APPENDIX A

MODULE N° B0-10: IMPROVED OPERATIONS THROUGH ENHANCED EN-ROUTE TRAJECTORIES

<table>
<tr><td rowspan="1">Summary</td><td colspan="2">To allow the use of airspace which would otherwise be segregated (i.e. special use airspace) along with flexible routing adjusted for specific traffic patterns. This will allow greater routing possibilities, reducing potential congestion on trunk routes and busy crossing points, resulting in reduced flight length and fuel burn.</td></tr>
<tr><td>Main performance impact as per Doc 9854</td><td colspan="2">KPA-01 – Access & Equity, KPA-02 – Capacity, KPA-04 – Efficiency, KPA-05 – Environment, KPA-06 – Flexibility, KPA-09 – Predictability.</td></tr>
<tr><td>Operating environment/ Phases of flight</td><td colspan="2">En-route, TMA</td></tr>
<tr><td>Applicability considerations</td><td colspan="2">Applicable to en-route and terminal airspace. Benefits can start locally. The larger the size of the concerned airspace the greater the benefits, in particular for flex track aspects. Benefits accrue to individual flights and flows.

Application will naturally span over a long period as traffic develops. Its features can be introduced starting with the simplest ones.</td></tr>
<tr><td>Global concept component(s) as per Doc 9854</td><td colspan="2">AOM – airspace organization and management
AUO – airspace users operations
DCB – demand and capacity balancing</td></tr>
<tr><td>Global plan initiatives (GPI)</td><td colspan="2">GPI-1: Flexible use of airspace
GPI-4: Align upper airspace classifications
GPI-7: Dynamic and flexible airspace route management
GPI-8: Collaborative airspace design and management</td></tr>
<tr><td>Main dependencies</td><td colspan="2">NIL</td></tr>
<tr><td rowspan="6">Global readiness checklist</td><td></td><td>Status (ready now or estimated date)</td></tr>
<tr><td>Standards readiness</td><td>✓</td></tr>
<tr><td>Avionics availability</td><td>✓</td></tr>
<tr><td>Ground systems availability</td><td>✓</td></tr>
<tr><td>Procedures available</td><td>✓</td></tr>
<tr><td>Operations approvals</td><td>✓</td></tr>
</table>

1. NARRATIVE

1.1 General

1.1.1 In many areas, flight routings offered by air traffic services (ATS) are static and are slow to keep pace with the rapid changes of users operational demands, especially for long-haul city-pairs. In certain parts of the world, legacy regional route structures have become outdated and are becoming constraining factors due to their inflexibility.

1.1.2 The navigational capabilities of modern aircraft make a compelling argument to migrate away from the fixed route structure towards a more flexible alternative. Constantly changing upper winds have a direct influence on fuel burn and, proportionately, on the carbon footprint. Therein lies the benefit of daily flexible routings. Sophisticated flight planning systems in use at airlines now have the capability to predict and validate optimum daily routings. Likewise, ground systems used by ATS have significantly improved their communication, surveillance and flight data management capabilities.

1.1.3 Using what is already available on the aircraft and within air traffic control (ATC) ground systems, the move from fixed to flex routes can be accomplished in a progressive, orderly and efficient manner.

1.2 Baseline

1.2.1 The baseline for this module is varying from a State/region to the next. However, while some aspects have already been the subject of local improvements, the baseline generally corresponds to an airspace organisation and management function which is at least in part characterized by: individual State action, fixed route network, permanently segregated areas, conventional navigation or limited use of area navigation (RNAV), rigid allocation of airspace between civil and military authorities. Where it is the case, the integration of civil and military ATS has been a way to eliminate some of the issues, but not all.

1.3 Change brought by the module

1.3.1 This module is aimed at improving the profiles of flights in the en-route phase through the deployment and full application of procedures and functionalities on which solid experience is already available, but which have not been systematically exploited and which are of a nature to make better use of the airspace.

1.3.2 The module is the opportunity to exploit performance-based navigation (PBN) capabilities in order to eliminate design constraints and operate more flexibly, while facilitating the overall handling of traffic flows.

1.3.3 The module is made of the following elements:

a) airspace planning: possibility to plan, coordinate and inform on the use of airspace. This includes collaborative decision-making (CDM) applications for en-route airspace to anticipate on the knowledge of the airspace use requests, take into account preferences and inform on constraints;

b) flexible use of airspace (FUA) to allow both the use of airspace otherwise segregated, and the reservation of suitable volumes for special usage; this includes the definition of conditional routes; and

c) flexible routing (flex tracking): route configurations designed for specific traffic pattern.

1.3.4 This module is a first step towards more optimized organisation and management of the airspace but which would require more sophisticated assistance. Initial implementation of PBN, RNAV for example, takes advantage of existing ground technology and avionics and allows extended collaboration of air navigation service providers (ANSPs) with partners: military, airspace users, neighbouring States.

1.4 Element 1: Airspace planning

1.4.1 Airspace planning entails activities to organize and manage airspace prior to the time of flight. Here it more specifically refers to activities to improve the strategic design by a series of measures to better know the anticipated use of the airspace and adjust the strategic design by pre-tactical or tactical actions.

1.5 Element 2: Flexible use of airspace (FUA)

1.5.1 Flexible use of airspace is an airspace management concept according to which airspace should not be designated as either purely civil or purely military airspace, but should be considered as one continuum in which all users' requirements have to be accommodated to the maximum extent possible. There are activities which require the reservation of a volume of airspace for their exclusive or specific use for determined periods, owing to the characteristics of their flight profile or their hazardous attributes and the need to ensure effective and safe separation from non participating air traffic. Effective and harmonized application of FUA needs clear and consistent rules for civil/military coordination which should take into account all users' requirements and the nature of their various activities. Efficient civil/military coordination procedures should rely on rules and standards to ensure efficient use of airspace by all users. It is essential to further cooperation between neighbouring States and to take into account cross border operations when applying the concept of FUA.

1.5.2 Where various aviation activities occur in the same airspace but meet different requirements, their coordination should seek both the safe conduct of flights and the optimum use of available airspace.

1.5.3 Accuracy of information on airspace status and on specific air traffic situations and timely distribution of this information to civil and military controllers has a direct impact on the safety and efficiency of operations.

1.5.4 Timely access to up-to-date information on airspace status is essential for all parties wishing to take advantage of airspace structures made available when filing or re-filing their flight plans.

1.5.5 The regular assessment of airspace use is an important way of increasing confidence between civil and military service providers and users and is an essential tool for improving airspace design and airspace management.

1.5.6 FUA should be governed by the following principles:

a) coordination between civil and military authorities should be organized at the strategic, pre-tactical and tactical levels of airspace management through the establishment of agreements and procedures in order to increase safety and airspace capacity, and to improve the efficiency and flexibility of aircraft operations;

b) consistency between airspace management, air traffic flow management and air traffic services should be established and maintained at the three levels of airspace management in order to ensure, for the benefit of all users, efficiency in airspace planning, allocation and use;

c) the airspace reservation for exclusive or specific use of categories of users should be of a temporary nature, applied only during limited periods of time-based on actual use and released as soon as the activity having caused its establishment ceases;

d) States should develop cooperation for the efficient and consistent application of the concept of FUA across national borders and/or the boundaries of flight information regions, and should in particular address cross-border activities; this cooperation shall cover all relevant legal, operational and technical issues; and

e) ATS units and users should make the best use of the available airspace.

1.6 Element 3: Flexible routing

1.6.1 Flexible routing is a design of routes (or tracks) designed to match the traffic pattern and other variable factors such as meteorological conditions. The concept, used over the North-Atlantic since decades can be expanded to address seasonal or week end flows, accommodate special events, and in general better fit the meteorological conditions, by offering a set of routes which provide routings closer to the user preferences for the traffic flows under consideration.

1.6.2 When already in place, flex tracks systems can be improved in line with the new capabilities of ATM and aircraft, such as PBN and automatic dependent surveillance (ADS).

1.6.3 A current application of the element is the dynamic air route planning system (DARPS), used in the Pacific Region with flexible tracks and reduced horizontal separation to 30 NM using RNP 4 and ADS and controller pilot data link communications (CPDLC).

