Operating in the North Atlantic MNPS Airspace

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This paper considers the issue of operating aircraft through the North Atlantic's Minimum Navigation Performance Specification (MNPS) airspace. Noting that aircraft constantly strive for reduced fuel burn and uplift, it describes how flight operators and pilots conduct safe, efficient flights through the region. Reference is made to mechanisms of the North Atlantic MNPS airspace in terms of its Organized Track Structure and other routes that exist. These different structures emphasize the level of flexibility available. Flight planning procedures and requirements necessary to obtain oceanic Air Traffic Control (ATC) clearances are mentioned, as is an account of how communication and position reporting procedures operate to apply the Mach Number technique. Other aspects of MNPS operations such as ETOPS operational restrictions, meteorological effects, the employment of Reduced Vertical Separation Minima and planned regional changes aim to provide an overview of the MNPS system's current and future air traffic management.

1. INTRODUCTION. The concept of Minimum Navigation Performance Specification (MNPS) airspace permits an increased flow of air traffic in an environment constrained by a lack of navigational and communication infrastructure, which is often subject to meteorologically-restrictive operating zones, with consequent reliability hazards. This approach to air traffic management ensures that all aircraft in the airspace have the capability to optimise their performance based on a set of navigational criteria.

The rationale and foundation for MNPS is based on a mathematical model which expresses the relationship between collision risk and separation within the appropriate Target Level of Safety (TLS). This Reich collision risk model considers separate risks in lateral, longitudinal and vertical dimensions, with aircraft represented as boxes.

The integrity of MNPS airspace is maintained by a series of procedures for its operations plus continuous monitoring of the navigation accuracy of aircraft using this airspace. Such aircraft are required to meet a minimum navigation performance specification in the horizontal plane through mandatory carriage and use of a minimum scale of equipment which has an acceptable standard of performance.

The North Atlantic area is the most pertinent example of MNPS airspace due to its high density traffic in an oceanic environment with limited communication and navigational aids.

2. THE NORTH ATLANTIC'S MNPS AIRSPACE. To analyse Minimum Navigation Performance Specification (MNPS) airspace, consider the North Atlantic region as displayed in Figure 1, where MNPS was developed many years ago. Effective from Flight Levels (FL) 285 to 420 inclusive, it was created due to the lack of navigation aids and to cope with the situation in this geographical area, which is unique because of passenger demands, time zone differences and airport noise

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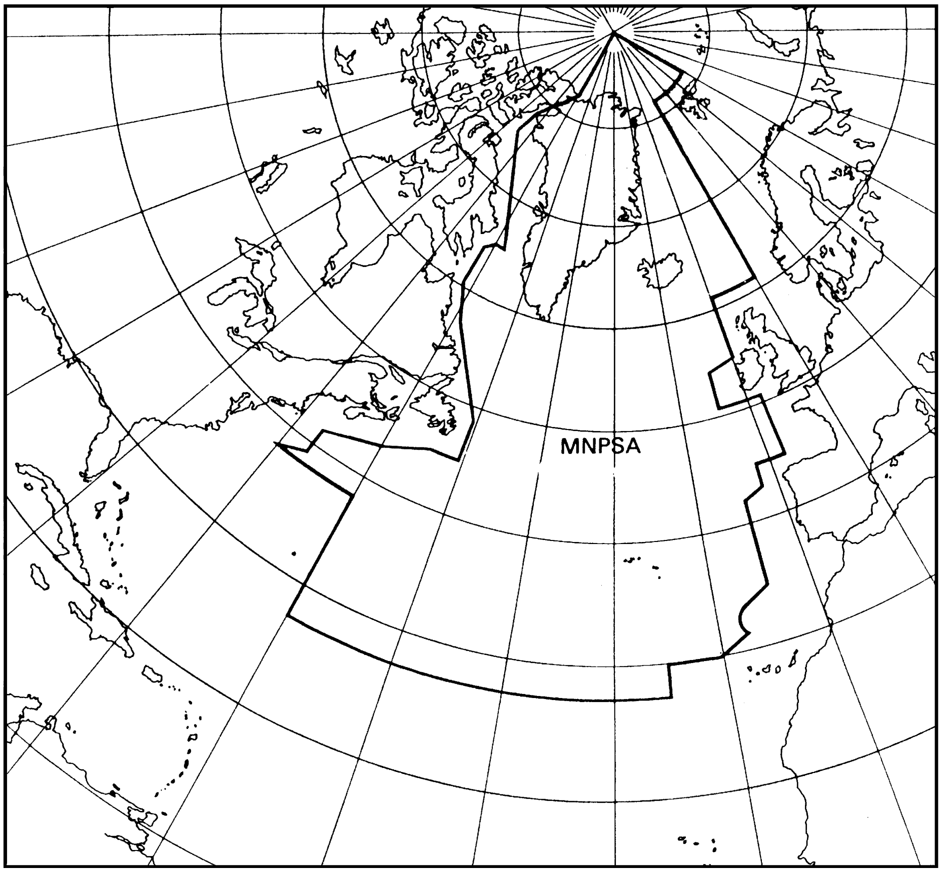

Figure 1. The North Atlantic's MNPS airspace.

restrictions. Such factors led to the requirement for a stated level of navigational accuracy.

Most of the North Atlantic air traffic contributes to either a westbound flow departing Europe in the morning, or an eastbound flow departing North America in the evening. The traffic flow is therefore concentrated in a unidirectional manner, with westbound peaks normally from 1130 to 1900UTC and eastbound from 0100 to 0800UTC. The airspace is extremely congested during these periods because of:

(i) the constraints of communications reliability between ATC and pilots
(ii) the absence of timely and reliable position information at control centres
(iii) the large horizontal separation criteria required for procedural clearances
(iv) wind-restricting operating zones
(v) a limited height band in which aircraft can fly economically.

A variety of different variable and fixed airspace structures exists to minimize the effects of these reasons for congestion. It should be noted that such structures and routes, which are described below, are based on latitude and longitude coordinates. Users include both scheduled and charter commercial airlines, general aviation, corporate business aviation and military aircraft.

