REQUIRED NAVIGATION PERFORMANCE (RNP) - A NAVIGATION UPDATE

R.G. Chellappa* and S.K. Saraswati**

Abstract

In the recent years, air traffic has increased globally. The rate of growth of air traffic has been estimated to be 8% per annum. In India, the international and domestic aircraft movements have posted an increase of 12.1 and 11% respectively, over the previous year's figures. This growth in air traffic manifests into operational problems like congestion and bottle necks in air traffic affecting the economy of aircraft operations. Recent increase in fuel costs also added to the need for achieving economy in aircraft operations. The aircraft operators felt a need to drive the costs down. In order to sustain the air traffic growth and also to ensure safe, regular and economic flow of air traffic, ICAO, the concerned contracting states of ICAO in Asia and other related organizations like the IATA, SITA etc., joined together and decided to introduce a route structure with more air routes which are parallel and closer. This Revised ATS (Air Traffic Service) Route structure - Europe, Middle East, Asia Route Structure South of Himalayas (EMARSSH) was introduced on the 28th November 2002. However, the inherent drawbacks in navigation along such closely defined air routes had to be tackled. With safety foremost in mind, it is essential to be able to define the requirements for accurate navigation and to use the best tool available to qualify aircraft for today's demanding operations. This was achieved by suitably defining the Required Navigation Performance (RNP) to be complied by the aircraft.

Introduction

Air Navigation is the art of flying the aircraft between two points using navigational aids. There are two types of facilities being used to help an aircraft navigate from one point to the other. There are autonomous airborne navigation aids, which do not require any help from any outside facility and there are navigation facilities which generate positional and derived information in conjunction with some external to the aircraft facilities. The Conventional Navigational aids are of the second type and the current ones in use were defined in Annex 10 to the Chicago Convention of 1944 and are all installed on ground. Performance of such navigational aids is limited by the terrain conditions and it becomes difficult to install such navigational aids in hilly terrains and in oceanic area. Because of these problems the routes followed by the pilots in civil aviation become longer than the straight line between two points. This results in more flying times and also more fuel consumption. Such conventional air-routes are also prone to congestion of air-traffic since the aircraft are required to fly these defined routes only, in spite of enough of air-space being available around these fixed routes. In such a situation, pilots are unable to fly their optimum flight level again leading to reduction in fuel economy. It is therefore required to straighten air-routes and introduce more routes to ensure safe, regular and economic flow of air-traffic. Accordingly a new set of routes which are called the Area Navigation Routes, were introduced recently with active coordination between International Civil Aviation Organization (ICAO) and countries right from Australia to Europe. However the aircrafts flying on such routes should have the Required Navigation Performance (RNP) to avail this advantage. Area Navigation mainly uses navigational aids like Inertial Navigation Systems (INS), Inertial Reference System (IRS) etc. Therefore navigation may be dependent on ground based navigational aids or airborne systems like INS/IRS.

Ground Based Navigational Aids

Ground-based navigational aids are electronic systems like the Very high frequency Omni Range (VOR) co-located with Distance Measuring Equipment (DME) or the

* Manager (Communication), Airports Authority of India, Sourthern Region, Chennai Airport (ATS Complex) Chennai-600 027, India
** Executive Director (CNS-Planning), Airports Authority of India, Rajiv Gandhi Bhavan Safdarjung Airport, New Delhi-110 003, India, Email : redsr_aai@vsnl.net
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Non Directional Beacon (NDB) or any such aids. Although these systems have their inherent limitations, the accuracy of these systems is considered to be within tolerable limits for the purpose of civil aviation. Whereas VOR/DME gives the distance and heading (ρ-θ) information to the pilot for navigation to/away from the system, NDB helps the pilot in navigating towards or abeam the location where the facility is installed. Because of its relatively better performance, VOR/DME is preferred for navigation purposes. But even this system is not free from limitations.

- Since VOR/DME operate in VHF band of frequency spectrum, their range is limited by line-of-sight which is hardly 200 nautical miles (nm) at flight level 290 (29,000 ft).
- Performance of VOR/DME is also limited by the extent of level-terrain available around the radiating system, which makes the facility difficult to be installed in hilly terrain and impossible over oceanic area.