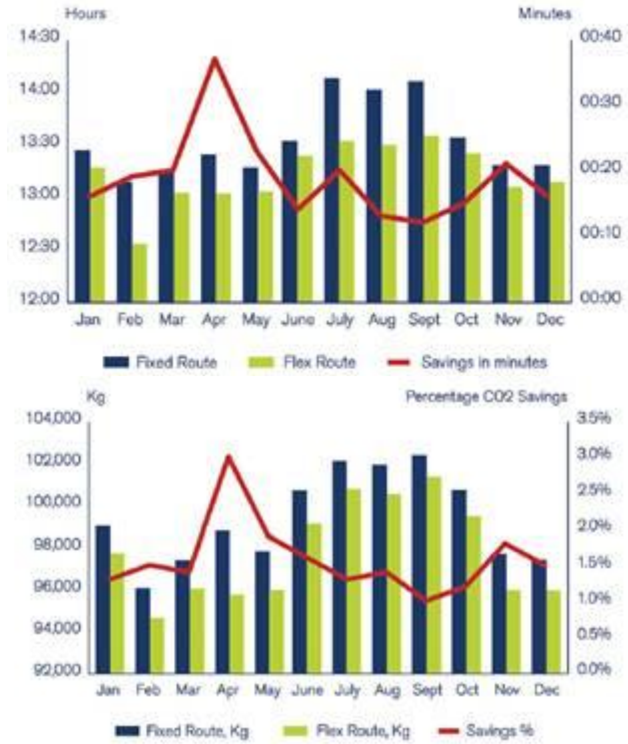
1.6.4 Convective meteorological conditions, particularly deep convection associated with towering cumulus and/or cumulonimbus clouds, causes many delays in today's system due to their hazardous nature (severe icing, severe turbulence, hail, thunderstorms, etc.), often-localized nature and the labour intensive voice exchanges of complex reroutes during the flight. New data communications automation will enable significantly faster and more efficient delivery of reroutes around such convective activity. This operational improvement will expedite clearance delivery resulting in reduced delays and miles flown during convective meteorological conditions.

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).

Access and Equity	Better access to airspace by a reduction of the permanently segregated volumes.
Capacity	The availability of a greater set of routing possibilities allows reducing potential congestion on trunk routes and at busy crossing points. The flexible use of airspace gives greater possibilities to separate flights horizontally. PBN helps to reduce route spacing and aircraft separations. This in turn allows reducing controller workload by flight.
Efficiency	The different elements concur to trajectories closer to the individual optimum by reducing constraints imposed by permanent design. In particular the module will reduce flight length and related fuel burn and emissions. The potential savings are a significant proportion of the ATM related inefficiencies. The module will reduce the number of flight diversions and cancellations. It will also better allow avoiding noise sensitive areas.

Environment	Fuel burn and emissions will be reduced; however, the area where emissions and contrails will be formed may be larger.
Flexibility	The various tactical functions allow reacting rapidly to changing conditions.
Predictability	Improved planning allows stakeholders to anticipate on expected situations and be better prepared.
Cost Benefit Analysis	Element 2: FUA As an example, over half of the United Arab Emirates (UAE) airspace is military. Currently, civil traffic is concentrated on the northern portion of the UAE. Opening up this airspace could potentially enable yearly savings in the order of: a) 4.9 million litres of fuel; and b) 581 flight hours. In the U.S. a study for NASA by Datta and Barington showed maximum savings of dynamic use of FUA of $7.8M (1995 $). Element 3: Flexible routing. Early modelling of flexible routing suggests that airlines operating a 10-hour intercontinental flight can cut flight time by six minutes, reduce fuel burn by as much as 2% and save 3,000 kilograms of CO_2 emissions. These improvements in efficiency directly help the industry in meeting its environmental targets. Some of the benefits that have accrued from flex route programmes in sub-region flows include: a) reduced flight operating costs (1% to 2% of operating costs on long-haul flights); b) reduced fuel consumption (1% to 2% on long-haul flights); c) more efficient use of airspace (access to airspace outside of fixed airway structure); d) more dynamic flight planning (airlines able to leverage capability of sophisticated flight planning systems); e) reduced carbon footprint (reductions of over 3,000 kg of CO_2 on long-haul flights); f) reduced controller workload (aircraft spaced over a wider area); and g) increased passenger and cargo capacity for participating flights (approximately 10 extra passengers on long-haul flights).



Comparison of Flight Time and Fuel Burn using Fixed and Flex Routes using Sao Paulo-Dubai flights throughout the year 2010 (Source: IATA iFLEX Preliminary Benefit Analysis)

In the U.S. RTCA NextGen Task Force Report, it was found that benefits would be about 20% reduction in operational errors; 5-8% productivity increase (near term; growing to 8-14% later); capacity increases (but not quantified). Annual operator benefit in 2018 of $39,000 per equipped aircraft (2008 dollars) growing to $68,000 per aircraft in 2025 based on the FAA Initial investment Decision. For the high throughput, high capacity benefit case (in 2008 dollars): total operator benefit is $5.7B across programme lifecycle (2014-2032, based on the FAA initial investment decision).

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 Required procedures exist for the main. They may need to be complemented by local practical guidance and processes; however, the experience from other regions can be a useful reference source to be customized to the local conditions.

3.2 The development of new and/or revised ATM procedures is automatically covered by the definition and development of listed elements. However, given the interdependencies between some of the modules, care needs to be taken so that the development of the required ATM procedures provides for a consistent and seamless process across these modules.

3.3 The airspace requirements (RNAV, RNP and the value of the performance required) may require new ATS procedures and ground system functionalities. Some of the ATS procedures required for this module are linked with the processes of notification, coordination and transfer of control, supported by messages exchange (Module B0-25).

3.4 **Element 1: Airspace planning**

3.4.1 See general remarks above.

3.5 **Element 2: FUA**

3.5.1 The ICAO *Civil/Military Cooperation in Air Traffic Management* (Cir 330) offers guidance and examples of successful practices of civil and military cooperation. It realizes that successful cooperation requires collaboration that is based on communication, education, a shared relationship and trust.

3.6 **Element 3: Flexible routing**

3.6.1 A number of operational issues and requirements will need to be addressed to enable harmonized deployment of flex route operations in a given area such as:

a) some adaptation of letters of agreement;

b) revised procedures to consider the possibility of transfer of control at other than published fixes;

c) use of latitude/longitude or bearing and distance from published fixes, as sector or flight information region (FIR) boundary crossing points;

d) review of controller manuals and current operating practices to determine what changes to existing practices will need to be developed to accommodate the different flows of traffic which would be introduced in a flex route environment;

e) specific communication and navigation requirements for participating aircraft will need to be identified;

f) developing procedures that will assist ATC in applying separation minima between flights on the fixed airway structure and flex routes both in the strategic and tactical phases;

g) procedure to cover the transition between the fixed network and the flex route airspace both horizontally and vertically. In some cases, a limited time application (e.g. during night) of flex route operations could be envisaged. This will require modification of ATM procedures to reflect the night traffic patterns and to enable the transition between night flex route operations and daytime fixed airway operations; and

h) training package for ATC.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 Deployment of PBN is ongoing. The benefits provided to flights can facilitate its dissemination, but it will remain linked to how aircraft can fly.

4.1.2 Dynamic re-routing can require aircraft connectivity (Aircraft communication addressing and reporting system (ACARS)) to its flight operating centre for flight tracking and the up-load of new routes computed by the FOC flight planning system (FPS), and possibly FANS 1/A capability for the exchange of clearance with ATC.

4.2 Ground systems

4.2.1 Technology is available. Even CDM can be supported by a form of internet portal. However, since aviation operations are global, standardization of the information and its presentation will be increasingly required (see thread 30 on SWIM).

4.2.2 Basic FUA concept can be implemented with the existing technology. Nevertheless for a more advanced use of conditional routes, a robust collaborative decision system will be required including function for the processing and display of flexible or direct routes containing latitude/longitude. In addition to published fixes a coordination function is also needed and may need specific adaptations to support transfer of control over non published points.

4.2.3 Enhanced FPS today are predicated on the determination of the most efficient flight profile. The calculations of these profiles can be driven by cost, fuel, time, or even a combination of the factors. All airlines deploy FPS at different levels of sophistication and automation in order to assist flight dispatchers/planners to verify, calculate and file flight plans.

4.2.4 Additionally, the flight dispatcher would need to ensure the applicability of over-flight permissions for the over-flown countries. Regardless of the route calculated, due diligence must always be exercised by the airline in ensuring that NOTAMs and any restrictive flight conditions will always be checked and validated before a flight plan is filed. Further, most airlines are required to ensure a flight following or monitoring program to update the crews with any changes in the flight planning assumptions that might have changed since the first calculation was made.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 The roles and responsibilities of controller/pilot are not affected. However, 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. 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 The required training is available and the change step is achievable from a human factors perspective. 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/STANDARDISATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

- Regulatory/standardization: use current published requirements that include the material give in Section 8.4.