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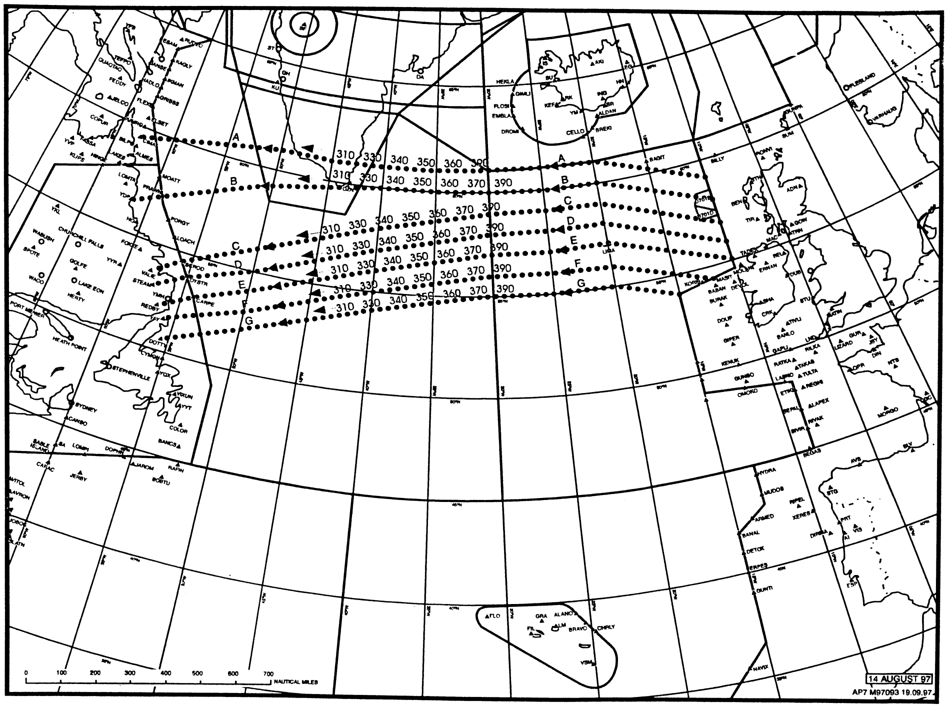

Figure 2. The Organized Track Structure.

In order to provide the best service to the bulk of the traffic, a relatively restrictive system of organized parallel tracks is constructed every day in both directions at the appropriate times. This Organized Track Structure (OTS), portrayed in Figure 2, attempts to accommodate the users' preferred routeings. Due to the energetic nature of the prevailing weather systems, eastbound and westbound tracks are seldom identical: the day-time westbound track system tends to be more northerly than the night-time eastbound structure, which is usually designed to make use of the more southerly jet stream winds. The tracks are alphabetically identified and are available at specific Flight Levels.

A Polar Track Structure (PTS) and other routes which lie beneath, within and adjacent to the MNPSA are also used to accommodate the different types of traffic. The PTS is a fixed track system which consists of ten routes in the Reykjavik control area and five through the Bodø area, as per Figure 3. Flight plans are not mandatory and abbreviated clearances are used by ATC. The pilots use position reports which replace the normal latitude coordinate with the word 'Polar' followed by the track code.

The routes that exist beneath the OTS, so called non-MNPS airspace, are usually frequented by General Aviation aircraft which are un-pressurized or not capable of reaching altitudes in time to use the organized structure. Commonly flown within range of VHF communication facilities to use VOR and NDB navigation aids, these routes are constructed to minimize the length of time over water. Separation techniques are similar to those employed for domestic air traffic control.

Other routes which are adjacent to North Atlantic MNPS airspace include:

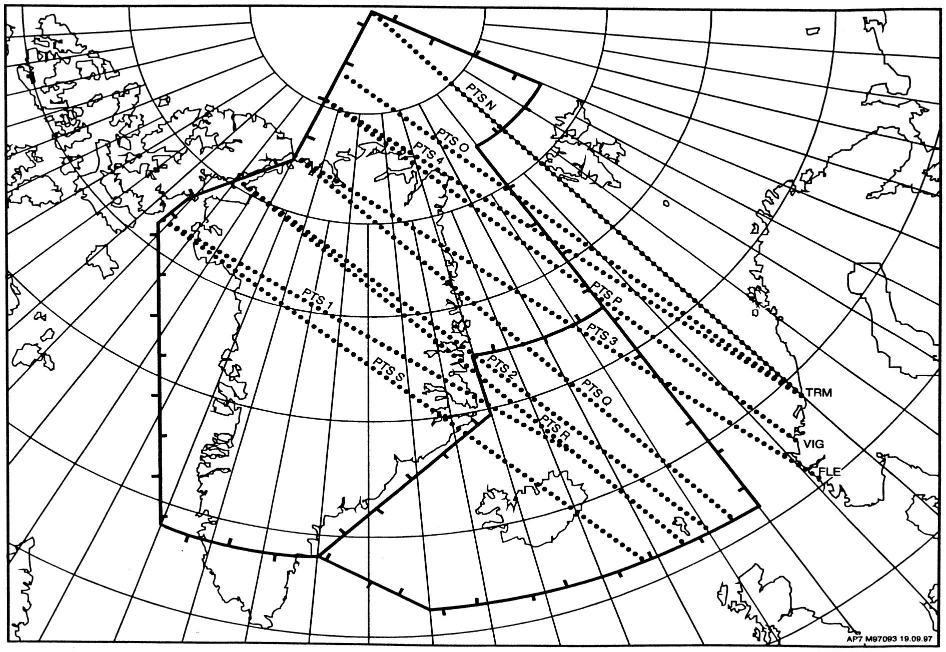

Figure 3. The Polar Track Structure.

(i) Concorde's route structure, which comprises three fixed tracks termed SM, SN and SO. They enable the supersonic aircraft to perform its required cruise climbs above the MNPS airspace
(ii) the Irish and UK domestic route system which enables entry to the oceanic track system
(iii) Canadian domestic track systems.

3. preparing transatlantic trips. It is evident in the previous section that the Polar Track Structure and those routes which lie beneath, within and adjacent to the MNPSA are all fixed routes. However, the vast majority of operators make use of either the organized or random transatlantic tracks. The latter are often parallel or related to the organized track structure. Hence the need to understand how both track scenarios are managed, and the effect that Extended Twin engine OPerationS (ETOPS) have on planning North Atlantic flights.