Such problems not only make it impossible to have a straight air-route (which are obviously preferred due to economy) between two destinations but also necessitates an alternative navigation system(s), the performance of which is not limited because of the factors mentioned above.

Airborne Navigation Systems

Navigation using conventional ground-based navigational aids poses serious handicap in the case of trans-continental flights, which fly for very long distances and duration over land and high seas. In such cases, the pilot has to navigate using some other system which are independent of the conventional ground based facilities. There are some navigation systems viz, Inertial Navigation System (INS) and Inertial Reference System (IRS) that are used by the pilots for navigation when they are either out of range of ground based navigation facilities or there are no such systems installed on that particular route segment. INS and IRS, though autonomous, their accuracy degrades with the duration of flights. However, in order to accommodate the deteriorating performance of these systems and to meet the operational requirements, such systems are permitted by ICAO by suitably separating the air-routes to accommodate the depreciation of performance. That is to say, the air-routes are so wide-spread that an aircraft in one air-route shall not conflict with or stray into the near-by air-route because of degraded accuracies of the INS/IRS over long-routes. Although it may seem that this is the best via-media to overcome the range and site limitations of the conventional navigational aids, this type of route-structure, over the years, has manifested into serious operational problems.

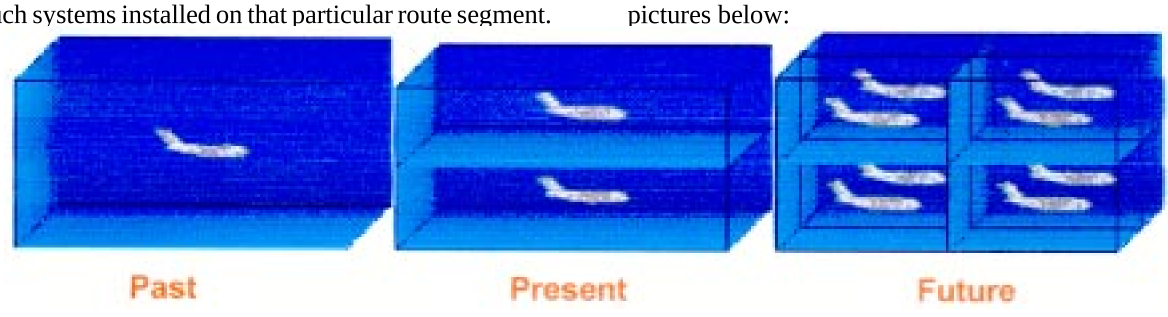
Problems of Conventional Route-structure

The requirement of wide-spread (conventional) route structures limits the number of routes and the flights bound for various destinations are required to follow a single route for a significant portion of their travel. This situation coupled with the manifold increase in the air-traffic, has posed operational problems resulting in

1. congestion
2. bottle necks for smooth flow of air-traffic
3. longer flying time
4. aircrafts unable to fly at the optimum flight level
5. reduced fuel economy in view of 3 and 4 above

Solution to the Problems

"The continuing growth of aviation places increasing demands on airspace capacity and emphasizes the need for the optimum utilization of the available airspace. These factors, allied with the requirement for operational efficiency in terms of direct routings and track keeping accuracy, together with the enhanced accuracy of current navigation systems, have resulted in the concept of RNP." [Reference ICAO Doc 9613-AN/937, Manual on Required Navigation Performance (RNP)]. RNP will enhance the airspace utilization, as is obvious from the pictures below:



In view of the above, ICAO, contracting states, airline operators and other related organizations were forced to look for a better route-structure which can handle the present days' volume of air-traffic and anticipated growth with better efficiency and economy. After a series of meetings, it was decided to introduce more air-routes which are parallel and straight to a greater extent separated by a lateral distance of 50 nautical miles. This envisages the optimal use of the air space and also the present days aircraft's navigation capabilities. These are called the Area Navigation Routes or the RNP routes.

Definitions and Explanation of Related Terms

Area Navigation (RNAV) : RNAV is a method of navigation, which permits aircraft operation on any desired flight path within the coverage of station reference navigation aids or within limits of the capability of self-contained aids, or a combination of these (ICAO Doc 4444-ATM501).

