues to provide separation to the Succeeding Aircraft by issuing clearances and instructions.

Maintaining Own Visual Separation phase

In this phase, the responsibility of the flight crew is to maintain own visual separation from the Preceding Aircraft. In addition to the out the window information, the flight crew of the Succeeding Aircraft also uses the information provided by the Traffic Display to perform this task. In particular, the distance and speed information provided by the Traffic Display allows respectively for a better evaluation of the actual distance from the Preceding Aircraft and for an earlier detection of speed variations.

The ATSA-VSA application modifies the decision process (e.g. the flight crew of the Succeeding Aircraft can decide that a speed reduction is required due to an excessive speed difference detected on the Traffic Display but that is not yet detectable visually) but it does not change the manoeuvre: any manoeuvre shall be undertaken with visual reference to the Preceding Aircraft.

The procedure in case of abnormal modes is identical to the current visual procedure (i.e. without the support of the Traffic Display).

Termination phase

In nominal conditions, the clearance for own visual separation ends when the Preceding Aircraft lands.

NOTE : *Under specific circumstances (e.g. under FAA procedures), the application*

ends when the Preceding Aircraft clears the runway.

4.6.3.2 Requirements for the onboard avionics

The requirements for the on-board avionics are very close to the ones of the ATSA – AIRB application.

It is assumed that the ATSA – VSA clearances will be exchanged by voice between the ATC and the flight crew.

The main requirement for the on-board avionics will be to display the ADS-B traffic to the flight crew to help him visualise it outside the window.

An option can be proposed, which would consist in helping the crew by allowing him to select the traffic concerned by the VSA application, within the ADS-B traffic, and to display it on the Navigation Display, in a different way compared to the other traffic.

4.6.3.3 High-level functional break-down

The ATSA – VSA functional breakdown is very close to ATSA – AIRB one :

- receive ADS-B messages from the surrounding traffic
- manage the ADS-B traffic information together with the TCAS information
- display the ADS-B and TCAS traffic information to the flight crew
- option : select the VSA traffic and display it in a different way
- monitor and display to the flight crew of the ATSA – VSA function status

4.6.3.4 Proposed Allocation for Avionics Reference Architectures

The allocation of the ATSA – VSA sub-functions to the aircraft functions is similar to the one proposed for the ATSA – AIRB application, with just a small difference related to the proposed option.

The ADS-B traffic concerned by the VSA application could be selected by the crew to be displayed in a different manner compared to the other traffic, by the means of the MCDU, or another specific means as a traffic selector.

	Impacted Functions				
	TC	Display - ND	TC - MCDU	Traffic Selector	Warning
Receive ADS-B messages	X				
Manage ADS-B traffic information together with TCAS information	X				

Display ADS-B and TCAS traffic information to the flight crew	X	X	X		
Select the VSA traffic and display it in a different way	X	X	X	X	
Monitor and display the ATSA – VSA function status to the flight crew	X	X	X		X

4.6.4 ATSA - ITP

4.6.4.1 NextGen/SESAR concept description

The ATSA – ITP application (In-Trail Procedure) is described in RTCA DO-xxx/EURAE ED-159 document.

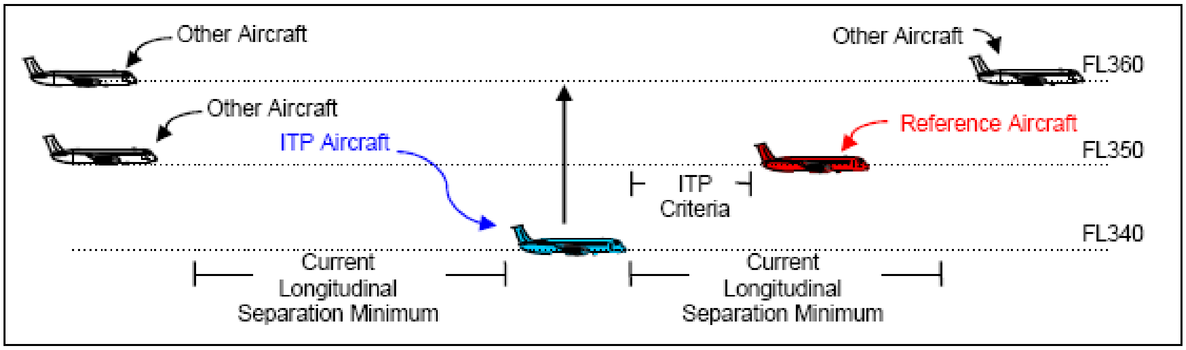
“The objective of the In-Trail Procedure (ITP) is to enable aircraft that desire Flight Level changes in Procedural Airspace to achieve these changes on a more frequent basis, thus improving flight efficiency while maintaining safe separation from other aircraft. ATSA-ITP achieves this objective by permitting a climb-through or descend-through manoeuvre past the Reference Aircraft, in compliance with an assumed distance-based longitudinal separation minimum (the ITP Separation Minimum) during the manoeuvre. This assumed separation standard is known as “Longitudinal Separation Minima based on distance using ADS-B in-trail procedure (ITP)”.