3.1. *Using the OTS.* The Organized Track Structure (OTS) is devised twice daily. Gander Oceanic Area Control Centre is responsible for designing and publishing the eastbound (night-time) OTS, whereas Shanwick Oceanic Area Control Centre in Prestwick deals with the westbound (day-time) structure. Both consider the anticipated requirements of each other's opposite direction traffic demand and airspace restrictions such as Danger Areas and military airspace activities.

The procedure of track creation is based on the users' preferred route messages, which are sent to the oceanic area control centre up to 14 hours in advance. These detail the minimum time routes which aircraft would like to fly, given forecasted winds and other operational specifics such as aircraft performance. The control centre assembles all these routes and publishes a track message, which gives full details of all track coordinates, their hours of validity, the relevant Flight Levels and entry-exit

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points. Based on the track message, users send in their desired routeing(s) in the form of flight plans requesting either established or random airways.

For OTS-related routes, flights are planned so that specified ten degrees of longitude (20° W, 30° W, 40° W, etc.) are crossed at whole degrees of latitude in order to operate on approximations to great circle tracks joining significant points. In addition to these waypoints, the planned cruising Mach Number and Flight Level (FL) must be given. Each point at which a change of Mach Number or FL is requested must be specified as coordinates in latitude and longitude or using one of the waypoint names.

3.2. *Random Tracking*. Depending on the prevailing weather conditions and the optimal route between the departure and destination airports, it may be shorter to plan flights outside the Organized Track Structure and perform random tracking. Operational constraints such as ETOPS, which is discussed in the next section, may be another reason that forces the operator to request a random track.

All users have the right to file a random track even if it conflicts with the OTS. The ability to satisfy the random requests depends solely on the traffic situation. In practice, aircraft are not cleared across the busy track structures because of the requisite time delay that must be imposed on track traffic. According to an en-route planner, 'crossing tracks sterilizes 30 minutes or 240 miles of the airspace'. Therefore, random requests are invariably satisfied by clearing above or below the OTS, joining the outer track of the system, or being cleared on an organized track that approximates the random route as closely as possible.

In between the track operating times, random flight plans are filed when in MNPS airspace. Several hours elapse between the termination of one structure and the commencement of the other. However, operators are encouraged to flight plan a random route at Flight Levels appropriate to the direction of flight. Hence, careful route planning is required with the time of crossing being an important consideration. This is particularly relevant to corporate business users.

3.3. *Planning for ETOPS*. Historically, twin-engined aircraft were penalized on most North Atlantic MNPS routes because of the constraint of needing to stay within a certain distance of an alternate airport should one engine fail. This was before Extended Twin-engine OPerationS (ETOPS), when aircraft were either totally excluded from certain routes or were subject to dog-leg tracking.

Non-ETOPS routeings mean that aircraft must fly within one hour of an adequate diversion airport, as portrayed in Figure 4. The rule distance, denoted by the circles, is that length which a particular aircraft type can travel with one engine inoperative (under standard conditions in still air) in normal cruise with the other engine set at maximum continuous thrust.

Economics are further hindered by the total track length being longer than the optimum track, and the disadvantage of jet streams or prevailing westerly winds on westbound flights. Correspondingly eastbound non-ETOPS flights cannot take advantage of the jet stream core, as it is invariably at a more southerly latitude. Hence, severe time and cost implications exist because the route meanders over Newfoundland (for Gander), Greenland (for Sondre Stromfjord) and Iceland (for Reykjavik). These routes are quite mountainous and potentially dangerous in themselves.

Eligibility for flight under the stringent ETOPS regulations means that aircraft must be type-certificated and the operator must hold an ETOPS operation approval.

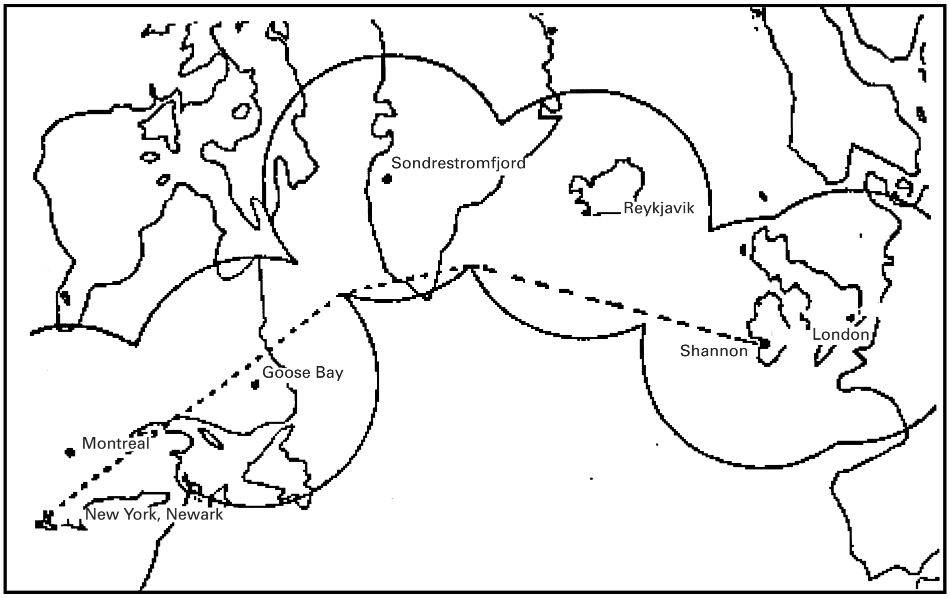

Figure 4. 60 minutes non-ETOPS situation.