RNAV equipment operates by automatically determining the aircraft position from one or more of a variety of inputs. Distances along and across track are computed to provide the estimated time to a waypoint, together with a continuous steering guidance. RNAV capability permits flight in any air-space within prescribed accuracy tolerances without the need to fly over ground-based navigation facility. RNAV capability offers a number of possibilities for air-space planning and design including:

- establishment of more direct routes
- establishment of parallel routes
- establishment of bypass routes to avoid high density terminal areas
- establishment of contingency routes
- establishment of optimum locations for holding patterns
- reduction in ground-based navigation aids

Area Navigation Route : An ATS (Air Traffic Service) route established for use by aircraft capable of employing area navigation (ICAO Doc 4444-ATM501).

Required Navigation Performance (RNP) : It is a statement of the navigation performance necessary for operation within a defined airspace (ICAO Doc.4444-ATM501). There are additional requirements, beyond accuracy (such as integrity, continuity and availability) applied to a particular RNP type. [RTCA DO-236A, Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation]

RNP Type : A containment value expressed as a distance in nautical miles from the intended position within which flights would be for at least 95% of the total flying time. (ICAO Doc 4444-ATM501). The RNP type is based on a navigation performance accuracy value which is expected to be achieved at least 95 percent of the time by the population of aircraft operating within the airspace. (ICAO Doc 9613-AN/937, Manual on Required Navigation Performance (RNP)) Examples, RNP 10, RNP 4, RNP 2, RNP 1, RNP 0.3. i.e. an aircraft approved for and operating in RNP 1 airspace would be expected to remain within ±1 NM of route centerline 95 percent of the time. RNP value includes all errors, i.e. navigation system error and flight technical error. Example: RNP 10 represents a navigational accuracy of +/- 10 nm on a 95% containment basis.

RNP characterizes an airspace wherein the navigation performance accuracy defined by the RNP type which must be achieved by the airspace users. The primary means of achieving required RNP type is by the use of RNAV equipment for navigation. The RNP type for an airspace will thus depend upon the over all navigation performance supported in that airspace and aircraft suitably equipped for that RNP type or better will be able to take advantage of the RNP type of that airspace.

ICAO has adopted RNP 1, 4, 10, 12.6, and 20 with accuracies of +/- 1.0nm, 4.0nm, 10.0nm, 12.6nm and 20.0nm respectively for 95% of the time. Some states have implemented RNP 5 for an interim period.

Aircraft Equipment : Many different types of navigation equipment are currently available that would meet the RNP requirements. Generally, aircraft sensors and navigation equipment may encompass:

- FMS - an integrated system consisting of airborne sensor, receivers and computer with both navigation and performance databases that would provide optimum performance guidance to a display and automatic flight control system.
- Systems which use external navigation aids, such as VOR/DME, DME/DME, GNSS, LORAN-C
- Systems which are self-contained, e.g. INS or IRS

RNP Route : An RNAV route classified in terms of RNP type applicable to the route.

Waypoint : A waypoint is specified geographical location used to define an RNAV route or the flight path of an aircraft employing RNAV (ICAO Doc 4444-ATM501).

Track : The projection on the earth's surface of the path of an aircraft, the direction of which path at any point is usually expressed in degrees from North (true, magnetic or grid). (ICAO Doc 4444-ATM501).

RNP 10 : To initiate the entry of the concept, it has been proposed to structure RNP10 routes in most of the airspace. RNP 10 represents a navigation performance accuracy of ±10nm on a 95% containment basis.

RNP 10 capability additionally requires that aircraft operating in oceanic and remote areas are equipped with at least two independent and serviceable Long Range Navigation System (LRNS) comprising INS/IRS, FMS or GPS of integrity such that the navigation systems do not provide information with an unacceptable probability.

RNP-10 Routes : These are parallel air-routes separated by 50nm laterally. aircrafts with RNP 10 capability, shall have a cross-track and along-track error of less than 10nm for 95% of the flight time in RNP 10 airspace. The error includes positioning error, flight technical error, path definition error and display error. Out of theses errors, Flight Technical Error is the dominant contributor for RNP-10 navigation and the other errors are insignificant. Pictorially the errors can be represented as given in Fig.1.