ATSA-ITP enables flight crew to use information derived on the aircraft to determine whether criteria can be met to enable a climb or descend manoeuvre with reduced separation in Procedural Airspace. The criteria are designed such that the spacing between the estimated positions of the ITP Aircraft and Reference Aircraft, throughout the manoeuvre, is never less than the ITP Separation Minimum.

The ATSA-ITP application does not change the responsibilities of either pilots or controllers. The flight crew continues to be responsible for the operation of the aircraft and conformance to its clearance, and the controller continues to be responsible for separation and the issuance of clearances throughout the ATSA-ITP application. Initial conditions, and the crew’s compliance with the ITP procedure, are in place to ensure the safety of the Flight Level change.”

“The set of potential ITP manoeuvre geometries are as follows:

- A Following Climb.
- A Following Descent.
- A Leading Climb.
- A Leading Descent.
- A Combined Leading-Following Climb.
- A Combined Leading-Following Descent.”



ITP Following Climb

"To assure safety during an ITP manoeuvre, the proposed ITP Separation Minimum applied between the ITP Aircraft and the Reference Aircraft during the brief portion of the Flight Level change where vertical separation does not exist is 10 NM. To assure that the ITP Separation Minimum is met throughout the ITP manoeuvre, ITP initiation criteria have been established. The criteria are designed such that the horizontal distance between the estimated positions of the ITP Aircraft and Reference Aircraft, during the portion of the climb or descent where vertical separation will not exist, is never less than the ITP Separation Minimum."

"The following ITP Speed/Distance Criteria, measured between the ITP Aircraft and the Reference Aircraft, can be used to support the proposed 10 NM ITP Separation Minimum (note that other initiation criteria or implementations, to include variable Closing Ground Speed Differential criteria based on ITP Distance, may be developed that satisfy the ITP Separation Minimum requirement):

- initiation ITP Distance of no less than 15 NM and a Closing Ground Speed Differential of no more than 20 kts; or
- initiation ITP Distance of no less than 20 NM and a Closing Ground Speed Differential of no more than 30 kts.

These initiation Distance Criteria values, 15 NM and 20 NM, were selected such that when a Flight Level change at 300 fpm is performed with the related 20 or 30 kts Closing Ground Speed Differential, the distance between the aircraft does not become less than the ITP Separation Minimum (i.e. 10 NM). With zero Ground Speed Differential or Ground Speed Differentials that result in increasing distance between the aircraft (i.e. negative Ground Speed Differentials) an initiation ITP Distance of 15 NM (or greater) is allowable.

Note: the Reference Aircraft is to be no more than:

- 3000 ft above or below the ITP Aircraft if the required vertical separation is 1000 ft; or
- 2000 ft above or below the ITP Aircraft if the required vertical separation is 2000 ft.

The ITP Aircraft must assess the ADS-B data from the Reference Aircraft and the ITP Aircraft must maintain (1) a minimum 300 fpm rate of climb or descent and (2) constant cruise Mach number throughout the ITP manoeuvre.

The ITP manoeuvre may be initiated from any distance at or beyond the minimum ITP Distance criteria. The minimum ITP Distance criteria are the same for climbs and descents and for both leading and following situations. These consistent criteria are valid because of the requirements to maintain the cruise Mach and to maintain a minimum 300 fpm rate of climb or descent during the ITP manoeuvre; the only variable in the ITP Speed/Distance Criteria is the Closing Ground Speed Differential which then determines the minimum ITP Distance."