- Approval plans: to be determined, based upon regional applications. Possible regional mandates of PBN should be considered.

6.1 Element 1: Airspace planning

6.1.1 See general remarks above.

6.2 Element 2: FUA

6.2.1 Until today, the Article 3 of the Chicago Convention expressly excludes the consideration of State aircraft from the scope of applicability.

6.2.2 Exemption policies for specific State aircraft operations and services are currently used as a method to cope with the discrepancy of civil and military aviation needs. Some States already realize that for State aircraft a solution lays in an optimum compatibility to civil aviation, although military requirements have to be met.

6.2.3 ICAO provisions related to coordination between civil and military in support to the flexile use of airspace can be found in several annexes, PANS and manuals.

6.2.4 Annex 11 — *Air Traffic Services* allows States to delegate responsibility for the provision of ATS to another State. However, States retain sovereignty over the airspace so delegated, as confirmed by their adherence to the Chicago Convention. This factor may require additional effort or coordination in relation to civil/military cooperation and an appropriate consideration in bilateral or multilateral agreements.

6.3 Element 3: Flexible routing

6.3.1 LoA/LoCs: Letters of agreement (LoA) and/or letters of coordination (LoC) might be required to reflect the specificities of flex route operations. Local hand-off procedures, timings and frequency allocations must be clearly detailed. Allocation schemes are also useful in designing major unidirectional flows, such as the EUR-Caribbean flows.

6.4 Common enabler: PBN procedures

6.4.1 Within an airspace concept, PBN requirements will be affected by the communication, surveillance and ATM environments, the navaid infrastructure, and the functional and operational capabilities needed to meet the ATM application. PBN requirements also depend on what reversionary, non-RNAV means of navigation are available and what degree of redundancy is required to ensure adequate continuity of functions.

6.4.2 The selection of the PBN specification(s) for a specific area or type of operation has to be decided in consultation with the airspace users. Some areas need only a simple RNAV to maximize the benefits, while other areas such as nearby steep terrain or dense air traffic may require the most stringent RNP. International public standards for PBN are still evolving. International PBN is not widespread. According to the ICAO/IATA Global PBN Task Force, international air traffic management and state flight standards rules and regulations lag behind airborne capability.

6.4.3 There is a need for worldwide harmonization of RNP requirements, standards, procedures and practices, and common flight management system functionality for predictable and repeatable RNP procedures, such as fixed radius transitions, radius-to-fix legs, required time of arrival (RTA), parallel offset, VNAV, 4D control, ADS-B, data link, etc.

6.4.4 A safety risk management document may be required for every new or amended procedure. That requirement will extend the time required to implement new procedures, especially PBN-based flight procedures.

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

7.1 Current use

7.1.1 Most of the proposed elements have already been implemented in at least a region.

7.1.2 In particular, one will note the following realizations which can be taken as examples of how to achieve the module.

7.2 Element 1: Airspace planning

- **Europe**: Airspace planning is implemented in European States with airspace management cells, and at European scale through the network operations plan (NOP) which provide advanced notice on the (de)-activation of segregated airspace and conditional routes.

- **LARA:** LARA (local and subregional airspace management support system) is an initiative aimed at improving performance-based airspace management (ASM).

  LARA provides a software application to support ASM. It is focused on automation at local and regional levels for civil-military and military-military coordination. It is intended to provide a more efficient and transparent decision-making process between civil and military stakeholders for ATM performance enhancement. It will also provide information for civil-military coordination at network level to support the MILO function (military liaison officer function at central flow management unit (CFMU)). The LARA application will support the following:

a) airspace planning: to manage airspace bookings; to incorporate air traffic flow and capacity management (ATFCM) data into the airspace planning process; to facilitate the analysis and creation of a national/regional airspace plan; to assess network scenario proposals and to facilitate coordination for decision-making on a national level;

b) airspace status: to provide real-time, airspace common situation awareness; and

c) statistics: in collating airspace data and measuring airspace utilization through meaningful civil-military key performance indicators (KPIs), LARA will archive the data for further analysis.

A demonstrator was developed and successfully tested in January 2008. In 2009 LARA first prototype and various incremental versions based on it were delivered. Support to a functional airspace block Europe central (FABEC) trial has been initiated.

7.3 **Element 2: Flexible use of airspace (FUA)**

7.3.1 FUA has been implemented in Europe in the 90s and regularly improved on an as-needed basis. It leans on the airspace planning features described above, and coordination mechanisms to address the tactical coordination actions.

7.3.2 Collaboration decision-making (CDM) is implemented in the US NASCSC.

7.4 **Element 3: Flexible routing**

- **North-Atlantic**: Implemented with two daily sets of organized track systems

- **Japan**: Coordination of airspace use: In the coordination of rerouting for avoidance of airspace capacity saturation or hazardous meteorological conditions, air traffic management control (ATMC) and airline operators share and use the "rerouting list" of the flight routes between city pairs, which has been established and updated after making the necessary coordination with airline operators and ATC facilities. Using the rerouting list makes coordination simple and the coordination is effective to decrease the demand of the congesting airspace and to identify the variation of air traffic flow. The major airline operators are able to coordinate by ATM workstations. ATMC coordinates usage of the areas for IFRs flights with the military liaison officers, and then IFRs flights are able to fly through the segregated areas following ATC instructions. Also taking into account requirements for which IFRs flights enter the certain segregated area for avoiding adverse weather, ATMC is able to coordinate with military liaison officers for using military training/testing areas temporarily.

- **IATA**: IATA in conjunction with Emirates Airlines and Delta Airlines proposes to conduct a proof of concept of Flex Route capability on the Dubai – Sao Paulo and Atlanta – Johannesburg city-pairs respectively. The goal of the proof of concept trial is to gather performance data, measure tangible results and identify areas where mitigation may be required to address operational, procedural, and technical issues. Dependent on the results of the proof of concept trial, an operational trial with broader participation may be initiated in the future. This will allow airlines and ANSPs to take advantage of past experience and provide valuable guidance on what can be achieved, as they seek to implement flexible routing.

- **United States**: FAA published a number of PBN procedures to deliver more direct routes, saving time and fuel and reducing emissions. Specifically, the FAA published fifty required RNP authorization required and published 12 RNAV routes.

  Alaska Airlines is saving more than 217 flight miles per day and nearly 200,000 gallons of fuel per year by using parallel flight routes, or Q routes, between Seattle, Portland and Vancouver on one end, and airports in the San Francisco Bay and Los Angeles basin areas on the other. The initial parallel routes were developed in 2004 in partnership with the FAA.

- **Oceanic areas**: Pacific Region: Dynamic air route planning system (DARPS), used with flexible tracks and reduced horizontal separation to 30 NM using RNP 4 and automatic dependent surveillance (ADS) and controller pilot data link communications (CPDLC).

7.5 **Planned or ongoing activities**

- **Asia and South Pacific** initiative to reduce emissions (ASPIRE)

  Using advanced technologies and oceanic procedures (ATOP) conflict probe capabilities and improved communications techniques with the operators, a limited number of oceanic trajectory optimization demonstration flights were performed in 2008 in partnership with Air Europa. These demonstrations resulted in fuel savings of 0.5 percent-1 percent, validating the concept. During 2009, the additional partners participated in 119 oceanic optimization flights over the Atlantic. According to initial data analysis, the estimated fuel savings from re-routings on these flights averaged 1.4 per cent, equivalent to about 230 gallons of fuel and more than 2 tons of carbon dioxide reductions per flight.

  The 2008-09 demonstrations were limited to westbound routes and lateral rerouting. In 2010, the lateral reroute procedures tests continued, and the FAA initiated investigations on the benefits of vertical rerouting and eastbound routes. In addition, automatic dependent surveillance-contract climb and descent procedures were conducted in an operational trial over the Pacific Ocean to examine a reduction in oceanic separation from 30 to 15 miles, in an effort to better accommodate more efficient and user-preferred routes.

  The ASPIRE initiative was launched in 2008 by the United States, Australia and New Zealand. Japan joined it in October 2009 and Singapore in January 2010. United Airlines, Qantas and Air New Zealand flew the original demonstrations. Japan Airlines' first demonstration flight, a Boeing 747 operating from Honolulu to Osaka, explored NextGen concepts such as user-preferred route and dynamic airborne rerouting capabilities, plus a number of weight- and energy-saving techniques. In gate-to-gate demonstrations of emissions reduction on transpacific routes, the average fuel saving during en route operations was 2.5 percent.

