APPENDIX A

MODULE NO. B0-40: IMPROVED SAFETY AND EFFICIENCY THROUGH THE INITIAL APPLICATION OF DATA LINK EN-ROUTE

Summary	To implement an initial set of data link applications for surveillance and communications in ATC, supporting flexible routing, reduced separation and improved safety.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-10 – Safety	
Operating environment/ Phases of flight	En-route flight phases, including areas where radar systems cannot be installed such as remote or oceanic airspace.	
Applicability considerations	Requires good synchronization of airborne and ground deployment to generate significant benefits, in particular to those equipped. Benefits increase with the proportion of equipped aircraft.	
Global concept component(s) as per Doc 9854	ATM/SDM – ATM service delivery management	
Global plan initiatives (GPI)	GPI-9: Situational awareness GPI-17: Implementation of data link applications GPI-18: Electronic information services	
Main dependencies		
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	✓
	Avionics availability	✓
	Ground systems availability	✓
	Procedures available	✓
	Operations approvals	✓

1. NARRATIVE

1.1 General

1.1.1 Air-ground data exchanges have been the subject of decades of research and standardization work and are an essential ingredient of the future operational concepts since they can carry reliably richer information than what can be exchanged over radio. Many technologies exist and now have been implemented widely in aircraft, often motivated by aeronautical operational control (AOC) and airline administrative communications (AAC) reasons as well. In recent years, a number of applications have started to become a reality for ATM, but they have not been completely deployed. In addition, there are further ongoing efforts to ensure that the applications are interoperable to diverse aircraft fits, a task being addressed with priority by the Operational Data Link Panel (OPLINKP). This module covers what is available and can be used more widely now.

1.1.2 One element of the module is the transmission of aircraft position information, forming the automatic dependent surveillance contract (ADS-C), principally for use over oceanic and remote areas where radar cannot be deployed for physical or economical reasons.

1.1.3 A second element is controller pilot data link communications (CPDLC) comprising a first set of data link applications allowing pilots and controllers to exchange ATC messages concerning communications management, ATC clearances and stuck microphones. CPDLC reduces misunderstandings and controller workload giving increased safety and efficiency whilst providing extra capacity in the ATM system.

1.2 **Baseline**

1.2.1 Prior to this module, air-ground communications used voice radio (VHF or HF depending on the airspace), known for limitations in terms of quality, bandwidth and security. There are also wide portions of the globe with no radar surveillance. ATC instructions, position reports and other information have to be transmitted through HF radios where voice quality is especially bad most of the time, leading to significant workload to controllers and pilots (including HF radio operators), poor knowledge of the traffic situation outside radar coverage, large separation minima, and misunderstandings. In high density airspace controllers currently spend 50% of their time talking to pilots on the VHF voice channels where frequencies are a scarce resource; this also represents a significant workload for controllers and pilots and generates misunderstandings.

1.3 **Change brought by the module**

1.3.1 The module concerns the implementation of a first package of data link applications, covering ADS-C, CPDLC and other applications for ATC. These applications provide significant improvement in the way ATS is provided as described in the next section.

1.3.2 An important goal of the global ATM operational concept within the area of data link is to harmonize the regional implementations and to agree on a common technical and operational definition, applicable to all flight regions in the world. This is planned to be achieved through Block 1 changes. At the moment, data link implementations are based on different standards, technology and operational procedures, although there are many similarities.

1.4 **Element 1: ADS-C over Oceanic and remote areas**

1.4.1 ADS-C provides an automatic dependent surveillance service over oceanic and remote areas, through the exploitation of position messages sent automatically by aircraft over data link at specified time intervals. This improved situational awareness (in combination with appropriate PBN levels) is improving safety in general and allows reducing separations between aircraft and progressively moving away from pure procedural modes of control.

1.5 **Element 2: Continental CPDLC**

1.5.1 This application allows pilots and controllers to exchange messages with a better quality of transmission. In particular, it provides a way to alert the pilot when the microphone is stuck as well as a complementary means of communication. CPDLC is used as supplemental means of communications. Voice remains primary.

1.5.2 Over dense continental airspace, they can significantly reduce the communication load, allowing better task organization by the controller, in particular by not having to interrupt immediately to answer radio. They provide more reliability for the transmission and understanding of frequency changes, flight levels and flight information etc, thereby increasing safety and reducing the number of misunderstandings and repetitions.

2. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT

2.1 Element 1: ADS-C over Oceanic and remote areas

2.1.1 Metrics to determine the success of the module are proposed in the *Manual on Global Performance of the Air Navigation System* (Doc 9883).

Capacity	A better localization of traffic and reduced separations allow increasing the offered capacity.
Efficiency	Routes/tracks and flights can be separated by reduced minima, allowing to apply flexible routings and vertical profiles closer to the user-preferred ones.
Flexibility	ADS-C permits to make route changes easier
Safety	Increased situational awareness; ADS-C based safety nets like cleared level adherence monitoring, route adherence monitoring, danger area infringement warning; better support to search and rescue.
Cost Benefit Analysis	The business case has proven to be positive due to the benefits that flights can obtain in terms of better flight efficiency (better routes and vertical profiles; better and tactical resolution of conflicts). To be noted, the need to synchronize ground and airborne deployments to ensure that services are provided by the ground when aircraft are equipped, and that a minimum proportion of flights in the airspace under consideration are suitably equipped.

2.2 Element 2: Continental CPDLC

2.2.1 Metrics to determine the success of the module are proposed in the *Manual on Global Performance of the Air Navigation System* (Doc 9883).