Navigational Errors (Lateral)

Position Estimation Error : Position Estimation is, determining the aircraft's position over the surface of the earth. Position Estimation Error (PEE) is the difference between true position and estimated position.

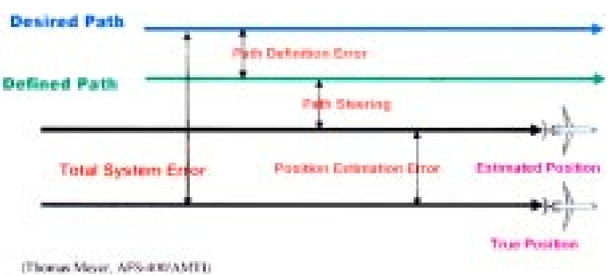


Fig. 1

Path Definition Error : Path Definition Error (PDE) is the difference between the defined path and the desired path at a specific point.

Path Steering Error : Path Steering Error (PSE) is distance from the estimated position to the defined path. The PSE includes both FTE and display error (e.g., CDI centering error).

Flight Technical Error (FTE) : The Accuracy with which the aircraft is controlled as measured by the indicated aircraft position, with respect to the indicated command or desired position is the FTE.

Display Error : These errors include error components contributed by any input, output or signal conversion equipment used by the display as it presents either the aircraft position or guidance commands and by any course definition entry device employed.

Total System Error : The difference between true position and desired position. This error is equal to the vector sum of the path steering error, path definition error, and position estimation error.

Navigation Errors (Vertical)

Additional components of error in vertical plane may be depicted as in Fig. 2.

Altimetry System Error (ASE) : This error is attributable to the aircraft altimetry installation including position effects resulting from normal aircraft flight attitudes.

Horizontal Coupling Error (HCE) : The vertical error resulting from horizontal along track position estimation error coupling through the desired path.

Vertical Flight Technical Error (FTEz) : The accuracy with which the aircraft is controlled as measured by the indicated aircraft position with respect to the indicated vertical command or desired vertical position.

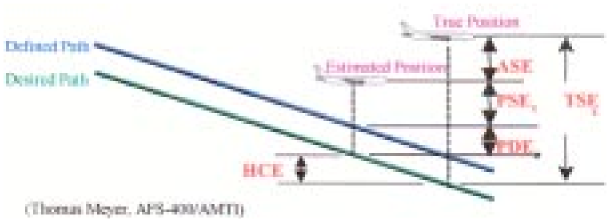


Fig. 2

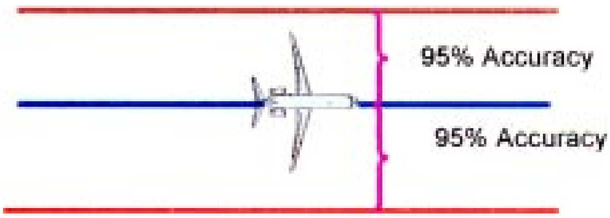


Fig. 3

Vertical Path Definition Error (PDEz) : The vertical difference between the defined path and the desired path at the estimated lateral position.

Vertical Path Steering Error (PSEz) : The distance between the estimated vertical position to the defined path. The PSEz includes both FTE and display error (e.g., vertical deviation centering error).

Vertical Total System Error (TSEz) : The difference between true vertical position and desired vertical position at the true lateral position. This error is equal to the sum of the vertical path steering error, path definition error, position estimation error (altimetry system error) and horizontal coupling error.

Requirement of RNP Certification

With all the above said errors, the aircraft can not, obviously, maintain its track (defined path).

Under the circumstances, having the routes closer (50nm), throws a serious challenge on the air safety. It has, therefore, to be ensured that the aircraft more or less maintain the track within the allowed error limits. The present error limit allowed is ±10nm during 95% of its flying time which is otherwise called as RNP-10. However, not all the navigation systems (INS/IRS) behaves identically in terms of accuracy. This necessitates certification of the navigation system for RNP-10 compatibility.