  In its annual report for 2009, issued before Japan joined, ASPIRE estimated that if all 156 transpacific flights per week between Australia, New Zealand, the United States and Canada operated under conditions adopted for its demonstrations, airlines would save more than 10 000 000 gallons of fuel and avoid more than 100 000 tons of carbon emissions per year. Air New Zealand in October 2009 cited ASPIRE as a significant contributor to a fuel saving of 10 per cent and a reduction of more than 385,000 tons of carbon emissions in its 2009 financial year compared with the previous year.

- **Dynamic airborne reroute procedure (DARP)**

  Flights take advantage of the six hourly update of the upper air wind and temperature forecast to effectively re-plan the flight en-route through a procedure called a DARP. This process can be completed as forecasts become available. Use of DARP commences with an aircraft data link request for a DARP to the Air New Zealand Flight Dispatch Office in Auckland. Immediately the latest wind/temperature forecast becomes available, the flight dispatch officer recalculates the optimum track from a predetermined point just ahead of the current aircraft airborne position. Once calculated the revised route is uplinked to the aircraft for the crew to consider. The crew then downlink a request for the revised route to the Oceanic control centre and once approved, accept the revised route into the active side of the flight management computer (FMC). Savings vary greatly from day to day dependent on the accuracy of the original forecast, the average AKL-SFO flight would save 70 US gallons.

8. REFERENCE DOCUMENTS

8.1 Standards

- ICAO Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management*, Chapter 5

8.2 Guidance material

- ICAO Doc 9426, *Air Traffic Services Planning Manual*
- ICAO Doc 9554, *Manual Concerning Safety Measures Relating to Military Activities Potentially Hazardous to Civil Aircraft Operations*
- ICAO Doc 9613, *Performance-based Navigation (PBN) Manual*
- ICAO Doc 9689, *Manual on Airspace Planning Methodology for the Determination of Separation Minima*
- ICAO CDM and ATFM (under development) Manual
- ICAO Circular 330 AN/189, *Civil/Military Cooperation in Air Traffic Management*

8.3 Approval documents

- ICAO Doc 9426, *Air Traffic Services Planning Manual*
- ICAO Doc 9689, *Manual on Airspace Planning Methodology for the Determination of Separation Minima*
- ICAO Doc 9613, *Performance-based Navigation (PBN) Manual*
- ICAO Doc 9554, *Manual Concerning Safety Measures Relating to Military Activities Potentially Hazardous to Civil Aircraft Operations*
- ICAO Circular 330 AN/189, *Civil/Military Cooperation in Air Traffic Management*

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APPENDIX B

MODULE NO. B0-35: IMPROVED FLOW PERFORMANCE THROUGH PLANNING BASED ON A NETWORK-WIDE VIEW

Summary	Air traffic flow management (ATFM) is used to manage the flow of traffic in a way that minimizes delay and maximizes the use of the entire airspace. ATFM can regulate traffic flows involving departure slots, smooth flows and manage rates of entry into airspace along traffic axes, manage arrival time at waypoints or flight information region (FIR)/sector boundaries and re-route traffic to avoid saturated areas. ATFM may also be used to address system disruptions including crisis caused by human or natural phenomena.	
Main performance impact as per Doc 9854	KPA-01 – Access & Equity, KPA-02 – Capacity, KPA-04 – Efficiency, KPA-05 – Environment, KPA-08 – Participation by the ATM community; KPA-09 – Predictability.	
Operating environment/ Phases of flight	Pre-flight phases, some action during actual flight.	
Applicability considerations	Region or subregion	
Global concept component(s) as per Doc 9854	DCB – demand and capacity balancing TS – traffic synchronization AOM – airspace organization and management	
Global plan initiatives (GPI)	GPI-1: Flexible use of airspace GPI-6: Air traffic flow management GPI-8: Collaborative airspace design and management	
Main dependencies	NIL	
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	2013
	Avionics availability	N/A
	Ground systems availability	✓
	Procedures available	2013
	Operations approvals	2013

1. **NARRATIVE**

1.1 **General**

1.1.1 The techniques and procedures brought by this module capture the experience and state-of-the-art of the current ATFM systems in place in some regions, and which have developed as they were facing demand-capacity imbalances. Global ATFM seminars and bi-lateral contacts have allowed the dissemination of good practices.

1.1.2 Experience clearly shows the benefits related to managing flows consistently and collaboratively over an area of a sufficient geographical size to take into account sufficiently well the network effects. The concept for ATFM and demand and capacity balancing (DCB) should be further exploited wherever possible. System improvements are also about better procedures in these domains, and creating instruments to allow collaboration among the different actors.

1.1.3 Overall, to meet the objectives of balancing demand and capacity, keeping delays to a minimum and avoiding congestion, bottlenecks and overload, ATFM undertakes flow management in three broad phases. Each flight will usually have been subjected to these phases, prior to being handled operationally by ATC.

1.1.4 Strategic ATFM activity takes place during the period from several months until a few days before a flight. During this phase, comparison is made between the expected air traffic demand and the potential ATC capacity. Objectives are set for each ATC unit in order for them to provide the required capacity. These objectives are monthly reviewed in order to minimise the impact of the missing capacity on the airspace users. In parallel, an assessment of the number and routings of flights, which aircraft operators are planning, enables ATFM to prepare a routing scheme, balancing the air traffic flows in order to ensure maximum use of the airspace and minimize delays.

1.1.5 Pre-tactical ATFM is action taken during the few days before the day of operation. Based on the traffic forecasts, the information received from every ATC centre covered by the ATFM service, statistical and historical data, the ATFM notification message (ANM) for the next day is prepared and agreed through a collaborative process. The ANM defines the tactical plan for the next (operational) day and informs aircraft operators (AOs) and ATC units about the ATFM measures that will be in force on the following day. The purpose of these measures is not to restrict but to manage the flow of traffic in a way that minimises delay and maximizes the use of the entire airspace.

1.1.6 Tactical ATFM is the work carried out on the current operational day. Flights taking place on that day receive the benefit of ATFM, which includes the allocation of individual aircraft departure times, re-routings to avoid bottlenecks and alternative flight profiles to maximize efficiency.

1.1.7 ATFM has also progressively been used to address system disruptions and evolves into the notion of management of the performance of the Network under its jurisdiction, including management of crises provoked by human or natural phenomena.

1.2 **Baseline**

1.2.1 It is difficult to describe an exact baseline. The need for ATFM has emerged as traffic densities increased, and it took form progressively. It is observed that this need is now spreading progressively over all continents, and that even where overall capacity is not an issue, the efficient management of flows through a given volume of airspace deserves a specific consideration at a scale beyond that of a sector or an ACC, in order to better plan resources, anticipate on issues and prevent undesired situations.

1.3 **Change brought by the module**

1.3.1 ATFM has developed progressively over the last thirty years. It is noticeable from the European experience that key steps have been necessary to be able to predict traffic loads for the next day with a good accuracy, to move from measures defined as rate of entry into a given piece of airspace (and not as departure slots) to measures implemented before take-off and taking into account the flows/capacities in a wider area. More recently the importance of proposing alternative routings rather than only a delay diagnosis has been recognized, thereby also preventing over-reservations of capacity. ATFM services offer a range of web-based or business to business services to ATC, airports and aircraft operators, actually implementing a number of CDM applications.

1.3.2 In order to regulate flows, ATFM may take measures of the following nature:

a) departure slots ensuring that a flight will be able to pass the sectors along its path without generating overflows;

b) rate of entry into a given piece of airspace for traffic along a certain axis;

c) requested time at a way-point or an FIR/sector boundary along the flight;

d) miles-in-trail figures to smooth flows along a certain traffic axis;

e) re-routing of traffic to avoid saturated areas;

f) sequencing of flights on the ground by applying departure time intervals (MDI);

g) level capping; and

h) delaying of specific flights on the ground by a few minutes ("take-off not before").

1.3.3 These measures are not mutually exclusive. The first one has been the way to resolve the problem of multiple interacting flow regulation measures addressed independently by several ATFM units in Europe before the creation of the CFMU and proved to be more efficient than the second one which pre-existed CFMU.

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).