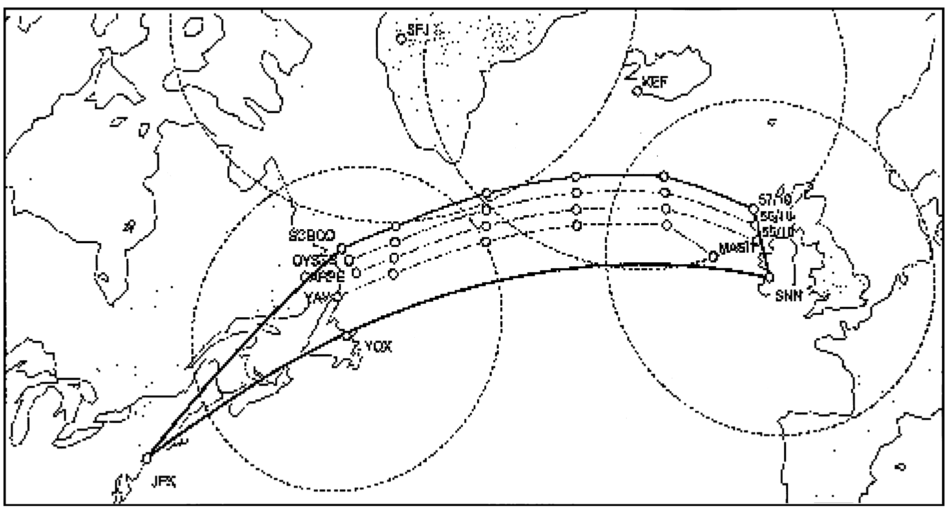

Figure 5. The 90 minute diversion circles.

The degree to which an operator and its aircraft are ETOPS-rated is given by the number of minutes it would take the aircraft to travel (on one engine) to an alternate airfield.

To illustrate the various limitations which the lower ETOPS-approved times impose, consider the following ratings:

(i) 90 minutes: as shown in Figure 5, the ability to fly westbound on the very northern OTS tracks only, if at all, renders the distance travelled considerably

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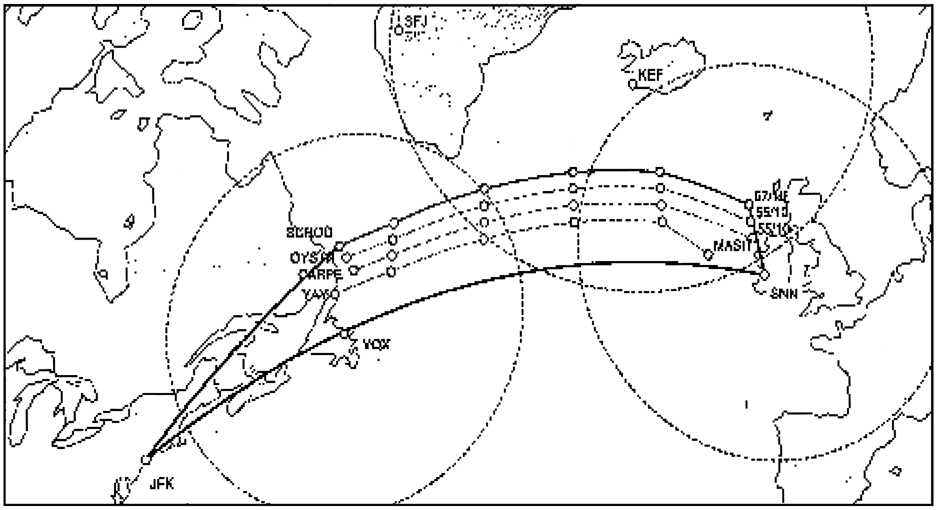

Figure 6. The 90 min + 15 % diversion circles.

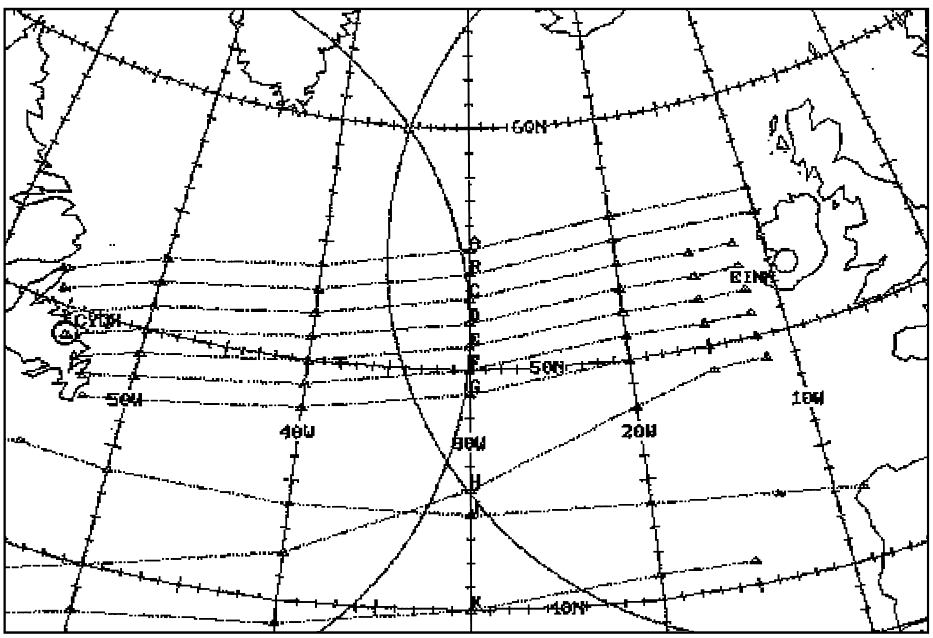

Figure 7. The 120 min + 15 % ETOPS diversion circles.

greater than the Great Circle Distance, with consequential financial and time implications. The eastbound traffic situation is worse due to being unable to use jet stream tailwinds.

(ii) 90 minutes + 15 % ETOPS, equal to $103\frac{1}{2}$ minutes diversion as portrayed in Figure 6, copes with some of the planning impracticalities of 90 minutes,

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consequently enabling planners to use more of the northerly westbound track system.

(iii) 120 minutes covers most westbound routes, but still hinders eligibility for some eastbound. Hence the introduction of 120 minutes + 15 % which equals 138 minutes, as demonstrated in Figure 7.

(iv) 180 minutes ETOPS certification is the current maximum diversion time which leaves the operator with the ability to choose optimum tracks for both westbound and eastbound traffic.

Planning for ETOPS therefore involves obtaining the route, its Flight Level and calculating the required amount of fuel which optimizes both time and operating costs. The concept of the Critical Fuel Point (CFP) is essential in ETOPS planning: flight time to an alternate airport and conditions such as de-pressurisation are taken to occur at the most critical point in terms of overall fuel requirements. This time is based on immediate descent to 10 000 ft followed by an optimum cruise to the diversion airfield, a descent to pattern altitude with provision for 15 minutes' holding and three approaches. Five percent additional fuel is allowed for errors in wind forecasts.