RNP-10 Certification: (FAA Order No. 8400/12A - RNP10)

RNP 10 certification will be done for specific combination of aircraft and navigation systems. If the navigation system which is to be certified for RNP 10 is an INS, IRS or any other system whose accuracy decreases with increasing flight time, the certification will be limited to the number of hours during which the aircraft can be expected to satisfy both lateral (across track) and longitudinal (along-track) accuracy criteria of RNP 10. The certification is based on statistical tests that use data gathered from repeated flights. In each trial, the operator measures two errors, namely

1. the longitudinal position-determination error of the navigation system
2. the lateral deviation of the aircraft from its planned route

In order for the statistical test to be valid,

- the data gathered in each trial must be independent of those gathered in any other trial. In other word, the outcome of each trial must not influence the outcome of any subsequent trial.
- Data will typically be gathered after an aircraft has flown at least as long as the time for which operational certification is required, while being guided solely by the navigation system which is to be certified for RNP 10
- The operator may not ignore the data that show large errors

As far as determination of errors (1 and 2 above) is concerned, there should be a reference system with whose position estimates, those of the candidate navigation system may be compared. Such a reference system should have an accuracy which is of much higher level as compared to the candidate system.

Reference Navigation Systems : In order to determine the lateral and longitudinal error data, the operator must simultaneously obtain position estimates from:

1. the navigation system for RNP 10 certification
2. a reference system, which must be highly accurate in the area where the position is estimated. (The estimate from the reference system is taken to represent the aircraft's actual position).

The above estimates should be measured simultaneously. The reference systems may be:

- DME/DME positions taken within 200nm of both DME stations, derived automatically and displayed on systems such as Flight Management Computers
- GPS derived positions
- VOR/DME positions taken within 25nm of the navigation aid.

Longitudinal and Lateral Errors : The positions simultaneously reported by both the systems must be expressed in the same coordinate system. The longitudinal error a_i is the distance between the position reported by the reference system and the position reported by the Candidate navigation system, measured along a line parallel to the planned route of flight. (Thus, if the two reported positions are connected by a vector, and the vector is resolved into a components parallel and perpendicular to the route, a_i is the magnitude of the component parallel to the route. The lateral deviation c_i is the distance between the planned route of the flight and the position reported by the reference system i.e. the position reported by the candidate system has no role in determining the value of c_i. The distances a_i and c_i must be absolute distances expressed in nm i.e. expressed in non-negative numbers. Longitudinal errors in opposite directions do not offset each other; nor do lateral deviations to the left and right offset each other. The values of a_i and c_i are determined using statistical procedures and steps as given below.

Statistical Procedures : Sequential sampling procedures are used to determine whether a candidate aircraft and navigation system should receive RNP 10 approval. A sequential sampling procedure typically requires fewer trials than does a statistical test that has a fixed number of trials and has the same probability of making correct decision. In general, the better an aircraft navigates, the fewer trials it will need to pass the test. However, it is desirable, to have sufficiently high confidence in the test results, and so even an aircraft that navigates perfectly will need to perform at least 13 trials in order to demonstrate that it meets the RNP 10 lateral containment criterion and at least 19 trials to demonstrate that it meets the RNP 10 longitudinal accuracy criterion. On the other end, an aircraft that navigates poorly will need relatively few trials before failing the test. The test has been designed so that the average number of trials needed for it to reach a decision is approximately 100.

Steps Involved : The data collected indicate the difference between the aircraft's navigation system and highly accurate reference system. The position determined from the reference system is presumed to be the aircraft's actual position.

- Operator collects the following independent data on each eligible flight:

  - on the last waypoint and the 'to' waypoint on the desired path.

  - The reference system (e.g. DME/DME) computed aircraft position.

  - Aircraft guidance system (e.g.INS) computed aircraft position for each system

- The data must be taken after the guidance system (candidate navigation system) has been operating without any external update for a time at least as long as the time limit being requested.