Access and Equity	Improved access by avoiding disruption of air traffic in periods of demand higher than capacity. ATFM processes take care of equitable distribution of delays.
Capacity	Better utilization of available capacity, network-wide; in particular the trust of ATC not being faced by surprise to saturation tends to let it declare/use increased capacity levels; ability to anticipate difficult situations and mitigate them in advance.
Efficiency	Reduced fuel burn due to better anticipation of flow issues; a positive effect to reduce the impact of inefficiencies in the ATM system or to dimension it at a size that would not always justify its costs (balance between cost of delays and cost of unused capacity). Reduced block times and times with engines on.
Environment	Reduced fuel burn as delays are absorbed on the ground, with shut engines; rerouting however generally put flight on a longer distance, but this is generally compensated by other airline operational benefits.
Participation by the ATM community	Common understanding of operational constraints, capabilities and needs.
Predictability	Increased predictability of schedules as the ATFM algorithms tends to limit the number of large delays.
Safety	Reduced occurrences of undesired sector overloads.
Cost Benefit Analysis	The business case has proven to be positive due to the benefits that flights can obtain in terms of delay reduction.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 An ICAO guidance material on ATFM is being developed and need to be completed and approved. US/Europe experience is enough to help initiate application in other regions.

3.2 New procedures are required to link much closer the ATFM with ATS in the case of using miles-in-trail or Arrival management or Departure management (see Module B0-15).

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 No avionics requirements.

4.2 Ground systems

4.2.1 When serving several FIRs, ATFM systems are generally deployed as a specific unit, system and software connected to the ATC units and airspace users to which it provides its services. Regional ATFM units have been the subject of specific developments. The main functions for ATFM systems are: demand and capacity balancing, performance measurements and monitoring, network operations plan management and traffic demand management.

4.2.2 Some vendors propose light ATFM systems.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 Controllers are protected from overloads and have a better prediction of their workload. ATFM does not interfere in real-time with their ATC tasks. However, 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 Flow managers in the flow management unit and controllers in area control centres (ACCs) using the remote flow management information or applications needs specific training and airline dispatchers using the remote flow management information or applications need training.

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: new standards and requirements is required for standard ATFM messages.

- Approval plans: to be determined.

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

7.1 Current use

- **Europe**: Detailed example – network operations plan (NOP) (CFMU)

  The network operations plan (NOP) portal was launched in February 2009 and as it exists today is a recognized major step on simplifying the ATM partners' access to ATM information. The NOP portal through one application provides one single view for all partners of several relevant ATM information like: - a map displaying the air traffic flow information, including the status of the congested areas in Europe and a corresponding forecast for the next three hours; - scenarios and events enriched with context and cross-reference information; - the collaborative process for building the season operations plan is now formalized; - the summary information of the preceding day is now immediately available with access to archive reports.

- **United States**: Detailed Example – National Playbook (ATCSCC)

  The national playbook is a traffic management tool developed to give all stakeholders a common product for various system wide route scenarios. The purpose is to aid in expediting route coordination during periods of reduced capacity in the ATM System that occur en route or at the destination airport. The playbook contains the most common scenarios that occur each severe weather season (such as the hurricane season or tornado season). The "play" includes the resource or flow impacted, facilities included, and specific routes for each facility involved

7.2 Planned or ongoing activities

- **Europe:** The following improvement items are being validated or implemented in Europe for 2013 or earlier:

  a) enhanced flight plan filing facilitation;

  b) use of free routing for flight in special airspace volumes;

  c) shared flight intentions;

  d) use of aircraft derived data to enhance ATM ground system performance;

  e) automated support for traffic load management;

  f) automated support for traffic complexity assessment;

  g) network performance assessment;

  h) moving airspace management into day of operation;

  i) enhanced real time civil/military coordination of airspace utilization;

  j) flexible sectorization management;

  k) modular sectorization adapted to variations in traffic flow;

  l) enhanced ASM/ATFCM coordination process;

m) short-term ATFCM measures;

n) interactive network capacity planning;

o) SWIM enabled NOP;

p) management of critical events;

q) collaborative management of flight updates;

r) ATFM slot swapping; and

s) manual user driven prioritization process.

- **United States:** Plans are currently being developed to test operational feasibility of strategic planning using severe weather and traffic forecast in the 24 to 48 hour timeframes.

8. REFERENCE DOCUMENTS

8.1 Standards

8.1.1 To be determined.

8.2 Procedures

8.2.1 To be determined.

8.3 Guidance material

- ICAO CDM and ATFM (under development) Manual.

8.4 Approval documents

- ICAO CDM and ATFM (under development) Manual.

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APPENDIX C

MODULE NO. B1-10: IMPROVED OPERATIONS THROUGH OPTIMIZED ATS ROUTING

Summary	To provide, through performance-based navigation (PBN), closer and consistent route spacing, curved approaches, parallel offsets and the reduction of holding area size. This will allow the sectorization of airspace to be adjusted more dynamically. This will reduce potential congestion on trunk routes and busy crossing points and reduce controller workload. The main goal is to allow flight plans to be filed with a significant part of the intended route specified by the user-preferred profile. Maximum freedom will be granted within the limits posed by the other traffic flows. The overall benefits are reduced fuel burn and emissions.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-04 – Efficiency, KPA-05 – Environment; KPA-06 – Flexibility.	
Operating environment/ Phases of flight	En-route, including oceanic and remote areas and TMA	
Applicability considerations	Region or subregion: the geographical extent of the airspace of application should be large enough; significant benefits arise when the dynamic routes can apply across flight information region (FIR) boundaries rather than imposing traffic to cross boundaries at fixed pre-defined points.	
Global concept component(s) as per Doc 9854	AOM – airspace organization and management	
Global plan initiatives (GPI)	GPI-1: Flexible use of airspace GPI-8: Collaborative airspace design and management	
Main dependencies	B0-10	
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	✓
	Avionics availability	✓
	Ground system availability	✓
	Procedures available	Est. 2018
	Operations approvals	Est. 2018

1. NARRATIVE

1.1 Baseline

1.1.1 The baseline is the use of published routes and fixed sectors; some of them possibly defined flexibly as a result of flexible use of airspace (FUA), or to better accommodate flows and/or other flight conditions such as meteorological conditions. Published routes cannot afford for individual flight requirements as they are designed for significant/regular flows; typically flights from/to small airports with infrequent traffic will seldom find their optimum route pre-designed. In addition, published routes offer little freedom once they are published. This issue can be solved by authorizing flights to fly direct from a certain position to another point downstream their trajectory; this is generally a benefit to airspace users, but at the price of a significant workload for air traffic control (ATC).

1.1.2 In addition, where/when traffic flows and density justifies the pre-arrangement of traffic over published routes as a means to systemise traffic management by ATC and maximize the resulting capacity, the dispersion of navigational errors, especially during turns of aircraft equipped with traditional RNAV, leads to apply spacing based on that dispersion and prevents the achievement of an efficient route design.

1.2 **Change brought by the module**

1.2.1 The module is the opportunity to exploit further PBN capabilities, beyond the benefits achieved by Module B0-10, in order to continue eliminating design constraints and operating more flexibly.

1.2.2 The module is made of the following elements:

a) free routing;

b) reduced route spacing; and

c) dynamic sectorization.

1.3 **Element 1: Free routing**

1.3.1 Free routing corresponds to the ability for flights to file a flight plan with at least a significant part of the intended route which is not defined according to published route segments but specified by the airspace users. It is a user-preferred route, not necessarily a direct route, but the flight is supposed to be executed along the direct route between any specified way-points.

1.3.2 The use of free routing may be subject to conditions, in particular inside a defined volume of airspace, at defined hours, for defined flows. Its use may be limited to traffic under a certain density in order for controllers to be able to perform conflict detection and resolution with limited automation and while still being fully in the loop.

1.3.3 It is also in these conditions of density that the greater freedom for individual flights is less to be traded-off against the achievement of capacity objectives at the network level.

1.3.4 This module would mark the greatest advancement in terms of routings by providing maximum individual freedom. However, it is also recognized in the global concept that there are conditions where individual freedom has to give way to a more collective handling of traffic flows so as to maximize the overall performance.

1.3.5 The benefits of free routing are primarily in terms of adherence to the user-preferred profile. ATC may need to be provided with the necessary tools to ensure flight progress monitoring and coordination activities, and conflict prediction.

1.4 **Element 2: Reduced route spacing**

1.4.1 A key tenet of the PBN concept is to combine the accuracy and functionality of navigation in specifications which can be tailored to the intended operations.