"The considered ATSA – ITP procedure is comprised of four successive phases :

- Initiation;
- Instruction;
- Execution; and
- Termination.

Initiation phase

The flight crew is required to make an assessment of whether an ITP manoeuvre is appropriate using specific initiation criteria. If that assessment determines that an ITP manoeuvre is permissible, the flight crew then makes the appropriate request to ATC. Finally, if clearance is given, the flight crew must perform a reassessment of the requested manoeuvre immediately before execution in the event that clearance is granted.

Instruction phase

The Initiation Phase concludes with the flight crew making the ITP Request. The Instruction Phase includes the consideration of the request by the Controller, the provision of the clearance if the controller allows the ITP request, and, if clearance is provided, the reassessment by the flight crew that the ITP manoeuvre is still appropriate.

Execution phase

Whilst executing the manoeuvre the flight crew is expected to maintain their flight plan or otherwise assigned Mach number, monitor their vertical speed and ensure they execute only the manoeuvre they have been cleared to execute. The crew would be expected to follow regional contingency procedures in the event of not being able to safely continue an ITP manoeuvre.

Termination phase

The procedure terminates when the ITP Aircraft reports that it is established at the new Flight Level. If the ITP manoeuvre cannot be successfully completed once the climb or descent has been initiated, the flight crew must notify ATC and request an alternative clearance."

4.6.4.2 Requirements for the onboard avionics

It is assumed that the ATSA – ITP clearances will be exchanged by voice between the ATC and the flight crew, or through a classical flight level change CPDLC requ

The ATSA – ITP application requires the display of the ADS-B traffic, as allowed by the ATSA – AIRB application.

The requirements for the on-board avionics, will be, on top of the requirements for the ATSA – AIRB application :

- to assess the possibility for the own traffic to perform an ITP : check whether the distance, and ground speed difference criteria are met for the new intended flight level, with the surrounding traffic concerned by the flight level change
- to execute the ITP flight level change
- to monitor the execution of the ITP flight level change, to ensure that separation with the ITP traffic is maintained, to provide the flight crew with the appropriate monitoring information.

4.6.4.3 High-level functional break-down

The ATSA – ITP functional breakdown is the following one :

- receive ADS-B messages from the surrounding traffic
- manage the ADS-B traffic information together with the TCAS information
- display the ADS-B and TCAS traffic information to the flight crew
- allow the flight crew to select an ITP target flight level
- assess the ITP feasibility criteria, identify the concerned traffic
- execute the ITP flight level change
- monitor the execution of the ITP level change
- monitor and display to the flight crew the ATSA – ITP function status

4.6.4.4 Proposed Allocation for Avionics Reference Architectures

The following table presents the aircraft functions which will be impacted by the ATSA – ITP application :

	Impacted Functions				
	TC	Display - ND	TC - MCDU	Warning	FG
Receive ADS-B messages	X				
Manage ADS-B traffic information together with TCAS information	X				
Display ADS-B and TCAS traffic information to the flight crew	X	X	X		
Allow the flight crew to select an ITP target flight level			X		

Assess the ITP feasibility criteria, identify the concerned traffic	X		X		
Execute the ITP flight level change					X
Monitor the execution of the ITP level change	X	X	X		
Monitor and display the ATSA – ITP function status to the flight crew	X	X	X	X	

4.6.1 NextGen/SESAR concept description

4.6.2 Requirements for the onboard avionics

4.6.3 High-level functional break-down

4.6.4 Proposed Allocation for Avionics Reference Architectures

4.7 Traffic awareness

4.7.1 NextGen/SESAR concept description

4.7.2 Requirements for the onboard avionics

4.7.3 High-level functional break-down

4.7.4 Proposed Allocation for Avionics Reference Architectures

4.8 Enhanced Vision

4.8.1 NextGen/SESAR concept description

4.8.2 Requirements for the onboard avionics

4.8.3 High-level functional break-down

4.8.4 Proposed Allocation for Avionics Reference Architectures

4.9 Synthetic Vision

4.9.1 NextGen/SESAR concept description

4.9.2 Requirements for the onboard avionics

4.9.3 High-level functional break-down

4.9.4 Proposed Allocation for Avionics Reference Architectures

4.10 Airborne Information Management

4.10.1 NextGen/SESAR concept description

[NextGen: Onboard demand of airspace information and self-separation]

[SESAR component of the European ATM Enterprise Architecture?