Note that there is a need for the provision of greater fuel uplift on eastbound flights than on westbound, aside from diversion contingencies and uncertainty regarding en-route winds. It is in the users' interests to determine how tight a margin may be allowed for fuel uplift purposes: the less fuel taken that won't be used, the better.

The relevance of ETOPS to the North Atlantic region cannot be overstated. In 1992, ETOPS accounted for one in every three transatlantic crossings, whereas it now constitutes over 80 %. This is often because many commercial scheduled and charter routes are flown on thin markets, which do not warrant the capacity of a three or four-engined aircraft. Frequency of operations and good rates of climb are other economic reasons for employing twin-engined aircraft.

4. migrating across the region. In order to appreciate what must be done to get aircraft across the North Atlantic and how the required and necessary separation is achieved under the stringent MNPS airspace requirements, there is a need to understand the region in terms of its rules, infrastructure and meteorological conditions.

4.1. *Operational Fundamentals.* Pilots must not fly within the North Atlantic MNPS airspace unless the flight has been certified by the State of registration or by the State of the operator. Airworthiness and operational approval is normally granted for each individual operator and for each specific aircraft type used in this particular airspace. The certification procedures involved vary with country, although compatibility between States is assured to achieve a uniform standard. This applies to the integrity, continuity, availability, coverage, reliability, capacity and time to recover of individual navigation systems.

An adequate alternate airport is one which an operator and its authority consider sufficient for the performance requirements applicable at the expected landing weight. In particular, it should be anticipated that at the expected time of use, the aerodrome will be available and equipped with the necessary ancillary services such as ATC, lighting, communications, weather reporting, navaids and at least one letdown aid for an instrument approach. All suitable, en-route, alternate airports' services should be appropriate for the particular aircraft. Due to the natural variability of the weather

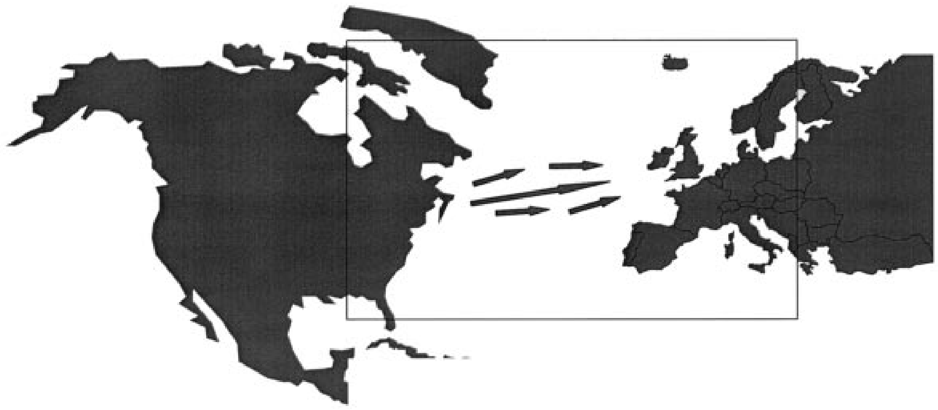

Figure 8. Jet streams in the North Atlantic region. Jet streams are tubes of of very strong winds extending over vast distances and reaching speeds exceeding 200 mph. Located from FL295 to FL360, their effect on NAT traffic is greater in winter than in summer.

conditions with time, the en-route alternate weather minima for planning purposes are generally higher than the weather minima necessary to initiate an instrument approach.

The en-route weather systems which exist in the North Atlantic have profound effects on aircraft operations in the region. Dominant features of the weather systems are the sub-tropical anti-cyclone known as the Azores HIGH, jet streams, and weather fronts on which new storms intensify and old storms often redevelop. Therefore, there is a need for enhanced accuracy of weather forecasts from sources such as weather satellites which scan the Earth from pole to pole every 75 minutes, and balloons carrying radio transmitters 66000 ft into the stratosphere.

Referring to Figure 8, jet streams are winds which are concentrated into fast flowing rivers of air only a few miles in depth, but a few hundred miles wide and up to a thousand miles long. Their significance on navigation is evident by the location of the Organized Track Structure: eastbound traffic favours the use of jet streams as tail winds, whereas westbound traffic tries to avoid their adverse headwind effect. With the wind force weaker and located further north in summer, operators have a greater chance of choosing their westbound track closer to the optimum great circle. Therefore, there is a necessity for operators accurately to predict the en-route winds. This is done by computer models using wind measuring centres' data to forecast the values and publish upper air contour charts, and by reports from airborne aircraft.

4.2. *Maintaining Aircraft Separation.* The way in which aircraft navigate non-stop across the North Atlantic MNPS region has changed dramatically since Captain Charles Lindbergh made the first solo flight. It took him 33 hours, 30 minutes and 29·8 seconds to travel from New York to Paris in 1927. As previously stated, oceanic airspace congestion means that traffic management in the form of MNPS is employed to find a compromise. This currently exists in the form of required separation minima which are maintained between aircraft by applying procedural control. There are two separation types, both of which are fundamental concepts:

(i) *Horizontal*: split into longitudinal (along the track) and lateral (across the track), the former may be attained through the implementation of time or

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distance separation control. The latter accommodates navigation system accuracy and the lack of ATC surveillance for most of the ocean tracks.

(ii) *Vertical*: the general Vertical Separation Minimum (VSM) standards between aircraft used worldwide were established by ICAO in 1960. They are 1000 ft between levels below FL290, and 2000 ft above that. The issue of implementing Reduced VSM (RVSM) in MNPS airspace is dealt with in Section 5.1.

The separation intervals imposed by air traffic services are large due to poor radio communication over the ocean and difficulty in observing exact aircraft positions, with an expected element of cross-track wander by aircraft. Present MNPS airspace separation criteria in the horizontal plane are 60 nm laterally between tracks and 10 min longitudinally between successive aircraft, although a reduction in the latter to 5 min is possible.