1.4.2 A serious problem with the use of classical RVAV in the last decades has not been the achieved accuracy on straight segments, but the behaviour of aircraft in transiting phases, especially turns, where significant differences are noted from one aircraft to the next and depending on conditions such as wind. This has resulted in the inability to exploit the intrinsic accuracy and to design better routes, due to the need to protect large volumes of airspace.

1.4.3 This element addresses not only routes. It also provides improvements to other issues related to lateral navigation and can be summarized as follows:

a) closer route spacing, particularly en route;

b) maintaining same spacing between routes on straight and turning segments without a need to increase route spacing on the turn;

c) reduction of the size of the holding area to permit holds to be placed closer together or in more optimum locations;

d) aircraft ability to comply with tactical parallel offset instructions as an alternative to radar vectoring; and

e) means of enabling curved approaches, particularly through terrain rich areas.

1.4.4 The selection of a suitable PBN specification will eliminate the above shortcomings, and allow to design in both en-route and TMA routes which require lower spacing between them, directly resulting in higher airspace capacity, additional design flexibility and generally more efficient routes as well.

1.4.5 A safety assessment which considers operational errors may be required for the introduction of the reduced route spacing.

1.5 **Element 3: Dynamic sectorization**

1.5.1 The improvements in the design of the route network or the possibility to fly outside of a fixed route network make the pattern and concentration of traffic not always the same. Where sectorization is designed to create capacity for ATC, the implementation of the above elements requires that the sectorization be adjusted more dynamically than only in strategic ATC phases.

1.5.2 This dynamic sectorization can take several forms, the most complex/dynamic ones with real-time design computing are considered beyond Block 1. In this module, dynamic sectorization can take simple forms such as:

a) a pre-defined volume of airspace being swapped from a sector to an adjacent sector;

b) catalogues of pre-defined sector configurations based on a defined mosaic of elementary volumes, allowing a more general application of the above; and

c) sectors based on an organized (dynamic) track structure.

1.5.3 The dynamic sectorization is applied in real-time by selecting the most suitable configuration among those available. Unlike grouping/de-grouping of sectors, it does not affect the number of control position in use. Dynamic sectorization should be based on an assessment of the traffic situation expected in the next minute/hour.

1.5.4 Dynamic sectorization can also be applied across FIR/ANSP boundaries.

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	The availability of a greater set of routing possibilities allows reducing potential congestion on trunk routes and at busy crossing points. This in turn allows reducing controller workload by flight. Free routings naturally spreads traffic in the airspace and the potential interactions between flights, but also reduces the "systematization" of flows and therefore may have a negative capacity effect in dense airspace if it is not accompanied by suitable assistance. Reduced route spacing means reduced consumption of airspace by the route network and greater possibility to match it with flows.
Efficiency	Trajectories closer to the individual optimum by reducing constraints imposed by permanent design and/or by the variety of aircraft behaviours. In particular the module will reduce flight length and related fuel burn and emissions. The potential savings are a significant proportion of the ATM related inefficiencies. Where capacity is not an issue, fewer sectors may be required as the spreading of traffic or better routings should reduce the risk of conflicts. Easier design of high-level temporary segregated airspace (TSAs).
Environment	Fuel burn and emissions will be reduced; however, the area where emissions and contrails will be formed may be larger.
Flexibility	Choice of routing by the airspace user would be maximized. Airspace designers would also benefit from greater flexibility to design routes that fit the natural traffic flows.
Cost Benefit Analysis	The business case of free routing 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).

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 The airspace requirements (RNAV, RNP and the value of the performance and functionality required) may require new ATM procedures and ground system functionalities. Some of the ATM procedures required for this module are linked with the processes of notification, coordination and transfer of control. Care needs to be taken so that the development of the required ATM procedures provides for a consistent application across regions.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 Aircraft need to be suitably equipped. This is a matter of accuracy and functionality, i.e. a suitable PBN specification(s).

4.2 Ground systems

4.2.1 An adequate navigation infrastructure in the airspace of application is required that may be provided by ground navigation aids. For free routings, the flight planning and the flight data processing functionalities need to be upgraded to support the air traffic controller with the means to understand/visualise the flight paths and their interactions, as well as to communicate with adjacent controllers.

4.2.2 Dynamic sectorization requires the flight data processing functionality to be able to work with different sector configurations and sector grouping/de-grouping functionality. This functionality is available in many systems today.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 The change step is achievable from a human factors perspective. The roles and responsibilities of controller/pilot are not affected. Free routing, when compared to a structured route system, can reduce the number of potential interactions between flights but makes their occurrence less predictable and their configurations more variable. This is why it needs to be supported by automated assistance to understand/visualise the flight paths and their interactions as soon as traffic is significant. It is easier to implement it progressively, e.g. starting in low traffic conditions/periods. Reduced route spacing has no direct human performance incidence.

5.1.2 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 risk mitigation strategies such as training, education and redundancy.

5.2 Training and qualification requirements

5.2.1 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.

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

- Regulatory/standardization: use current published requirements that include the material give in Section 8.4:

  - ICAO Doc 9426, *Air Traffic Services Planning Manual*
  - ICAO Doc 9689, *Manual on Airspace Planning Methodology for the Determination of Separation Minima*
  - ICAO Doc 9613, *Performance-based Navigation (PBN) Manual*
  - ICAO Doc 9554, *Manual Concerning Safety Measures Relating to Military Activities Potentially Hazardous to Civil Aircraft Operations*

- Updates to ICAO Doc 4444 for new ATS procedures in PANS-ATM

- Approval plans: to be determined, based upon regional applications. Specific PBN specifications may be necessary

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

7.1 Current use

- **United States**: Navigation reference system (NRS) waypoints are currently implemented in the US since 2005. The approximately 1600 waypoints are spaced evenly covering the continental United States. Flights can file using the NRS Waypoints instead of VORs to take advantage of RNAV capabilities.

- **Europe**: Several States have declared their airspace as “free routes”: Ireland, Portugal, Sweden or planning to do so (Albania, Benelux-Germany in Maastricht UAC, Cyprus, Denmark, Finland, Estonia, Latvia, Malta, Norway on a 24-hour basis; Bulgaria, Greece, Hungary, Italy, Romania, Serbia at night).

  A cost-benefit analysis (CBA) conducted in 2001 for a free route airspace (FRA) implementation initially planned in Europe in 2006 concluded as follows:

  FRA is planned to be introduced in 8 European States: Belgium, Denmark, Finland, Germany, Luxembourg, the Netherlands, Norway and Sweden. This CBA has assumed that it will be introduced from the end of 2006 and in the airspace above Flight Level 335.

  The total costs of implementing FRA are estimated at € 53M, incurred mostly in 2005 and 2006. The benefit (reduced flight distances and times due to more direct flights) in the first year of operation, 2007, is € 27M, and the benefit is expected to increase each year with traffic growth. FRA is likely to become ‘financially beneficial’ (i.e. the financial benefits will be greater than the costs) because the costs are mostly incurred once while the benefits cumulate year on year. The CBA shows that, under the baseline assumptions, the cumulative benefits will overtake the costs in 2009. Over the 10 year project lifetime, from 2005 to 2014, the project has a net present value (NPV) of € 76M and an internal rate of return (IRR) of 40%.

  The costs of FRA do not fall evenly to all stakeholders. Aircraft operators flying GAT (mostly civilian airlines) receive almost all the financial benefits. The main costs fall to civil and military air traffic service providers (ATSP) and air defence units that must implement changes to their ground systems. Their costs differ according to how much work they must do to implement the necessary changes for FRA. The range of ATSP costs is from less than € 1M (Denmark) to € 10M (Germany).

  An estimate of the approximate costs and benefits to each State has been made. The analysis shows that, for most States, the total of ATC and air defence costs of FRA are much less than the benefit delivered to civil traffic in those States. For Germany, for example, FRA has an estimated NPV of € 53M when comparing all of the DFS’ ATC costs and Germany’s air defence costs against the benefit that Deutsche Flugsicherung GmbH (DFS) will deliver to civil traffic. For Norway, however, FRA has a small net cost because Norway has relatively high system upgrade costs to support FRA. Belgium and the Netherlands are a special case. In these States, the Maastricht UAC will deliver a benefit to civil traffic in FRA, but their military ATC and air defence organizations will still incur costs to implement FRA. In particular, the Belgian and Netherlands air forces will pay over € 9M to implement FRA and not see any significant financial benefits.

7.2 Planned or ongoing activities

- **SESAR**: Trials on user preferred routing within functional airspace blocks environment in a predetermined area and time period in 2012.