New communication, navigation and surveillance technologies are being introduced providing better access to information and

enabling the position of every aircraft (including GA) and vehicle to be electronically visible to other users of the system…*from a ground infrastructure perspective, but what about onboard perspective*?]

4.10.2 Requirements for the onboard avionics

Information and Data, supply and Management becomes a huge task in the future for an efficient but also safe (and secure) operation of an Aircraft. In this context we again have to focus our attention on:

- Accuracy
- Availability
- Continuity
- Completeness and
- Integrity

In order to accomplish such enabling structure we need an information management system onboard the A/C.

Several proposals exist for an aeronautical data and information server. A clear definition for the acquisition, storage and interrogation of such information from the server does not exist today but should be the focus for the architectural definition of the future Avionics Infrastructure of a SESAR/NextGen compatible A/C. It is also desired this architectural definition support an implementation into existing aircraft.

Should be in Section 4 (Architecture) a server is only one way of doing IM

Data in the future must not exist as technical information in engineering units only. Every dataset in the future must be accompanied with qualifying metadata. Some examples are:

- Time validity (from - to)
- Accuracy and other qualifying parameters.
- Source
- Generation time etc…

As one example, a lat/long position dataset only makes sense for the use of a separation application if accompanied with the time of position and accuracy information of this position.

In the future we must make sure Information and data are collected in an onboard server from various sources onboard (i.e. aircraft position, heading, flight phase), dataloaded by the airline or service providers (i.e. navigation database, airport maps, manuals), or uplinked in real time from the ground (i.e. NOTAMS, Weather, Flight Plan, Taxi Route) . This data should be available for any application in the avionics infrastructure that would have some use or need for it.

This should terminate the legacy avionics situation that different avionics applications work with different data of the same kind leading to incompatibilities and malfunctions. As an example, an INU today uses a Variation Database from the year of production (in some cases refreshed but outdated anyway) and an FMS comes with an actual refreshed dataset for the same information. This incapability of data can lead to the wrong display of information in the cockpit. This error can only be accomplished if all data and information sources are connected to a single (redundant) server and the interfaces to the information are of a well-defined open standard format.

In today's world of information management, we must also deal with periodic updates of data and information (Nav data, AMDB information, textual information, etc) to the aircraft as regulated by the AIRAC cycles. Some of this data are on different cycles, and of course the desire is to move to real-time data updates. The onboard information management system would make this much easier to handle multiple AIRAC cycles in conjunction with real-time data updates, and then provide the currently applicable and correct information to the inquiring avionics system. The avionics systems would not need to worry about effectivity or cycles, as the information management software would handle this.

Today, and especially in the future, more and more data and information are being defined, causing larger databases and storage systems in the avionics systems. This is especially true in the desire to have higher detailed terrain, more precise navigation data, and putting all chart and text manuals into electronic format. This is already causing some FMS avionics to run out of memory, and thus require hardware updates at a large certification cost to the airlines. Having a single onboard database server means that there is only a single copy of the data and information instead of multiple copies in different avionics.

There are a number of advantages in having a centralized information management system in the NextGen and SESAR enabled avionics architecture that will benefit the aircraft manufacturer and airline operator. It provides a single load point for all data instead of loading onto multiple locations. It allows the data to be processed and assembled into usable information prior to being delivered to the avionics, thus reducing processing time required by the avionics. It provides data consistency, where it can ensure that the same data and information is used by all subscribing systems. Data integrity can be ensured on the data and information being loaded and delivered by a single system. There can be a single point of security. There are other advantages that will save the operator unneeded costs.

The definition of the acquisition mode and the definition of the access mode for the user systems need a good definition but is not subject to this architectural specification 660B.

But it appears clear that only formats can be selected that have already been used on the ground, but they will need to be modified or the content reduced to the subset of data and meta data that is required in the aircraft due to limitations in the avionics.