- The data gathered as above is now used to calculate cross track error (lateral deviation c_i) and along track error (lateral deviation a_i)

- Cross Track Error (c_i): Calculate the perpendicular distance from the reference system computed aircraft position to the desired flight path (the desired flight path is a great circle line between the last way point and the to waypoint)

- Along Track Error (a_i): Calculate the distance between the reference system computed aircraft position and the guidance system (INS etc) computed aircraft position along a line parallel to the desired flight path

Cross Track Pass/Fail : *Mathematical (FAA Order No. 8400/12A - RNP10)*: After conducting at least 13 trials, the operator should add together all of the lateral deviations obtained upto that point. In n such trials, if the sum of lateral deviations does not exceed 2.968n - 37.853, the candidate aircraft and navigation system have demonstrated compliance with the RNP 10 lateral containment criterion. If the sum of lateral deviations equals or exceed 2.968n + 37.853 the candidate aircraft and navigation system do not meet the RNP 10 lateral containment criterion. If the sum of lateral deviations is between 2.968n - 37.853 and 2.968n + 37.853, the test cannot yield a decision. The operator must perform another trial to obtain an additional lateral deviation. This new lateral deviation is added to the sum obtained previously and the new sum is then compared to 2.968(n+1) - 37.853 and 2.968(n+1) + 37.853.

In other words,

Let $S_{c,n} = c_1 + c_2 + ... + c_n$ be the sum of (the absolute values of) the lateral deviations obtained in first n trials.

If $S_{c,n} < 2.968n - 37.853$, the aircraft and navigation system pass the lateral conformance test.

If $S_{c,n} \geq 2.968n + 37.853$, the aircraft and its navigation system fail the lateral conformance test.

If $2.968n - 37.853 < S_{c,n} < 2.968n + 37.853$, the operator must

- perform another trial to obtain c_{n+1}
- compute $S_{c,n+1} = c_1 + c_2 + ... + c_n + c_{n+1}$
- compare S_{cn+1} to 2.968 (n+1) - 37.853 and to 2.968 (n+1) + 37.853 and
- determine whether the candidate aircraft and navigation system pass the test or fail the test, or an (n+2)th trial is needed.

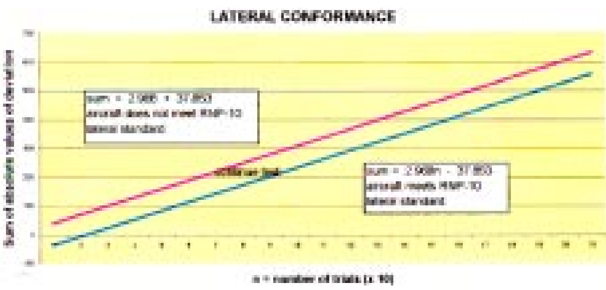
Cross Track Pass/Fail : *Graphical (FAA Order No. 8400/12A - RNP10)*: When the lateral deviation data are collected, $S_{c,n}$ may be calculated and plotted with the number of trials (n) as the x-coordinate and $S_{c,n}$ as the y-coordinate. The test ends as soon as a point falls into the lower right region or upper left region of the Graph 1.

- If it is in the lower right region, the aircraft and its navigation system are considered to satisfy the RNP 10 lateral containment criterion.
- If the point falls in the upper left region of the graph, the candidate aircraft and its navigation system are considered not meeting the criterion.
- Whenever a point is plotted in the middle region, the operator needs to accumulate more data.

In the event that the tests of $S_{c,n}$ do not yield a decision on the aircraft's lateral performance after 200 trials, the operator should perform the following computations:

- compute the quantity $D_1 = c_1^2 + \ldots + c_{200}^2$
- compute the quantity $D_2 = S_{c,200}^2 / 200$

  $= (c_1 + c_2 + \ldots c_{200})^2 / 200$



Graph 1

- Compute the quantity $D_c^2 = (D_1 - D_2) / 200$

If D_c^2 does not exceed 18.649, the aircraft and navigation system are considered to satisfy the criterion.

If D_c^2 does exceed 18.649, the aircraft and navigation system are considered not meeting the criterion and so do not qualify for RNP 10 certification.

Along Track Pass/Fail : *Mathematical (FAA Order No. 8400/12A - RNP10)* : After conducting at least 19 trials, the operator should add together the squares of all the longitudinal errors (a_i) obtained upto that point.

Let $S_{a,n} = a_1^2 + a_2^2 + \ldots + a_n^2$ be the sum of squares of the longitudinal errors obtained in first n trials.