Capacity	Reduced communication workload and better organization of controller tasks allowing to increase sector capacity
Safety	Increased situational awareness; reduced occurrences of misunderstandings; solution to stuck microphone situations
Cost Benefit Analysis	The European business case has proven to be positive due to: a) the benefits that flights can obtain in terms of better flight efficiency (better routes and vertical profiles; better and tactical resolution of conflicts); and b) reduced controller workload and increased capacity. A detailed business case has been produced in support of the EU regulation which was solidly positive. To be noted, there is a need to synchronize ground and airborne deployments to ensure that services are provided by the ground when aircraft are equipped, and that a minimum proportion of flights in the airspace under consideration are suitably equipped.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 Procedures have been described and are available in ICAO documents: *Manual of Air Traffic Services Data Link Applications* (Doc 9694) and the Global Operational Data Link Document (GOLD). Currently GOLD and LINK2000+ operational material is being merged, leading to an update of GOLD that allows global applicability, independent from airspace and technology.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 Standards for the enabling technology are available in ICAO documents and industry standards. Today, the existing data link implementations are based on two sets of ATS data link services: FANS 1/A and ATN B1, both will exist. FANS1/A is deployed in oceanic and remote regions whilst ATN B1 is being implemented in Europe according to European Commission legislation (EC Reg. No. 29/2009) – the data link services implementing rule.

4.1.2 These two packages are different from the operational, safety and performance standpoint and do not share the same technology but there are many similarities and can be accommodated together, thanks to the resolution of the operational and technical issues through workaround solutions, such as accommodation of FANS 1/A aircraft implementations by ATN B1 ground systems and dual stack (FANS 1/A and ATN B1) implementations in the aircraft.

4.2 Ground systems

4.2.1 For ground systems, the necessary technology includes the ability to manage ADS-C contract, process and display the ADS-C position messages. CPDLC messages need to be processed and displayed to the relevant ATC unit. Enhanced surveillance through multi-sensor data fusion facilitates transition to/from radar environment.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 ADS-C is a means to provide the air traffic controller with a direct representation of the traffic situation, and reduces the task of controllers or radio operators to collate position reports. In addition to providing another channel of communications, the data link applications allow in particular air traffic controllers to better organise their tactical tasks. Both pilots and controllers benefit from a reduced risk of misunderstanding of voice transmissions.

5.1.2 Data communications allow reducing the congestion of the voice channel with overall understanding benefits and more flexible management of air-ground exchanges. This implies an evolution in the dialogue between pilots and controllers which must be trained to use data link rather than radio. Automation support is needed for both the pilot and the controller. Overall, their respective responsibilities will not be affected.

5.1.3 Human factors have been taken into consideration during the development of the processes and procedures associated with this module. Where automation is to be used, the human-machine interface has been considered from both a functional and ergonomic perspective (See Section 6 for examples). The possibility of latent failures however, continues to exist and vigilance is requested during all implementation actions. It is further requested that human factor issues, identified during implementation, be reported to the international community through ICAO as part of any safety reporting initiative.

5.2 Training and qualification requirements

5.2.1 Automation support is needed for both the pilot and the controller which therefore will have to be trained to the new environment and to identify the aircraft/facilities which can accommodate the data link services in mixed mode environments**.**

5.2.2 Training in the operational standards and procedures are required for this module and can be found in the links to the documents in Section 8 to this module. Likewise, the qualifications requirements are identified in the regulatory requirements in Section 6 which form an integral part to the implementation of this module.

6. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

- Regulatory/standardization: use current published requirements that include the material given in Section 8.4. It should also be noted that new ICAO OPLINK OPS guidance material is under development.

- Approval plans: must be in accordance with application requirements.

- The GOLD ad hoc working group is working on an update of GOLD-Ed 1 in the framework of harmonization of procedures independent from airspace and technology.

7. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOW AT TIME OF WRITING)

7.1 Current use

Automatic dependent surveillance — contract (ADS-C)

- Remote & Oceanic areas: ADS-C is used primarily over remote and oceanic areas.

- ADS-C is already successfully used in a number of regions of the world, for example in the CAR/SAM Region (COCESNA, Brazil, etc) or in the South Pacific for FANS 1/A aircraft in combination with CPDLC messages. Also, in the NOPAC (North Pacific) route system it has allowed a reduction of separation minima.

- **Australia:** Australia has been operationally using CPDLC since the late 1990's and has provided ADS-C/CPDLC capability to all en-route controller positions since 1999. Integrated ADS-C and CPDLC based on FANS 1/A are used both in domestic en-route and oceanic airspace.

- **North Atlantic:** In March 2011, NAV CANADA and NATS implemented reduced longitudinal separation minima (RLongSM) of five minutes for properly equipped aircraft on tracks across the North Atlantic. Along with other procedural improvements, this will allow more aircraft to access optimal altitudes. The expected result is an estimated $1 million in customer fuel savings in the first year, along with 3 000 metric tons of emissions savings.

- **India:** ADS-C and CPDLC based on FANS 1/A has been in operation in Bay of Bengal and Arabian Sea Oceanic areas since 2005. India along with other South Asian countries have introduced 50 nm RLS (reduced longitudinal separation) in two RNAV ATS routes from July 2011 for aircraft with data link capability. The RLS were to be introduced in eight RNAV routes from December 2011. BOBASMA (Bay of Bengal Arabian Sea Safety Monitoring Agency) has been established in Chennai, India to support RLS operations and is endorsed by RASMAG/15.