  Trials on user preferred routing operations from TMA exit to TMA entry in the timeframe 2014-2015.

8. REFERENCE DOCUMENTS

8.1 Guidance material

- ICAO Doc 9426, *Air Traffic Services Planning Manual*
- ICAO Doc 9554, *Manual Concerning Safety Measures Relating to Military Activities Potentially Hazardous to Civil Aircraft Operations*
- ICAO Doc 9613, *Performance-based Navigation (PBN) Manual*
- ICAO Doc 9689, *Manual on Airspace Planning Methodology for the Determination of Separation Minima*
- ICAO Circ 330, *Civil/Military Cooperation in Air Traffic Management*

8.2 Approval documents

- ICAO Doc 9426, *Air Traffic Services Planning Manual*
- ICAO Doc 9689, *Manual on Airspace Planning Methodology for the Determination of Separation Minima*
- ICAO Doc 9613, *Performance-based Navigation (PBN) Manual*
- ICAO Doc 9554, *Manual Concerning Safety Measures Relating to Military Activities Potentially Hazardous to Civil Aircraft Operations*
- Updates to ICAO Doc 4444 for new ATS procedures in PANS-ATM

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APPENDIX D

MODULE NO. B1-35: ENHANCED FLOW PERFORMANCE THROUGH NETWORK OPERATIONAL PLANNING

<table>
<tr><td>Summary</td><td colspan="2">To introduce enhanced processes to manage flows or groups of flights in order to improve overall flow. The resulting increased collaboration among stakeholders in real-time regarding user preferences and system capabilities will result in better use of airspace with positive effects on the overall cost of ATM.</td></tr>
<tr><td>Main performance impact as per Doc 9854</td><td colspan="2">KPA-02 – Capacity, KPA-04 – Efficiency, KPA-05 – Environment, KPA-09 – Predictability, KPA-10 – Safety</td></tr>
<tr><td>Operating environment/ Phases of flight</td><td colspan="2">Mainly applicable to pre-flight phases, with some application in flight.</td></tr>
<tr><td>Applicability considerations</td><td colspan="2">Region or subregion for most applications; specific airports in case of initial user driven prioritization process (UDPP). This module is more particularly needed in areas with the highest traffic density. However, the techniques it contains would also be of benefit to areas with lesser traffic, subject to the business case</td></tr>
<tr><td>Global concept component(s) as per Doc 9854</td><td colspan="2">DCB – demand and capacity balancing
TS – traffic synchronization
AOM – airspace organization and management</td></tr>
<tr><td>Global plan initiatives (GPI)</td><td colspan="2">GPI-1: Flexible use of airspace
GPI-6: Air traffic flow management
GPI-8: Collaborative airspace design and management</td></tr>
<tr><td>Main dependencies</td><td colspan="2">Successor of: B0-35, B0-10 (FUA aspects in particular)</td></tr>
<tr><td rowspan="6">Global readiness checklist</td><td></td><td>Status (ready now or estimated date)</td></tr>
<tr><td>Standards readiness</td><td>Est. 2018</td></tr>
<tr><td>Avionics availability</td><td>NA</td></tr>
<tr><td>Ground systems availability</td><td>Est. 2018</td></tr>
<tr><td>Procedures available</td><td>Est. 2018</td></tr>
<tr><td>Operations approvals</td><td>Est. 2018</td></tr>
</table>

1. NARRATIVE

1.1 General

1.1.1 This module introduces enhanced processes to manage flows or groups of flights in order to improve overall fluidity. It also increases the collaboration among stakeholders in real time so as to better know user preferences, inform on system capabilities, and further apply CDM in a certain set of problems/circumstances, in particular to take into account priorities of an airline among flights within its schedule. It also extends the notion of flexible use of airspace so as to include network efficiency considerations.

1.2 **Baseline**

1.2.1 The previous Module B0-35, provided a solid foundation for regulating traffic flows, and B0-10 introduced flexible use of airspace (FUA). The experience shows that further improvements can be introduced: managing airspace and traffic flows needs to be better integrated into the notion of network operations, ATFM techniques and algorithms can be improved and in particular could better take into account user preferences.

1.3 **Change brought by the module**

1.3.1 This module introduces enhanced processes to manage flows or groups of flights in order to improve overall fluidity. This module refines ATFM techniques, integrates the management of airspace and traffic flows in order to achieve greater efficiency in their management. It also increases the collaboration among stakeholders in real time so as to better know user preferences, inform on system capabilities and further apply CDM in a certain set of problems/circumstances in particular to take into account priorities of an airline among flight within its schedule.

1.4 **Element 1: Improved ATFM and ATFM-AOM integration**

1.4.1 Studies have shown that there is room for improvement of the ATFM algorithms and techniques. The module will implement those that will have been validated in the period of reference.

1.4.2 A particular development is required to accommodate the use of free routings implemented in B1-10.

1.4.3 In addition, with ATFM having introduced the notion of re-routing, either for ATC capacity constraints or to avoid other phenomena such as hazardous meteorological conditions, it appears that a greater integration of ATFM and airspace organization and management would bring significant benefits to traffic, not only civil traffic, but also for the more dynamic definition of areas which may be used for military.

1.5 **Element 2: Synchronization**

1.5.1 When getting really closer to capacity limits, the small variations in take-off time allowed by ATFM slots may still generate local bunching of traffic at times, which are extremely sensitive at a small number of choke-points in the network. It would therefore be useful to be able to anticipate on these situations once the flight is airborne and the uncertainties on its trajectory are reduced compared to before take-off, by using trajectory predictions and perform additional smoothing, not only along a flow (miles in trail) but for several converging flows at a few number of most critical choke points in a given airspace.

1.6 **Element 3: Initial user driven prioritization process (UDPP)**

1.6.1 User driven prioritization process (UDPP) is designed to allow airspace users to intervene more directly in the implementation of flow regulations, in particular in cases where an unplanned degradation of capacity significantly impacts the realisation of their schedule. The module proposes a simple mechanism by which the affected airlines can collaboratively among themselves and with ATFM come to a solution which takes into account their commercial/operational priorities which are not known by ATM. Due to the potential complexity of several intricate prioritisation and allocation processes, this module will implement UDPP only in specific situations, e.g. when the perturbation affects one airport.

1.7 **Element 4: Full flexible use of airspace (FUA)**

1.7.1 ICAO's development of flexible of airspace (FUA) documentation on civil/military cooperation: The full FUA introduces mechanisms, in conjunction with the more dynamic ATS routes (Module B1-10) to make the airspace and its use as flexible as possible and a continuum that can be used in an optimal manner by the civil and military users.

1.8 **Element 5: Complexity management**

1.8.1 The introduction of improved complexity and workload assessment tools is a means to improve the accuracy and reliability of the identification and mitigation of capacity constraints, both in the tactical ATFM phase as well as during the flight. This exploits information on planned incoming traffic.

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	Better use of the airspace and ATM network, with positive effects on the overall cost-efficiency of ATM. Optimization of DCB measures by using assessment of workload/complexity as a complement to capacity.
Efficiency	Reduction of flight penalties supported by airspace users.
Environment	Some minor improvement is expected compared to the module's baseline.
Predictability	Airspace users have a greater visibility and say on the likelihood to respect their schedule and can make better choices based on their priorities.
Safety	The module is expected to further reduce the number of situations where capacity or acceptable workload would be exceeded.
Cost Benefit Analysis	The business case will be a result of the validation work being undertaken.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 There is a need to develop:

a) new procedures to exploit the new techniques: for ATC to communicate in-flight measures to crews; for informing operators before departure;

b) rules for information exchange and decision making between all the actors; and

c) UDPP rules and application requirements need to be defined.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 No avionics impact.

4.2 Ground systems

4.2.1 Building on the systems established to deliver Module B0-35, will require additional ground functionality in the form of enhanced algorithms, interactive services with ANSPs and aircraft operators through business to business applications, and connections with airspace management systems, either to integrate them or to receive in real-time airspace management information in conjunction with Module B1-10.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 Roles and responsibilities of controllers and pilots are expected not to be much affected in tactical operations (except by the more tactical re-routings or sequencing), but will need to understand that the decisions made on flights are for the common good.

5.1.2 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.

5.2 Training and qualification requirements

5.2.1 The new procedures will require training adapted to the collaborative nature of the interactions, in particular between ATFM units and airline operations personnel.

5.2.2 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.

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

- Regulatory/standardization: updates are required for enhanced operations in ICAO Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management*.