The level of equipment forms the basis for minimum navigation capability criteria to enter the MNPS airspace. Such communications, navigation and surveillance equipment that enable aircraft to navigate the North Atlantic in a safe and efficient manner includes:

(i) *Communications*. Very High Frequency (VHF) transceivers are used to provide voice air-ground contact between pilots and ATC when within line-of-sight coverage. High Frequency (HF) is used over areas exceeding VHF's range. This is the case with most North Atlantic communications, but there are drawbacks regarding HF's quality and reliability. Therefore, an increasing amount of communications are being performed with datalink, such as Controller Pilot Datalink Communications (CPDLC). On the ground, adjacent ATS units are linked by dedicated telephone lines between controllers and the Aeronautical Fixed Telecommunications Network (AFTN).

(ii) *Navigation*. When en-route over land, navigation is provided by Non-Directional Beacons (NDB), VHF Omni-directional radio Range (VOR) and Distance Measuring Equipment (DME) to enable aRea NAVigation (RNAV). Of more relevance to the North Atlantic MNPS region, Long Range Navigation Systems (LRNS) may include self-contained Inertial Navigation Systems (INS) or a flight management system using the inputs from one or more Inertial Reference Systems, LORAN-C, or DOPPLER sensor systems complying with MNPS specifications. The LRNS must be capable of providing a continuous indication to the flight crew of the aircraft position relative to the required track. It is also desirable that the navigation system be able to couple with the auto-pilot.

(iii) *Surveillance*. Primary and secondary radar (SSR) systems are used in continental and coastal areas, with oceanic areas using procedural voice reporting as mentioned in the next section. Traffic alert and Collision Avoidance System (TCAS) and Automatic Dependent Surveillance (ADS) are being increasingly employed in North Atlantic MNPS airspace.

To justify consideration for unrestricted operation in North Atlantic MNPS airspace, an aircraft needs to be equipped with two fully-serviceable Long Range Navigation Systems (LRNS), one HF-VHF transmitter and two VHF receivers. Procedures exist for systems failures. If the equipment fails or has a noticeable degradation in accuracy, ATC should be notified and any available visual sightings used in conjunction with VHF contact. Charts may also be employed. The overall navigation performance of all aircraft in the MNPS area is constantly compared with the Target Level of Safety (TLS) established for the region, to ensure that the necessary standards are being maintained.

4.3. *Controlling the Traffic*. Given the previous section's details of the equipment required to operate in the MNPS airspace, there is a need to analyse how air traffic control complements the technology to provide a safe and orderly air navigation system. Although ICAO is the overall agency responsible for air traffic management in the MNPS North Atlantic region, various national air traffic services co-operate to provide ATC coverage.

The concept of Oceanic Area Control centres being the authorities for their respective airspace has been deemed necessary by the sheer amount of air traffic condensed into such short time-frames. These Control Areas work in conjunction with other ATC units, which interface with the MNPS airspace and are crucial to current navigation procedures. As they execute the same roles in a similar manner, this section considers how Shanwick Oceanic Area Control Centre (SOACC) operates in order to understand the importance of ATC facilities regarding air traffic movements in the North Atlantic MNPS region. SOACC is considered a pertinent example because it deals with the bulk of both westbound and eastbound traffic and is also responsible for the generation, preparation and implementation of the westbound Organized Track Structure routes.

Shanwick's operations has its Oceanic Area Control Centre at Prestwick in Scotland and its associated aeradio relay station at Ballygirreen in Ireland. Liaising mainly with Gander Oceanic, SOACC is responsible for maintaining separation between aircraft and for allocating changes to their routeings. They have no means other than pilot position reports of ensuring that the separation between successive aircraft stays above the established minimum. Their intervention is normally necessary only if an aircraft is required to change its Mach Number due to conflicting traffic or to change its Flight Level. Should an aircraft require an immediate change of speed due to turbulence, for example, then SOACC must be notified as soon as possible.

Pilots make requests for tactical adjustments in cruise Mach Number due to reducing weight rendering their aircraft more fuel-efficient. ATC approval is given if traffic conditions permit. Correspondingly, step-climbs are accommodated where strategically possible, thereby enabling pilots to conserve fuel, with climb speed being the last assigned Mach Number.

The functions described in the previous two paragraphs are completed by two planners, the *Entry* planner and the *En-route* planner:

(i) the *Entry* planner deals with initial clearance requests and sees where and when aircraft can be slotted into the OTS based on their estimated times of arrival at the entry point. Adopting a first come – first served philosophy, the *Entry* planner 'tries to accommodate all reasonable requests'. There is, after all, a finite maximum number of permissible combinations.

(ii) the *En-route* planner regulates both east and westbound aircraft in the area. As the traffic is quite uni-directional, requests are usually in the same direction. However, contra-flows do exist and attention to detail is paramount. In-track climbs are implemented by asking the higher aircraft to move first, leaving a slot for a lower one. According to an *En-route* planner, pilots do not fully realise that the chance of obtaining re-routes and en-route step climbs is quite high in that 'All they have to do is ask!'.

Methods employed for aircraft monitoring in the Shanwick Oceanic area include:

(i) *Enhanced Traffic Management System* (ETMS), which uses computer-based information from Cambridge, Massachusetts, USA. Using radars located in the UK, Canada and the US, this system's Visual Display Unit (VDU) output shows all aircraft on the North Atlantic based also on position reports and flight plans. The image is refreshed once per minute.

(ii) *Flight Data Processing System* (FDPS) which is another computer system that constantly works out estimates of where the aircraft will be and checks for potential conflicts. Based on position reports from pilots and their estimates for the next two waypoints, this program alerts the controller, who attempts to talk with the aircraft to check whether data was input incorrectly, for example. A frequent problem is that pilots report times which are incorrect by an hour.

4.4. *Oceanic Clearances*. All aircraft wishing to cross the North Atlantic, whether through Minimum Navigation Performance (MNPS) airspace or not, are required to obtain an oceanic clearance from the relevant authorities. An oceanic clearance is a list of the aircraft routeing to be followed in the form of cleared Flight Levels and waypoints, either stated in longitude and latitude points or as named waypoints, applicable from the OTS boundary entry point. Pilots are required to request clearances at least thirty minutes prior to arriving at the Oceanic boundary from the air traffic control unit responsible for the first oceanic area within which they wish to operate.