- **Europe:** CPDLC data link services are being implemented, namely data link communications initiation capability (DLIC), ATC communications management service (ACM), ATC clearances and information service (ACL) and ATC microphone check service (AMC). To support them, the ATN B1 package is currently being deployed in 32 European flight information regions and upper flight information regions above FL285 (known as the LINK2000+ service deployment). European Commission legislation (EC Reg. No. 29/2009) – the data link services implementing rule - mandates implementation of a compliant solution, from:

  a) February 2013, in core European ground systems;

  b) February 2015, in the whole of Europe;

  c) January 2011, on newly produced aircraft intending to fly in Europe above FL285; and

  d) February 2015, retrofitted on all aircraft flying in Europe above FL285.

  Note.— Aircraft fitted with FANS 1/A prior to 2014 for oceanic operations are exempt from the regulation. In an effort to promote technical compatibility with the existing FANS 1/A+ fleet, a mixed interoperability document (ED154/DO305) was created that allows ATN B1 ground systems to provide ATS data link service to FANS 1/A+ aircraft. So far 7 out of 32 flight information regions and upper flight information regions have indicated they will accommodate FANS 1/A+ aircraft.

  Note.— Data link is operational at the Maastricht UAC since 2003. The PETAL II project extension finalised the validation of the ATN B1 applications by executing a pre-operational phase where aircraft equipped with certified avionics conducted daily operations with controllers in Maastricht upper airspace. The results were documented in the PETAL II final report and lead to the creation of the LINK 2000+ Programme to coordinate full scale European implementation.

  Note.— The decision of implementation is accompanied by an economic appraisal, business case and other guidance material available at the following address: http://www.EUROCONTROL.int/link2000/public/site_preferences/display_library_list_public.html#6.

- **United States**: Domestic Airspace: Beginning in 2014 departure clearance services will be deployed using FANS 1/A+. In 2017, en-route services will begin deployment to domestic en-route airspace.

7.2 Planned or ongoing trials

Automatic dependent surveillance — contract (ADS-C)

- **United States**: ADS-C In-trail climb procedure trial currently being conducted Expected operational use in 2016.

Controller-pilot data link communications (CPDLC)

- **United States:** Datacomm departure clearance service (DCL) trial will commence by 2014.

8. REFERENCE DOCUMENTS

8.1 Standards

- Commission Regulation (EC) No 29/2009 of 16 January 2009 laying down requirements on data link services for the single European sky.

- EUROCAE ED-100A/RTCA DO-258A, Interoperability Requirements for ATS Applications using ARINC 622 Data Communications.

- EUROCAE ED-110B/RTCA DO-280B, Interoperability Requirements Standard for Aeronautical Telecommunication Network Baseline 1 (Interop ATN B1).

- EUROCAE ED-120/RTCA DO-290, Safety and Performance Requirements Standard For Initial Air Traffic Data Link Services In Continental Airspace (SPR IC).

- EUROCAE ED-122/RTCA DO-306, Safety and Performance Standard for Air Traffic Data Link Services in Oceanic and Remote Airspace (Oceanic SPR Standard).

- EUROCAE ED-154A/RTCA DO-305A, Future Air Navigation System 1/A – Aeronautical Telecommunication Network Interoperability Standard (FANS 1/A – ATN B1 Interop Standard).

8.2 Guidance material

- ICAO Doc 9694, *Manual of Air Traffic Services Data Link Applications.*
- Global Operation Data Link Document (GOLD) Ed 2 (under development).

8.3 Approval documents

- ICAO Doc 9694, *Manual of Air Traffic Services Data Link Applications*.
- FAA AC20-140A, Guidelines for Design Approval of Aircraft Data Link Communication Systems Supporting Air Traffic Services (ATS).
- RTCA/EUROCAE DO-306/ED-122

- RTCA/EUROCAE DO-305A/ED-154A.
- RTCA/EUROCAE DO-290/ED-120.
- RTCA/EUROCAE DO-280B/ED-110B.
- RTCA/EUROCAE DO-258A/ED-100A.
- EC Regulation No. 29/2009: Data Link Services Implementing Rule.
- New OPLINK Material under development.

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APPENDIX B

MODULE NO. B1-40: IMPROVED TRAFFIC SYNCHRONIZATION AND INITIAL TRAJECTORY-BASED OPERATION

Summary	To improve the synchronization of traffic flows at en-route merging points and to optimize the approach sequence through the use of 4DTRAD capability and airport applications, e.g. D-TAXI.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-04 – Efficiency, KPA-05 – Environment, KPA-09 – Predictability, KPA-10 – Safety	
Operating environment/ Phases of flight	All flight phases	
Applicability considerations	Requires good synchronization of airborne and ground deployment to generate significant benefits, in particular to those equipped. Benefit increases with size of equipped aircraft population in the area where the services are provided.	
Global concept component(s) as per Doc 9854	CM – conflict management	
Global plan initiatives (GPI)	GPI-9: Situational awareness GPI-17: Implementation of data link applications GPI-18: Aeronautical Information	
Main dependencies	B0-40. Linkage with B1-25	
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	2013
	Avionics availability	Est. 2016
	Ground systems availability	Est. 2016
	Procedures available	Est. 2018
	Operations approvals	Est. 2018

1. NARRATIVE

1.1 General

1.1.1 This module is a step towards the goal to introduce trajectory-based operations that uses the capabilities of aircraft flight management systems to optimize aircraft flight trajectories in four dimensions. Trajectory-based operations will manage uncertainty by improving predictability for all ATM Stakeholders across all boundaries or ATM sector structures. In this context it will facilitate traffic synchronization and strategic conflict management supported by separation provision that minimizes tactical “radar type” intervention (e.g. open loop vectoring). It also introduces a number of airport applications that increase safety and reduce controller-pilot workload.