- Approval plans: to be determined.

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

7.1 Current use

Europe: Some European ACCs already exploit complexity management tools to better predict sector workloads and take measures such as de-grouping to absorb traffic bunching effects.

7.2 Planned or ongoing activities

Europe: SESAR will validate the initial UDPP requirements and procedures, as well as the airspace management and network operations related to the module.

8. REFERENCE DOCUMENTS

8.1 Guidance material

EUROCONTROL concept advanced flexible use of airspace (AFUA).

8.2 Approval documents

ICAO Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management.*

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APPENDIX E

MODULE NO. B2-35: INCREASED USER INVOLVEMENT IN THE DYNAMIC UTILIZATION OF THE NETWORK

Summary	CDM applications supported by SWIM that permit airspace users to manage competition and prioritisation of complex ATFM solutions when the network or its nodes (airports, sector) no longer provide enough capacity to meet user demands. This further develops the CDM applications by which ATM will be able to offer/delegate to the users the optimization of solutions to flow problems. Benefits include an improvement in the use of available capacity and optimized airline operations in degraded situations.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-09 – Predictability.	
Operating environment/ Phases of flight	Pre-flight phases	
Applicability considerations	Region or subregion	
Global concept component(s) as per Doc 9854	DCB – demand and capacity balancing TS – traffic synchronization AOM – airspace organization and management AUO – airspace users operations	
Global plan initiatives (GPI)	GPI-6: Air traffic flow management GPI-8: Collaborative airspace design and management	
Main dependencies	B1-35, B1-30 and probably B2-25	
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	Est. 2023
	Avionics availability	Est. 2023
	Ground systems availability	Est. 2023
	Procedures available	Est. 2023
	Operations approvals	Est. 2023

1. NARRATIVE

1.1 Baseline

1.1.1 The previous Module B1-35 has introduced an initial version UDPP, focused on the issues at an airport.

1.2 Change brought by the module

1.2.1 This module further develops the CDM applications by which ATM will be able to offer/delegate to the users the optimization of solutions to flow problems, in order to let the user community take care of competition and their own priorities in situation when the network or its nodes (airports, sector) does no longer provide actual capacity commensurate with the satisfaction of the schedules. This module also builds on SWIM for more complex situations.

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	Improved use of the available capacity in situations where it is constrained.
Predictability	The module offers airlines the possibility to have their priorities taken into account and optimize their operations in degraded situations.
Cost Benefit Analysis	To be established when the research on the module has progressed more significantly.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 Procedures are required to specify the conditions (in particular rules of participation, rights and duties, equity principles, etc) and notice for UDPP to be applicable. The process will need to be done in a way that does not conflict with or degrades the optimization of the network done by ATFM.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 None in addition to that required for participation in SWIM where applicable.

4.2 Ground systems

4.2.1 Will be supported by system-wide information management (SWIM) environment technology and ground-ground integration with all participants especially ATS and airlines. Automated functions allowing negotiation among users and connection with ATFM systems

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 No significant issues identified. Nevertheless, the module will introduce additional factors in the decision making related to flight preparation and planning which will need to be understood by airline personnel.

5.1.2 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 The new procedures will require training adapted to the collaborative nature of the interactions, in particular between ATFM units and airline operations personnel.

5.2.2 This module will eventually contain a 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: new standards and guidance needed to enable user optimization of CDM solutions.

- Approval plans: to be determined.

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

7.1 Current use

7.1.1 None at this time.

7.2 Planned or ongoing activities

Europe: SESAR work programme has just started to formulate the concept of UDPP, and will need to elaborate this module further before describing the trials for it**.**

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APPENDIX F

MODULE NO. B3-10: TRAFFIC COMPLEXITY MANAGEMENT

<table>
<tr><td>Summary</td><td colspan="2">Introduction of complexity management to address events and phenomena that affect traffic flows due to physical limitations, economic reasons or particular events and conditions by exploiting the more accurate and rich information environment of a SWIM-based ATM. Benefits will include, optimized usage and efficiency of system capacity,</td></tr>
<tr><td>Main performance impact as per Doc 9854</td><td colspan="2">KPA-02 – Capacity, KPA-04 – Efficiency, KPA-06 – Flexibility, KPA-09 – Predictability.</td></tr>
<tr><td>Operating environment/ Phases of flight</td><td colspan="2">Pre-flight and in-flight</td></tr>
<tr><td>Applicability considerations</td><td colspan="2">Regional or subregional. Benefits are only significant over a certain geographical size and assume that it is possible to know and control/optimize relevant parameters. Benefits mainly useful in the higher density airspace</td></tr>
<tr><td>Global concept component(s) as per Doc 9854</td><td colspan="2">AOM – airspace organization and management
TS – traffic synchronization
DCB – demand & capacity balancing</td></tr>
<tr><td>Global plan initiatives (GPI)</td><td colspan="2">GPI-6: Air traffic flow management
GPI-8: Collaborative airspace design and management</td></tr>
<tr><td>Main dependencies</td><td colspan="2">Successor of: B1-10, B2-35
Parallel progress with: B3-05, B3-15, B3-25, B3-85</td></tr>
<tr><td rowspan="6">Global readiness checklist</td><td></td><td>Status (ready now or estimated date)</td></tr>
<tr><td>Standards readiness</td><td>Est. 2028</td></tr>
<tr><td>Avionics availability</td><td>Est. 2028</td></tr>
<tr><td>Ground systems availability</td><td>Est. 2028</td></tr>
<tr><td>Procedures available</td><td>Est. 2028</td></tr>
<tr><td>Operations approvals</td><td>Est. 2028</td></tr>
</table>

1. NARRATIVE

1.1 General

1.1.1 With trajectory-based 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 capabilities needed to solve issues related to the increased complexity of certain traffic situations.

1.1.2 While trajectory-based operations are the long-term evolution of the management of an individual trajectory, a number of events and phenomena affect traffic flows due to physical limitations, economic reasons or particular events and conditions. The long-term evolution of their management is addressed in this module in relation with traffic densities higher than the present ones, and/or with a view to improve the solutions applied so far and provide optimized services while working closer to the system limits. This is referred to as "managing complexity".

1.1.3 The module integrates various ATM components to generate its extra performance benefits and will introduce further refinements in DCB, TS and AOM processes (and possibly SDM, AUO and AO) to exploit the more accurate and rich information environment expected from trajectory-based operations (TBO), system-wide information management (SWIM) and other longer term evolutions.

1.1.4 This is an area of active research, where innovative solutions are probably as important as the understanding of the uncertainties inherent to ATM and of the air transport mechanisms and behaviours to which ATM performance is sensitive to.

1.2 Baseline

1.2.1 Prior to this module, most of the ingredients of the Global ATM Operational Concept will have been progressively put in place, but not yet completely pending the dissemination of a certain number of capabilities and enablers, and also not fully integrated. There remains room to achieve performance gains by addressing the issues that the lack of optimized integration will raise.

1.3 Change brought by the module

1.3.1 The module provides for the optimization of the traffic flows and air navigation resources usage. It addresses the complexity within ATM due to the combination of higher traffic densities, more accurate information on trajectories and their surrounding environment, closely interacting processes and systems, and the quest for greater levels of performance.

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	Increase and optimized usage of system capacity.
Efficiency	Optimization of the overall network efficiency.
Flexibility	Accommodation of change requests.
Predictability	Minimize the impact of uncertainties and unplanned events on the smooth running of the ATM system.
Cost Benefit Analysis	To be established as part of the research related to the module.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 To be defined.

4. NECESSARY SYSTEM CAPABILITY

4.1 The module will exploit technology then available, in particular SWIM and TBO which will provide the accurate information on the flights and their environment. It will also likely rely on automation tools.

4.2 Avionics

4.2.1 None in addition to that required for participation in SWIM and/or TBO operations.

4.3 Ground systems

4.3.1 Intensive use of automated functions and sophisticated algorithms to exploit information.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 The high degree of integration of the traffic information and the optimization of the processes will likely require high levels of automation and the development of specific interfaces for the human operators.

5.1.2 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 Training requirements will be high, not only prior to entry into service but also as a regular maintenance of the skills.

5.2.2 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: to be determined
- Approval plans: to be determined.

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

7.1 Current use

7.1.1 None at this time.

7.2 Planned or ongoing activities

- **Europe:** The SESAR programme has established a research network on “complexity” together with research projects addressing some of the relevant issues.

- **United States:** Research is being conducted at NASA and Universities.

- No live trials in the foreseeable future.

— END —