In today's new onboard avionics some systems are already using the XML format and some AEEC specification recently established give specific guidance to this. Also binary representations of XML are suggested.

In the context of System Architecture and SWIM a specific guidance for an XML version that would align with AIXM would be essential. Such guidance could be used for many entities of data transfer in the new to come architecture. Caution should be taken as XML as well as binary XML is large in size compared to other formats currently used for data and information storage and transport. This means we need a universal reduced version of XML for avionics use. This would be the charter of a different committee or WG.

Some work for an aviation style onboard XML variant is already provided by Arinc 834 ADBP Protocol

Too much explanation of SESAR/NexGen?

Provide a list of functions in 660B that would require or be a candidates for IM

Provide an architectural overview of IM in the 660 Build Blochs

Data Security Issues for the Airborn Domain getting information from the Information domain.

4.10.3 High-level functional break-down

- Data synchronization & updates
- Data security/integrity onboard and during transmission
- Data interfaces for onboard use (cockpit, cabin) and for maintenance
- Different data quality levels to support various function (e.g. FMS data versus Manuals)
- Authentication and authorization of systems & users reading/writing from/to the DB system
- Failover and Criticality considerations
- Storage reliability and overall system performance
- Data effectivity and data update cycles, data bandwidth
- Acquire Aeronautical Data
  - By manual input
  - By data loading
  - By wireless data link
  - By onboard sensor
- Manage aeronautical data
  - Maintenance of existing data
  - Secure Update
  - Removal of invalid data
  - Mirror data for redundancy on a second (or 3rd.) device
- Health monitoring
  - Provide a regular content report
  - Monitor

  - completeness
  - accuracy
  - integrity
  - availability
  - Backup
- Data supply
  - Provide Data to user Systems
  - Provide security to user systems (fire wall if not place in the user system)

4.10.4 Proposed Allocation for Avionics Reference Architectures

4.11 Metrological Data

4.11.1 NextGen/SESAR concept description

4.11.2 Requirements for the onboard avionics

4.11.3 High-level functional break-down

4.11.4 Proposed Allocation for Avionics Reference Architectures

4.12 NOTAMs

4.12.1 NextGen/SESAR concept description

4.12.2 Requirements for the onboard avionics

4.12.3 High-level functional break-down

4.12.4 Proposed Allocation for Avionics Reference Architectures

5.0 Synthesis of the evolutions required on the different Avionics Reference Architectures

	Aircraft Equipage																														
Operational Capability	**SATCOM**	**Ka/Ku SATCOM**	**HF Radio**	**VHF Radio**	**Wireless LAN**	**COMM Management**	**Server**	**IP Router**	**Head Down Displays**	**Head Up Displays**	**Crew Interface Function**	**EFB**	**Flight Management**	**Airport Navigation**	**Flight Guidance**	**GNSS Receiver**	**GBAS**	**SBAS**	**IRU / IRS**	**Air Data System**	**DME**	**ILS**	**LRA**	**Other Sensors (VOR / ADF, etc)**	**Traffic Computer**	**TCAS**	**Transponder**	**Class A TAWS**	**Weather Radar**	**EVS**	**SVS**
PBN																															
Trajectory Based Operations																															
Approach and Landing																															
Surface Ops																															
ATS Data Link																															
ADS-B Applications																															
Traffic Awareness																															

	Aircraft Equipage																														
Operational Capability	**SATCOM**	**Ka/Ku SATCOM**	**HF Radio**	**VHF Radio**	**Wireless LAN**	**COMM Management**	**Server**	**IP Router**	**Head Down Displays**	**Head Up Displays**	**Crew Interface Function**	**EFB**	**Flight Management**	**Airport Navigation**	**Flight Guidance**	**GNSS Receiver**	**GBAS**	**SBAS**	**IRU / IRS**	**Air Data System**	**DME**	**ILS**	**LRA**	**Other Sensors (VOR / ADF, etc)**	**Traffic Computer**	**TCAS**	**Transponder**	**Class A TAWS**	**Weather Radar**	**EVS**	**SVS**
EVS																															
SVS																															
Airborne Information Management																															