1.2 Baseline

1.2.1 Traffic synchronization is based on the flight data processing information fed by flight plan data with current positions updated by surveillance information and on mental extrapolation by controllers. This is not accurate and represents a workload for assessing the situation and monitoring its evolution. Actions are difficult to anticipate in upstream sectors which may not be aware of the problem to be solved.

1.2.2 The transmission of information at and around airports, including for complex routings is done through voice radio, implying a high workload for pilots and controllers, frequent misunderstandings and repetitions.

1.3 **Change brought by the module**

1.3.1 This module implements additional air-ground data link applications to: download trajectory information and improve the synchronization of traffic flows at merging points, in particular in view of optimizing an approach sequence, with negotiation of a required time of arrival using the flight management system (FMS) functionality. Existing ground-ground coordination capabilities will be improved to allow complex route clearances to be exchanged across multiple airspace boundaries.

1.3.2 The module will also implement data transmission for airport/TMA related information and clearances.

1.4 **Element 1: Initial 4D operations (4D TRAD)**

1.4.1 Supporting this is 4D TRAD, a recognized approach to initial trajectory-based operations which offers an advanced view of the future ATM environment including seamless integration of operational goals through an increased situational awareness and by the sharing of air ground data in a strategic and tactical collaborative decision making environment.

1.4.2 4D TRAD requires the availability of sophisticated air ground data exchange that include use of new ADS-C and data link functionality beyond current capabilities and performance requirements. Furthermore, ground-ground data exchange to exchange complex clearances need to be secure and widely available.

1.4.3 As a step transition to trajectory-based operations, the introduction of a common time reference with the use of aircraft FMS required time of arrival (RTA) and speed control with less demanding performance and technology requirements to that of 4DTRAD promises early predictability and efficiency benefits to airspace users and service providers.

1.4.4 Using the aircraft RTA for planning arrival flows from en-route (or oceanic) into terminal airspace is feasible using current aircraft capability with lower performance requirements than for example 4D TRAD. This would only focus on building traffic flows and sequences leaving more precise metering and separation provision to be achieved through current operations or with new RNAV performance-based navigation procedures.

1.4.5 Synchronizing the RTA and controlled time of arrival (CTA) with appropriate performance-based navigation (PBN) levels offers the opportunity to further develop stable and predictable traffic flows into a terminal area, letting the pilot optimize the flight profile (e.g. top of descent and descent profile).

1.4.6 Furthermore, predictable pre-planned traffic flows facilitate consistent application of continuous decent operations and tailored arrival procedures whilst terminal holding can be avoided through pre-planned path stretching undertaken by the aircraft using the RTA or speed control as well as integrating both long and short haul flights into arrival sequences.

1.4.7 The deployment of RNP/RNAV procedures and use of techniques such as “point merge” and others provide the opportunity to manage aircraft without recourse to radar vectoring intervention, leading to a closed loop FMS operation and an informed ground system supporting efficient aircraft profiles and predictable ATM operations.

1.4.8 To realize such benefits, communication between en-route and terminal control units is needed to coordinate the CTA constraint which may be achieved through existing mechanisms such as on-line data exchange with delivery to the aircraft via R/T or coordination with the airline operations centres to deliver to long haul aircraft by company data link.

1.4.9 A wider approach to the block will consider the combination with arrival management techniques using currently available ground based tools providing a more demanding performance facilitating refined metering of traffic into terminal airspace and existing CPDLC capability to deliver the CTA.

1.4.10 A first step which relies on existing systems and capabilities or requiring only minor modifications will make use of current FMS capability to define and output a RTA or speed control. Existing data link capabilities such as CPDLC, AOC, or even voice could be used to agree this RTA or speed control with the ground CTA. Most ground systems are incorporating trajectory prediction functionality and existing AMAN calculate the equivalent of a CTA. Ground-ground communications infrastructure will enable the exchange of flight plan and can be updated to exchange CTA.

1.4.11 Beyond this first step more significant changes are anticipated to enable 4DTRAD and trajectory-based operations with advanced, and standardized FMS functionality able to provide more accurate and complete trajectory information which could be down linked with new ADS-C or CPDLC protocols. Depending on the definition of this trajectory information for download new data link technology may be required in the long term. The ground-ground communication infrastructure, in the context of SWIM will enable this trajectory information to be made available to the various en-route, terminal and airport systems which can use the common trajectory reference. System modifications to make full use of this trajectory information must also be planned.

1.4.12 Initial 4D operations can be broken down in to two steps; the first is the synchronization between air and ground of the flight plan or reference business trajectory. The second step is imposing a time constraint and allowing the aircraft to fly its profile in the most optimal way to meet that constraint.

2. TRAJECTORY SYNCHRONIZATION AND MONITORING

2.1.1 The ATM system relies on all actors having the same view; it is therefore essential that the trajectory in the flight management system (FMS) is synchronized with that held on the ground in the flight data processing systems (FDPS) and the wider network systems.

2.1.2 The crew and the ATC agree on the trajectory to be flown and during the entire execution, they continuously check if it is, and will be, followed by the aircraft. In case of non-conformance warning are raised and a new interaction between the crew and the responsible ATC occurs.