The request for clearance should include the aircraft call sign, the OTS or full random track coordinates, the Flight Level and Mach number, the ETA at area control entry point and any change to the filed flight plan which would affect its progression. ATC then replies and either changes the allocated track and Flight Level or confirms the expected clearances.

At airports situated within 30 minutes' flying time of the oceanic boundaries, the clearance is obtained before departure. Advantages of receiving the clearance when still on the ground include a more accurate knowledge of en-route fuel requirements and the ability to delay departure until a more suitable track and Flight Level become available. A perceived disadvantage by the relevant airlines is that Flight Level preference is given to those aircraft already in the air when requesting their clearance. Clearances may now be obtained using delivery frequencies when in coverage, HF to the control centre through the appropriate aeradio station, via domestic or other ATC agencies, or by datalink.

4.5. *Navigating Through The Airspace*. Application of the Mach Number Technique enables subsonic aircraft to operate successively along the respective (organized and random) tracks in a safe manner by maintaining appropriate Mach numbers for the track phase of their transatlantic flight. The principal objective of this method is to achieve improved utilization of the airspace on the long OTS route segments, noting that the Mach number measures airspeed as a percentage of the speed of sound.

The procedure in the North Atlantic Oceanic airspace is to include the desired Mach Number in the flight plan and calculate estimated times for the significant points along the track. The prescribed longitudinal separation between successive aircraft flying a particular track at the same Flight Level is established over the track entry point. It is imperative that pilots adhere strictly to their assigned Mach number. Two aircraft flying at different speeds may fly on the same track, whereby the Mach number effect is maintained by varying the 'entry time' between aircraft. Practical experience has shown that this method is more likely to maintain the required time interval between aircraft than any other technique.

Unless otherwise requested, position reports are made in accordance with the significant points on the assigned route. The average time interval between the reports is 30–50 minutes. Given verbally on HF, they include present position and time, fuel remaining, next waypoint and ETA at that position. If the estimated time for the next position report is found to be in error by three minutes or more, then the controlling authority is notified immediately. Therefore, it is essential that pilots conducting flights in MNPS airspace utilize accurate clocks which are synchronized with a standard time signal based on UTC.

Plotting on charts enhances the accuracy and safety of pre-flight preparation, provides the pilots with a visual presentation of the intended route and can often identify any potential en-route problems. It is also advisable to plot the nearest adjacent tracks and those that cross the planned or cleared route. The flight's progression is then superimposed on this navigation chart, paper or electronic, with any lateral offset of position immediately noticeable.

In the event of an inability to maintain an assigned level, in-flight contingency procedures are actioned after a revised ATC clearance has been obtained. If unable to comply with the above, the aircraft should leave its assigned route or track by turning 90° to the right or left and broadcast its intended movements on 121·5 MHz at frequent intervals and squawking A7700 when outside VHF range. Then it should start its descent while turning to acquire a parallel track laterally separated by 30 nm from its original route. For subsequent level flight, a level should be selected which differs from those normally used. Should an engine be lost, the aircraft's Mach Number and altitude will decrease. In the event of a problem which necessitates an en-route diversion to an alternate airport, a further turn towards the alternate aerodrome is expedited once below FL290.

It is essential that strict operating procedures are adhered to when navigating across the North Atlantic region, which is particularly necessary in this MNPS airspace because of the congested sections and the lack of easily accessible alternate aerodromes. However, an ever-increasing amount of traffic does make its way between the two continents, albeit with aircraft often not flying their optimum profiles.

5. future of mnps airspace. To further optimize and enhance operations in the North Atlantic's MNPS airspace, its capacity and efficiency must be improved. Providers of Air Traffic Services and the system's users work together to draft and implement suitable amendments which enable more aircraft to fly their optimal routes in terms of fuel consumption and flight time. Such co-operation is contained in ICAO's regional Air Navigation Plans.

ICAO's predominantly satellite-based global CNS/ATM aims to offer an affordable technological leap over conventional systems in regions which are invariably served by antiquated, inadequate conventional radar and voice-driven ATM systems. These future air navigation systems and concepts encompass all geographical, economical and technical considerations necessary to allow automated communications, navigation and surveillance of aircraft. They aim to provide enhanced air traffic management with continuous information on aircraft position and intentions. These systems and concepts must be applicable to aircraft operations from the corporate sector to future Very Large Aircraft.

However, current aircraft navigation systems are already capable of achieving predictable levels of performance accuracy. Therefore, Reduced Separation Minima (RSM) are now possible and may be seen as part of an evolutionary approach to optimising North Atlantic operations, enabling increases in system capacity. Indeed, MNPS will eventually be designated as a Required Navigation Performance (RNP) area – with aircraft ultimately able to fly their own optimized flight paths using tactical intervention for conflict resolution.

Both RSM and RNP are fundamental concepts in the struggle for enhancing the airspace and warrant further discussion as integral parts of the MNPS airspace's future. Evolution of the oceanic concept to improve service is based on reductions in separation minima and increased levels of flexibility in the system.

5.1. *Implementation of Reduced Separation Minima*. It is implicit in the concept of MNPS that all flights within the airspace achieve the highest standards of horizontal and vertical navigation performance and accuracy. Separation minima in the current Organized Track Structure environment governs the airspace capacity over the ocean. Hence, reduced separations would increase the number of slots available and, correspondingly, the chance of flying closer to an aircraft's optimal route profile through the availability of more fuel-efficient altitudes and tracks routeings.

The planned MNPS levels of separation minima are:

(i) *Reduced Vertical* (RVSM) to 1000 ft above FL290;
(ii) *Reduced Horizontal* (RHSM) to 30 nm lateral and 5 minutes longitudinal;
(iii) *Further Reduced Horizontal* (F-RHSM) to 15 nm both lateral and longitudinal.

Noting that the development sequence is structured to provide progressively more optimal routes and profiles for the predicted traffic levels, MNPS airspace is expected to be a mixture of:

(i) *Direct routes*: few organized tracks, with most traffic flying random tracks.
(ii) *Free Flight*: where each aircraft has the freedom to optimize its flight profile subject only to maintaining separation from other traffic.