If $S_{a,n} < 22.018n - 397.667$, the aircraft and its navigation system are considered to pass the longitudinal accuracy test.

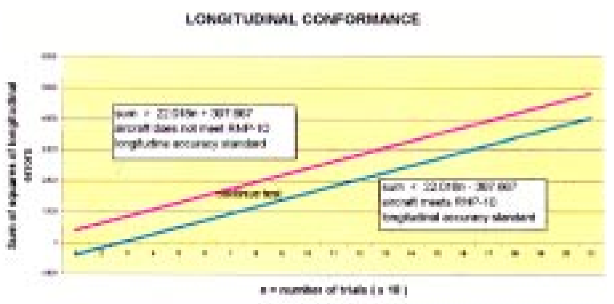
If $S_{a,n} \geq 22.018n + 397.667$, the aircraft and its navigation systems fails the longitudinal accuracy test.

If $22.018n - 397.667 < S_{a,n} < 22.018n + 397.667$, the operator must:

- perform another trial to obtain another longitudinal error a_{n+1}
- compute $S_{a,n+1} = a_1^2 + a_2^2 + \ldots a_n^2 + a_{n+1}^2$
- compare $S_{a,n+1}$ to 22.018 (n+1) - 397.667 and to 22.018 (n+1) + 397.667 and
- determine whether the candidate aircraft and navigation system pass the test or fail the test, or whether (n+2)th trial is needed

Along Track Pass/Fail : Graphical (FAA Order No. 8400/12A - RNP10)

When the longitudinal error data are collected, $S_{a,n}$ may be calculated and plotted with the number of trials (n) as the x-coordinate and $S_{a,n}$ as the y-coordinate. The test ends as soon as a point falls into the lower right region or upper left region of the Graph 2.



Graph 2

- If it is in the lower right region, the aircraft and its navigation system are considered to satisfy the RNP 10 longitudinal accuracy criterion.
- If the point falls in the upper left region of the graph, the candidate aircraft and its navigation system are considered not meeting the criterion.
- Whenever a point is plotted in the middle region, the operator needs to accumulate more data.

In the event that the tests of $S_{a,n}$ do not yield a decision on the aircraft's longitudinal performance after 200 trials, the operator should perform the following computations:

- compute the quantity $D_3 = (a_1 + a_2 + ... + c_{200})^2 \ / \ 200$
- compute the quantity $D_a^2 = (S_{c,200} - D_3) / 200$

If D_a^2 does not exceed 21.784, the aircraft and navigation system satisfy the criterion

- If D_a^2 does exceed 21.784, the aircraft and navigation system do not meet the criterion and so do not qualify for RNP 10 certification. Following each flight, the errors squared are summed up cumulatively. The error squared and the corresponding number of trials are plotted in Fig.2 as above. The along track RNP 10 requirements are passed when the plots of the cumulative errors squared fall below the lower pass line or fail if they pass above the upper fail line.

RNP Approvals (Boeing)

Further information on RNP capabilities of specific aircraft is available in Boeing published "public documents" that describe RNP navigation capabilities.

- 737-300,-400,-500 FMC Update 7.2/8.1 ANP/RNP certified for use with GPS/RNP on 1/17/95
- 747-400 FANS 1/RNP certified
- 777 series FANS 1/RNP certified
- 757 series FANS 1/RNP certified
- 767 series FANS 1/RNP certified
- Boeing RNP standard on all production aircraft by third quarter, 1998 (Thomas Meyer, AFS-400/AMTI).

RNP Implementation

The development of RNP concept recognizes that current aircraft navigation systems are capable of achieving a predictable level of navigation performance accuracy, and that a more efficient use of available airspace can be realized on the basis of this navigation capability. In 1998, ICAO first introduced RNP10 in oceanic and remote areas of the Pacific where availability of navigation aids is limited. The rationale for introducing RNP10 in support of 50 nautical miles(nm) longitudinal separation was developed by the Civil Aviation Authority of Australia (CAAS), while the rationale for implementing RNP10 in support of 50 nm lateral separation was developed by the US Federal Aviation Administration (FAA) (*Tegeder, Robert M, ICAO Seretariat*)