2.1.3 The early air/ground agreement on the trajectory to be flown and its execution allow the FMS to optimize the trajectory providing efficiency benefits to the user in terms of aircraft flight profile optimization and ensuring maximum environmental benefits, both through reduced fuel burn and optimum routings en-route, in the terminal area and in the vicinity of the airport avoiding noise sensitive areas.

2.1.4 Improved consistency between air and ground trajectory ensures that controllers have highly reliable information on aircraft behaviour. This more accurate trajectory prediction enables better performance from the decision support tools providing a better anticipation of congestion by allowing early detection of traffic bunching providing better adaptation to the real traffic situation and reduced inefficient radar based tactical intervention.

2.1.5 The increased levels of predictability mean that potential conflicts within a medium-term time horizon will be identified and resolved early while the increased accuracy of ground computed trajectory, especially for short term prediction, reduces the risk of unexpected events.

3. REQUIRED TIME OF ARRIVAL

3.1 The avionics function, required time of arrival (RTA), can be exploited by both en-route and TMA controllers for demand/capacity balancing, metering of flows and sequencing for arrival management.

3.2 By preparing the metering of aircraft at an earlier stage of their flight the impact of the constraint is minimized. This allows ATC to make optimum use of capacity at the right time, minimizing risks through complexity reduction to ensure that human capabilities are not exceeded. This also supports optimized aircraft profile management by the pilot.

3.3 Reduction of inefficient ATC tactical interventions through early planning of traffic en-route and in to the arrival management phase avoids severe and costly sequencing measures. This process enhances aircraft profile optimization, flight predictability and allows improvements in the stability and reliability of the sequence built by ATC.

3.4 It should lead to reduced need for aircraft to hold, inefficiently burning fuel with the associated chemical and noise pollution. Aircraft will be able to plan better and adhere more accurately to arrival schedules leading to better planning for the airlines due to increased flight predictability.

3.5 Element 2: Data link operational terminal information service (D-OTIS)

3.5.1 Before flight departure, the flight crew may request meteorological and operational flight information and NOTAMs of the departure and destination aerodrome using a single data link service, the data link-operational terminal information service (D-OTIS).

3.5.2 At any time during the flight, the pilot may receive automatic updates of the meteorological data, operational information and NOTAMS of the destination or alternate aerodromes. D-OTIS may be tailored for the specific flight crew needs and so the pilot can readily form a picture from meteorological and operational perspectives.

3.6 Element 3: Departure clearance (DCL)

3.6.1 The implementation of DCL eliminates potential misunderstandings due to VHF voice, hence enabling the ATC to provide a safer and more efficient service to their users. DCL also enables to reduce controllers' workload. DCL supports the airport system automation and information sharing with other ground systems.

3.6.2 For busy airports, the use of DCL data link results in a significant decrease in ATC tower frequency congestion. CPDLC systems that are integrated with FMS allow direct input of more complex clearances into the FMS.

3.7 Element 4: Data link TAXI (DTAXI)

3.7.1 This provides automated assistance and additional means of communication to controllers and pilots when performing routine communication exchanges during ground movement operations, start-up, pushback, routine taxi messages and special airport operations.

4. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT

4.1 Metrics to determine the success of the module are proposed in the *Manual on Global Performance of the Air Navigation System* (Doc 9883).

Capacity	Positively affected because of the reduction of workload associated to the establishment of the sequence close to the convergence point and related tactical interventions. Positively affected because of the reduction of workload associated to the delivery of departure and taxi clearances.
Efficiency	Increased by using the aircraft RTA capability for traffic synchronization planning through en-route and into terminal airspace. "Closed loop" operations on RNAV procedures ensure common air and ground system awareness of traffic evolution and facilitate its optimization. Flight efficiency is increased through proactive planning of top of descent, descent profile and en-route delay actions, and enhanced terminal airspace route efficiency.
Environment	More economic and environmentally friendly trajectories, in particular absorption of some delays.
Predictability	Increased predictability of the ATM system for all stakeholders through greater strategic management of traffic flow between and within FIRs en-route and terminal airspace using the aircraft RTA capability or speed control to manage a ground CTA; Predictable and repeatable sequencing and metering. "Closed loop" operations on RNAV procedures ensuring common air and ground system awareness of traffic evolution.
Safety	Safety at/around airports by a reduction of the misinterpretations and errors in the interpretation of the complex departure and taxi clearances.
Cost Benefit Analysis	Establishment of the business case is underway. The benefits of the proposed airport services were already demonstrated in the EUROCONTROL CASCADE Programme.

5. NECESSARY PROCEDURES (AIR AND GROUND)

5.1 New procedures have to be defined for the controller and pilot using extended phraseology and data link messages.

6. NECESSARY SYSTEM CAPABILITY

6.1 Avionics

The necessary technology is defined in the EUROCAE WG78/RTCA SC 214 standards and comprises airborne implementations of advanced data link services (4DTRAD, D-Taxi, D-OTIS) supported by CPDLC and ADS-C over ATN B2, and integrated with FMS.

6.2 Ground systems

6.2.1 For ground systems, the necessary functionalities include the ability to negotiate a time constraint over a given metering fix as well as to process the aircraft trajectory. Enhanced ground-ground data interchange, when available, will allow sharing the common trajectory reference. It also includes the ability to facilitate the provision of start-up, push-back and taxi clearances via data link. Enhanced surveillance through multi-sensor data fusion is required.

7. HUMAN PERFORMANCE

7.1 Human factors considerations

7.1.1 Data communications reduce the workload and the risk to misinterpret information in clearances, in particular when typing them in FMS. They allow reducing the congestion of the voice channel with overall understanding benefits and more flexible management of air-ground exchanges.