On 8 October 1998, vertical separation in the MNPS was reduced from 2000 ft to 1000 ft spanning Flight Levels 310 to 390. Thus, the choice of optimum levels was widened, making it easier for operators to file flight plans and obtain their preferred clearance. The implementation process has involved three overlapping, phased steps which provide progressive increases in capacity:

(i) *System verification trials*: the height-keeping performance of RVSM-approved operators was checked with ground and airborne equipment to ensure that safety goals were met and to gather statistics. Fixed-base height monitoring units, which were installed on both sides of the ocean to monitor aircraft actual height-keeping performance, were used in conjunction with airborne GPS monitoring units to assess operators' accuracy.

(ii) *Operational trials*: vertical separation was reduced to 1000 ft on 27 March 1997 in a portion of the MNPS airspace for FL330 to FL370 for one year to assess RVSM-specific air traffic control and operational procedures.

(iii) *Full operational capability*: commenced in early 1998, this phase included continuous system monitoring and verification trials, as per Phase (i). The number of RVSM operations in MNPS airspace now exceeds 90% of flights. The recent implementation is the penultimate phase: it will be fully operational when RVSM is introduced in Europe's spaghetti-like route structure in 2001.

During the Phase (ii) operational trials, the level of organized track demand dropped by 25%, resulting in more airspace available for random routeing. A $30 million reduction in the North Atlantic fuel penalty is expected for 1998. Indeed, operators will see an increase in economic benefits, operating capacity and efficiency at a minimal cost. Due to current congestion, users benefit immediately from RVSM. It is thought that 'reduced vertical separation on North Atlantic routes will nearly double air traffic capacity when the new rules are fully implemented', and officials reckon that safety will be ten times better under the new scheme because stricter altimetry accuracy requirements are being imposed.

One other estimate indicates that the overall benefits of RVSM are 4·6 times greater than the costs of implementation: the cumulative savings from the greater availability of more fuel-efficient tracks, estimated to be $176 million over a 20-year cycle, can be compared with a total cost of $38 m. This indicates a payback time of only $3\frac{1}{2}$ years. When fully operational with an 85% increase in available Flight Levels, the average reduction in fuel burn due to RVSM's introduction is reckoned to be approximately $1–1\frac{1}{2}$% of the fuel aircraft currently use in North Atlantic MNPS airspace.

Reductions in separation standards will result in more economically beneficial flights, with the ability to accommodate increased demand as long as there is no sacrifice in safety. RVSM is now well established, with the programme recently declared fully operational in the North Atlantic MNPS region. This is ICAO's proving ground for RVSM. Once the MNPS procedures are fully proven, RVSM should be technically feasible on a global basis.

Approval to operate at these reduced minima levels within MNPS airspace is subject to State authority and to additional requirements regarding aircraft height keeping performance in accordance with the Minimum Aircraft Systems Performance Specification (MASPS). Operators must provide detailed reports on the exact capability of their fleets to satisfy stipulated criteria, similar to obtaining ETOPS approval.

The aircraft and operator approval process comprises specific equipment requirements in the form of minimum equipment carriage and airworthiness approval regarding altimetry system errors. Details of aircraft which have been issued with RVSM airworthiness approval are sent to the Central Monitoring Agency, which is responsible for determining whether an operator's fleet has demonstrated acceptable performance. Aircraft must be re-checked every two years.

Unless wishing to fly above FL390, aircraft must have their altimetry systems individually flight tested to certify that they can meet the standards required to maintain safe separation. The actual MASPS standard height-keeping equipment necessary for aircraft to maintain the 1000 ft separation could be as low as $5000 for modern aircraft but as high as $300 000 for older aircraft.

5.2. *Required Navigation Performance*. The concept of Required Navigation Performance (RNP), characterized as 'a statement of the navigation performance accuracy necessary for operation within a defined airspace' was brought about because the increasing worldwide demand for air transport cannot be sustained by the current terrestrial infrastructure. RNP is currently being developed and implemented as an essential element of the global future air navigation system.

It was the ICAO Special Committee on Future Air Navigation Systems (FANS) which adopted this approach, using RNP 'types' to provide for existing and future levels of navigation accuracy for all phases of flight. These types are identified by a single value expressed in nautical miles for each stage. For example, RNP10 specifies that all flights must be within 10 nm of their intended position for 95 % of the total flying time.

In theory, any sort of navigation system can be used to provide RNP. The aforementioned 'types' are linked with expressions such as Basic and Precision-RNAV, whereby aRea NAVigation (RNAV) invariably enables aircraft to achieve a required navigation performance. This system is heavily dependent on ground-based aids, which has limited the implementation of RNP rules throughout the world's airspace. Consideration must therefore be given to individual regions' airspace infrastructure including communications, navigation, surveillance and ATC capabilities. Each route structure's traffic density and complexity are other factors which affect the development of new aircraft separation minima based on this concept.

6. summary. In this 'satellite' age, the North Atlantic air traffic management system may be perceived as somewhat out-dated; however, it works. RVSM is not really based on future air navigation systems and concepts. Indeed, it is maintained that some of the greatest benefits in cost and capacity will come, not from satellite navigation, but from the implementation of 1000 ft RVSM. It has enabled cost savings which have eluded users trying to reap rewards from the more sophisticated elements of FANS. Ironically, RVSM's success has made carriers reluctant to invest in expensive FANS avionics for operations because the incremental gains over the simple RVSM are not thought to be worth pursuing.

Although it has provided the current required increase in capacity, the ultimate solution to North Atlantic air traffic management problems is not just the implementation of RVSM. For instance, Reduced Horizontal Separation Minima (RHSM) will further increase air traffic flow when introduced in early 2000, using Automatic Dependent Surveillance (ADS) as a means of tracking aircraft. Trials already indicate future success. Consequently, the most appropriate way to alleviate its air traffic congestion problems is to maximise the efficiency of the current system and exploit any possible increases in capacity. It is imperative, however, that each concept is comprehensively tested prior to implementation.

It is hoped that the reader now has an understanding of how aircraft traverse MNPS airspace and the thinking behind the development of its structure. The transatlantic scenario highlights the various route layouts which are possible and how such track systems may be managed. Indeed, this paper has attempted to cover the available route planning options, including limitations such as ETOPS-restrictions and the potential benefits of changes in air traffic management.

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key words

1. Navigation Practice. 2. Safety. 3. Air Traffic Control.