EMARSSH

Europe, Middle East, Asia Route Structure South of Himalayas or EMARSSH, as it is more popularly known is --- a revised route structure implemented recently in November 2002, in line with the foregoing concepts, to ensure Safe, Efficient and Regular flow of air traffic in Asia Pacific Region. These routes are more direct and parallel from the Origin to Destination airport and they are separated by 50nm. Aircraft certified for RNP-10 criteria can fly these routes and avail the inbuilt advantages in terms of fuel economy and reduced flying time. For an example, there was only one route namely B466 which connected western destinations in the Middle East (Gulf) and Europe with eastern destinations like Chennai, Kulalumpur Singapore and Australia. Aircraft had to fly over Chennai and then abeam Mumbai for widespread destinations in the West including those in the Gulf region. This not only increased the flying time but also entailed congestion during peak hours making optimum cruising levels un-available to the aircraft; all reinforcing to reduce the economy of aircraft operations.

As may be seen from the Fig.4, prior to the implementation of EMARSSH routes, aircraft from east to west and vice versa had to overfly Chennai causing a significant bending of route. In the post-EMARSSH scenario, the

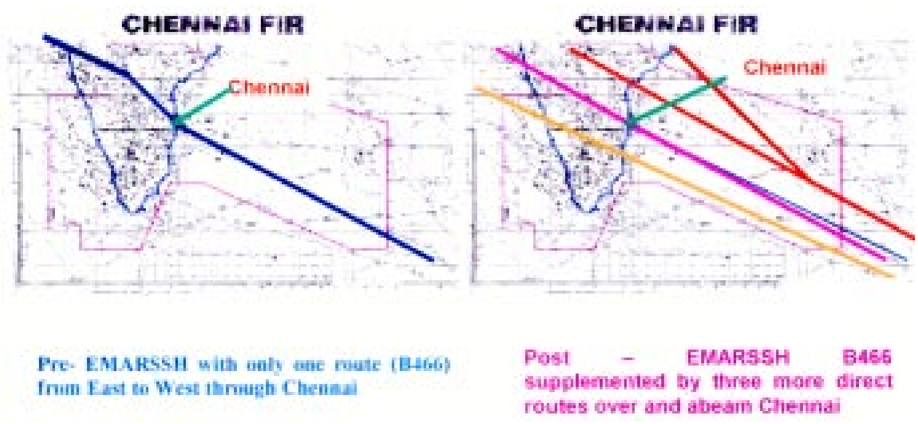


Fig. 4

situation has changed and aircraft need not fly over Chennai, instead they have choices to select their routes depending on their destinations since the B466 has been supplemented by four more routes namely N571, P574, N563 and M300 which are not only more direct towards western/eastern destinations and are definitely shorter than the B466. The B466, however, exists as a Contingency Route for use by aircrafts which are not able to conform to RNP-10 requirements either en-route or are not certified for RNP-10. This is only an example of such EMARSSH routes highlighted for better understanding of the subject and there are, however, many such routes introduced all over India and South of Himalayas.

Conclusion

Introduction of more direct routes in the form of EMARSSH route structure has supplemented the existing routes. This has reduced congestion, bottle necks and also flight time. According to IATA figures, flight times between Asia and Europe have been shortened by up to 30 minutes as well as a significant reduction in the amount of ground delays. Conservative estimates put the likely savings in fuel at somewhere in the order of 25,000 tons per year - and that is calculated just for the shortened route and one can expect that these savings will be much higher, if we take into consideration the fact that more aircraft are now able to fly their optimum cruise levels at a much earlier stage of flight, thanks to enhanced route capacity provided through EMARSSH. The beneficial effect in terms of reduced exhaust gas emissions has also added on to the list. Every one is a winner including the environment and the traveling public. The increased route capacity is enhanced further through the introduction of RVSM (Reduced Vertical Separation Minimum) in November, 2003, in the vertical plane, supplementing EMARSSH in the lateral plane. *One way for airlines to save money is to serve peanuts instead of cashews. Another way is to fly straighter routes together with more efficient airports approaches and departures (McCarmick, Caroll).* Being a Service Provider in Air Traffic, Airports Authority of India has done its part.

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