7.1.2 Automation support is needed for both the pilot and the controller. Overall their respective responsibilities will not be affected.

7.1.3 The identification of human factors considerations is an important enabler in identifying processes and procedures for this module. In particular, the human-machine interface for the automation aspects of this performance improvement will need to be considered and where necessary accompanied by mitigation risk mitigation strategies such as training, education and redundancy**.**

7.2 Training and qualification requirements

7.2.1 Automation support is needed for both the pilot and the controller which therefore will have to be trained to the new environment and to identify the aircraft/facilities which can accommodate the data link services in mixed mode environments.

7.2.2 Training in the operational standards and procedures will be identified along with the standards and recommended practices necessary for this module to be implemented. Likewise the qualifications requirements will be identified and included in the regulatory readiness aspects of this module when they become available**.**

8. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

- Regulatory/standardization: new or updated requirements for data link messages, ground services, operational procedures, etc are needed that includes:

  a) ICAO Doc 9694, *Manual of Air Traffic Services Data Link Applications*;

  b) RTCA/EUROCAE DO-XXX/ED-XXX, SC214/WG78 SPR, including Enhanced CPDLC Message Set and ADS-C enhancements;

  c) EC Regulation No. XX/XXXX: Data Link Services Implementing Rule; and

  d) Update of GOLD Ed 2 to GOLD Ed 3.

- Approval plans: publication of the EUROCAE WG78/RTCA SC 214 standards plus air and ground certification and approvals to be determined..

9. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

9.1 Current use

- **Europe -** Capability used ad hoc for tailored arrivals with RTA as well as arrival planning for Oceanic arrivals plus wide scale trials of point merge techniques now focused on deployment in European terminal airspace and approach areas with available OSED SPR material.

- **United States**: Domestic Airspace: Beginning in 2016 departure clearance services will be deployed using FANS-1/A+.

- **United States:** Oceanic tailored arrivals is currently operational in the US coastal aerodromes.

9.2 Reference documents

9.3 Standards

- EUROCONTROL, Point merge: Point merge integration of arrival flows enabling extensive RNAV application and continuous descent. Operational services and environment definition, July 2010

- EUROCAE ED-100A/RTCA DO-258A, Interoperability requirements for ATS applications using ARINC 622 data communications

- EUROCAE ED-122/RTCA DO-306, Safety and performance standard for air traffic data link services in Oceanic and remote airspace (Oceanic SPR Standard)

- EUROCAE ED-154/RTCA DO-305, Future Air Navigation System 1/A – Aeronautical telecommunication network interoperability standard (FANS 1/A – ATN B1 Interop Standard)

- EUROCAE WG-78/RTCA SC-214 Safety and performance requirements and interoperability requirements.

9.4 **Procedures**

9.5 **Guidance material**

- ICAO Doc 9694, *Manual of Air Traffic Services Data Link Applications*
- GOLD Ed 2 (under development)
- EUROCONTROL, 4DTRAD: Initial 4D – 4D Trajectory Data Link (4DTRAD) Concept of Operations, December 2008

9.6 **Approval documents**

- ICAO Doc 9694, *Manual of Air Traffic Services Data Link Applications*
- RTCA/EUROCAE DO-XXX/ED-XXX (TBD), SC214/WG78 enhanced CPDLC message set and ADS-C enhancements
- EC Regulation No. 29/2009: Data link services implementing rule

Note.– GOLD Edition 2 under development.

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APPENDIX C

MODULE NO. B3-05: FULL 4D TRAJECTORY-BASED OPERATIONS

Summary	The development of advanced concepts and technologies, supporting four dimensional trajectories (latitude, longitude, altitude, time) and velocity to enhance global ATM decision making. A key emphasis is on integrating all flight information to obtain the most accurate trajectory model for ground automation.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-04 – Efficiency, KPA-05 – Environment, KPA-10 – Safety.	
Operating environment/ Phases of flight	En-route/cruise, terminal area, traffic flow management, descent	
Applicability considerations	Applicable to air traffic flow planning, en-route operations, terminal operations (approach/departure), and arrival operations. Benefits accrue to both flows and individual aircraft. Aircraft equipage is assumed in the areas of: ADS-B IN/CDTI; data communication and advanced navigation capabilities. Requires good synchronization of airborne and ground deployment to generate significant benefits, in particular to those equipped. Benefit increases with size of equipped aircraft population in the area where the services are provided.	
Global concept component(s) as per Doc 9854	AOM – airspace organization and management DCB – demand and capacity balancing AUO – airspace user operations TS – traffic synchronization CM – conflict management	
Global plan initiatives (GPI)	GPI-5: RNAV/RNP (performance-based navigation) GPI-11: RNP and RNAV SIDs and STARs GPI-16: Decision support systems and alerting systems	
Main dependencies	B1-40, B2-31, B2-05,	
Global readiness checklist		Status (indicate ready with a tick or input date)
	Standards readiness	2025
	Avionics availability	2028
	Ground systems availability	2028
	Procedures available	2028
	Operations approvals	2028

1. NARRATIVE

1.1 General

1.1.1 This module implements 4D trajectory-based operations that use the capabilities of aircraft flight management systems to optimize aircraft flight trajectories in four dimensions plus velocity. Full TBO integrates advanced capabilities that will provide vastly improved surveillance, navigation, data communications, and automation for ground and airborne systems with changes in service provider roles and responsibilities.

1.2 Baseline

1.2.1 This module deploys an accurate four-dimensional trajectory with velocity that is shared among all of the aviation system users at the cores of the system. This provides consistent and up-to-date information system wide which is integrated into decision support tools facilitating global ATM decision-making. It continues the evolution in procedures and automation capabilities, both ground-based and aircraft-based, for using accurate trajectories to benefit the system. Optimized arrivals in dense airspace were previously enabled. Decision support capabilities are available that are integrated to assist ANSPs and users to make better decisions in arrival profile optimization. A consistent, integrated information base is available to all ANSPs and users to inform ATM decision-making.

1.2.2 With 4D trajectory operations, Block 3 will see the achievement of capabilities which optimize the individual trajectories, the traffic flows and the use of scarce resources such as runways and surface. This module is focused on the core 4D capabilities plus velocity, while modules B3-15 and B3-10 focus on the optimization of specific situations (high density/complexity).

1.3 Change brought by the module

1.3.1 In future en route airspace, mixed levels of aircraft performance and air crew authorizations are expected. High-performance aircraft will be capable of flying RNAV routes, accurately conforming to their route of flight, supporting data communications, communicating requests and aircraft state and intent information digitally with the air traffic control (ATC) automation, and receiving clearances and other messages digitally from the ATC automation.

1.3.2 Some en-route airspace will be designated for high-performance aircraft only, allowing the ATC system to engage operations that fully leverage the capabilities of those aircraft. Aircraft will communicate state and intent information to the ATC automation and closely follow their intended routes of flight. As a result, the automated problem prediction and resolution capabilities will be able to maximize user benefits by supporting user-preferred flight plans, minimizing changes to those plans as aircraft traverse the airspace, and improving services provided.

1.3.3 The controller's primary responsibilities will be to respond to problems predicted by the ATC automation, and to maintain accurate flight information in the ATC automation. Predicted problems will include:

a) aircraft to aircraft conflicts;

b) aircraft to special use or other types of restricted airspaces;

c) aircraft to hazardous meteorological conditions forecast areas;

d) aircraft to metering constraint problems including miles in trail restrictions;

e) the aircraft's capability to accurately fly its cleared route of flight, coupled with the state and intent information sent from the aircraft to the ATC automation, will increase the accuracy of trajectory modelling and problem prediction. Key aspects of full TBO are:

   1) the basis for all operations is an accurate four-dimensional trajectory that is shared among all of the aviation system users;

   2) consistent and up-to-date information describing flights and air traffic flows are available system-wide, supporting both user and service provider operations;

   3) data communication is used between the ground and aircraft to improve the accuracy of trajectories, request changes in 4D plus velocity trajectory, provide precise clearances to the flight, and exchange information without controller involvement;

f) area navigation (RNAV) operations remove the requirement for routes to be defined by the location of navigational aids, enabling the flexibility of point-to-point aircraft operations;

g) required navigation performance (RNP) operations introduce the requirement for onboard performance monitoring and alerting. A critical characteristic of RNP operations is the ability of the aircraft navigation system to monitor its achieved navigation performance for a specific operation, and inform the air crew if the operational requirement is being met;

h) en route controllers rely on automation to identify conflicts and propose resolutions allowing them to focus on providing improved services to the users;

i) the ability of cockpit automation to fly the aircraft more precisely and predictably reduces routine tasks of controllers;

j) performance-based services that require minimum flight performance levels are provided in designated airspace;

k) flow management automation will propose incremental congestion resolutions that will maintain congestion risk at an acceptable level, using flight-specific alternative intent options to the extent possible. Flight operation centres (FOC) will dynamically re-calculate and furnish the flight crew and flow management updated intent options and priority of the options as conditions change; and

l) time-based flow management that coordinates arrival flows for high traffic airports.

1.4 Element 1: Advanced aircraft capabilities

1.4.1 This element focuses on aircraft-based capabilities that assist pilots with weather and other aircraft avoidance, and thus enhance safety. Examples of such capabilities are ADS-B IN, air-to-air information exchange, and integration of weather into cockpit-based automation tools. This element also focuses on globally-harmonized standards development for trajectory data exchange between the ground and aircraft avionics systems such as the FMS.

1.5 **Element 2: Problem detection and resolution**

1.5.1 This element will continue the evolution to the use of ATM decision support tools, by ANSPs and users, which provide manoeuvres for flying the most economical descent profiles. Based on experiences gained from development and deployment of initial capabilities, extensions will be developed to generate more efficient and operationally acceptable arrival profile solutions. This element will also explore direct automation-to-automation negotiation capabilities to streamline the development of mutually acceptable ATM solutions. This element will also focus on getting the most accurate trajectory model in the system for use by all automation functions. This entails putting every clearance given to the aircraft into the automation, using automation generated resolutions to make it easier for the controllers to enter the clearance, and receiving flight specific data from the aircraft to include in the trajectory calculation and any resolution options.

1.6 **Element 3: Traffic flow management and time-based metering**

1.6.1 This element will harmonize the traffic flow management automation which continuously predicts the demand and capacity of all system resources, and will identify when the congestion risk for any resource (airport or airspace) is predicted to exceed an acceptable risk. Information from FOCs or flight crews indicates intent options and preferences, so that user reactions and adjustments to the 4DT to address constraints such as weather are accounted before the ANSP would take action. Traffic management will take action in the form of just in time reroutes and metering times to congested resources. The problem resolution element will create a manoeuvre that meets all system constraints.

2. **INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT**

2.1 Metrics to determine the success of the module are proposed in the *Manual on Global Performance of the Air Navigation System* (Doc 9883).

Capacity	Additional flights can be accommodated because of reduced controller workload. Less conservative decisions about permitting aircraft to utilize the airspace results in more aircraft being able to traverse the affected area. Similarly, terminal arrival/departure capacity will be enhanced by improved ability to plan for flows in and out of the airport.
Efficiency	Harmonized avionics standards. Users will be better able to plan and receive their preferred trajectory.
Environment	Cost savings and environmental benefits through reduced fuel burn.
Safety	a) increased flight crew situational awareness; b) reduction of conflicts between aircraft and more lead time in resolving those conflicts that exist; and c) number of incident occurrences.
Cost Benefit Analysis	The business case is still to be determined as part of the development of this module, which is in the research phase. Current experience with utilization of enhanced meteorological information to improve ATM decision making by stakeholders has proven to be positive due to the benefits of more efficient flight planning and less disruption to user-preferred trajectories.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 The use of ADS-B/CDTI and other cockpit capabilities to support aircraft avoidance is still a research topic and will necessitate procedures development, including the roles of ANSPs.

3.2 For strategic actions, the necessary procedures basically exist for ANSPs and users to collaborate on flight path decisions. Extensions to those procedures will need to be developed to reflect the use of increased decision support automation capabilities, including automation-to-automation negotiation.

3.3 For strategic actions, the necessary procedures basically exist for ANSPs and users to collaborate on flight path decisions. Extensions to those procedures will need to be developed to reflect the use of increased decision support automation capabilities, including automation-to-automation negotiation.

4. NECESSARY SYSTEM CAPABILITY (AIR AND GROUND)

4.1 Avionics

4.1.1 For this longer-term element, the needed technology is still in development. Aircraft-based capabilities, such as RTA exist, but applications are still being developed to support their extension (e.g. multiple RTA).

4.2 Ground systems

4.2.1 For the longer-term element, the needed technology is still in development. For ground-based technology, research is on-going into decision support tools that produce fuel efficient resolutions, and support the automated development of candidate mitigation strategies. Work is also needed to incorporate data from aircraft systems into ground trajectory models to ensure the most accurate trajectory.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 This module is still in the research and development phase so the human factors considerations are still in the process of being identified through modelling and beta testing. Future iterations of this document will become more specific about the processes and procedures necessary to take the human factors considerations into account. There will be a particular emphasis on identifying the human-machine interface issue if there are any and providing the high risk mitigation strategies to account for them.

5.2 Training and qualification requirements

5.2.1 This module will eventually contain and number of personnel training requirements. As and when they are developed, they will be included in the documentation supporting this module and their importance signified. Likewise, any qualifications requirements that are recommended will become part of the regulatory needs prior to implementation of this performance improvement**.**

6. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

- Regulatory/standardization: updates as required for enhanced information exchange ground-ground and air-to-air in:
  - ICAO Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management*
  - ICAO Doc xxxx, PANS-AIM (expected publication 2016)
  - FAA AC TBD, EASA AMD TBD
- Approval plans: to be determined.

6.1 Element 1: Advance aircraft capabilities

6.1.1 International standards for information exchange between systems to support these operations need to be developed. This includes development of global standards for the exchange of trajectory information between ground and air.

6.1.2 International standards for information exchange between systems to support these operations need to be developed. This includes development of global standards for the exchange of trajectory information between ground and air. Included in this is development of global standards for trajectory information exchange and certification decision on aircraft-based display and dissemination. Dissemination includes air-to-ground as well as air-to-air exchange of those observations via ADS-B

7. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

7.1 Current use

7.1.1 Since this module is in the category of long term issues, there are no examples of current operational use. Numerous entities are conducting research on ADS-B In applications that relate to aircraft avoidance via cockpit functionality. Such research efforts will help to inform the work to be done under this block.

7.2 Planned or ongoing trials

7.2.1 Element 1: Advance aircraft capabilities

7.2.2 No global demonstration trials are currently planned for this module. There is a need to develop such a plan as part of the collaboration on this module.

7.3 Reference documents

- ICAO Annex 10 — *Aeronautical Telecommunications,* Volume II — Communication Procedures including those with PANS Status; ICAO Doc 4444*, Procedures for Air Navigation Ser*vices — *Air Traffic Management*
- ICAO Doc 9694, *Manual of Air Traffic Services Data Link Applications*

- NextGen and SESAR Operational Concepts

- EUROCAE ED-100A/RTCA DO-258A, Interoperability Requirements for ATS Applications using ARINC 622 Data Communications

- EUROCAE ED-110/RTCA DO-280, Interoperability Requirements Standard for Aeronautical Telecommunication Network Baseline 1 (Interop ATN B1)

- EUROCAE ED-120/RTCA DO-290, Safety and Performance Requirements Standard For Initial Air Traffic Data Link Services In Continental Airspace (SPR IC)

- EUROCAE ED-122/RTCA DO-306, Safety and Performance Standard for Air Traffic Data Link Services in Oceanic and Remote Airspace (Oceanic SPR Standard)

- EUROCAE ED-154/RTCA DO-305, Future Air Navigation System 1/A – Aeronautical Telecommunication Network Interoperability Standard (FANS 1/A – ATN B1 Interop Standard);

- EUROCAE WG78/RTCA SC214 Safety and Performance requirements and Interoperability requirements.

7.4 **Approval documents**

- ICAO Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management*; (update required)
- ICAO Doc xxxx, PANS-AIM (expected publication 2016)
- FAA AC TBD, EASA AMD TBD

— END —