DAVOR FRANJKOVIĆ, B. Sc.
TINO BUCAK, M. Sc.
Fakultet prometnih znanosti
Zagreb, Vukelićeva 4
MAJA MARTEK, B. Eng.
Zagreb

Technology and Management of Traffic
Review
U. D. C. 656.7.008
Accepted: Feb, 14. 2000
Approved: May 22, 2000

BASIC AREA NAVIGATION (B-RNAV)

ABSTRACT

As a subprogram of wider area navigation, the basic area navigation defines operations within the European airspace in the ATS route network, and terminal controlled areas, according to the developed chronology of gradual implementation and clearly defined authorities regarding its implementation. The introduction of the basic area navigation operations into the airspace of the European Civil Aviation Conference, has resulted directly from a significant growth of traffic density and the impossibility of control using conventional methods. It will insure numerous advantages, first of all greater traffic throughput compared to the previous method of navigation guidance, thereby not disturbing the existing safety standards.

KEYWORDS

B-RNAV, ATM, ECAC, RNAV, ICAO FEATS, FUA, P-RNAV, EATMS

1. INTRODUCTION

Conventional aircraft navigation in the European continental airspace is based on the usage of navigation instruments located on the ground (such as e.g. VOR, DME and NDB) and the resultant ATS route (Air Traffic Services Route) is linked to the points where instruments are located. In this way, the route is completely dependent on the position of the ground navigation instruments. Considering geographically, such system is rigid and unadaptable and cannot be simply expanded so as to absorb the forecast traffic growth, which, regarding capacity, results in inefficient usage of available airspace.

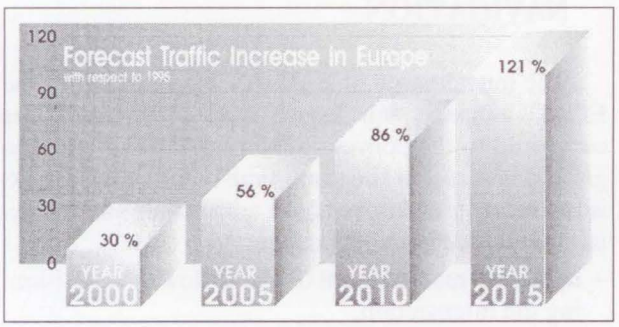

Figure 1 - Forecast air traffic increase in Europe

The present forecasts indicate that the air traffic intensity could more than double by the year 2010, compared to the traffic registered in 1995 (Figure 1 and Figure 2)

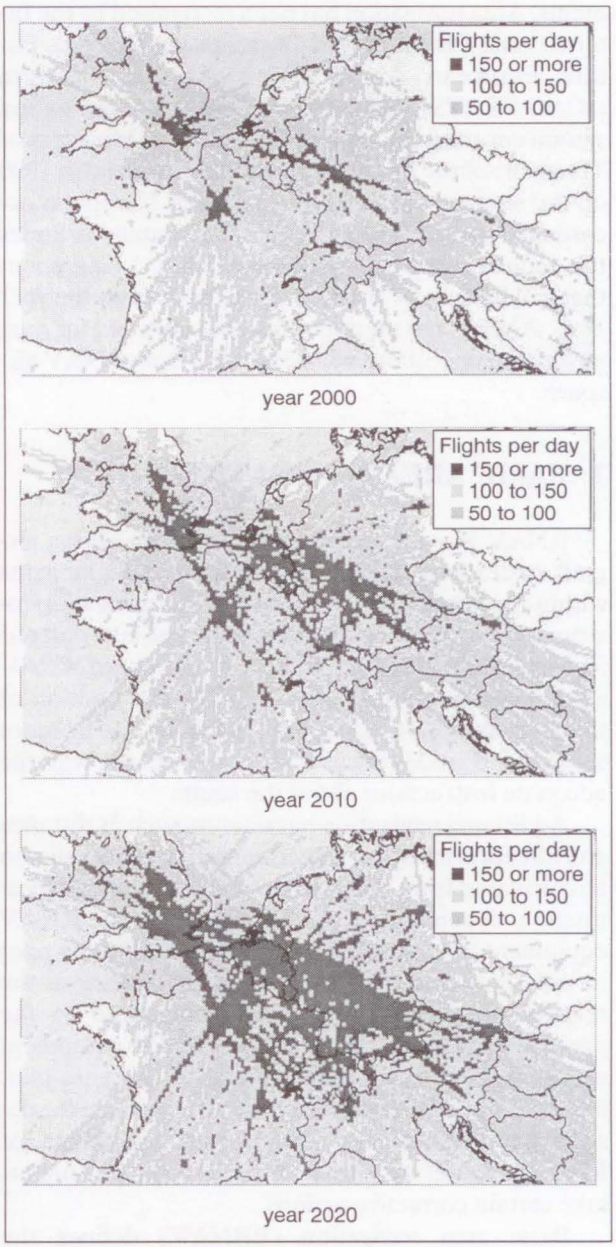

Figure 2 - Forecast of traffic density in Europe

This deep-rooted incapability of the Air Traffic Management services to continue to meet the users' expectations for improved operative adaptability, precision and cost reduction, and for full usage of the current and future technologies, establishes the need to develop a strategy regarding introduction of new concepts for operations in the future airspace under the authority of the European Civil Aviation Conference (ECAC), with the simultaneous maintenance of the existing air traffic quality and the related safety standards.

One of such concepts is the area navigation (RNAV – Area Navigation) – a navigation method which allows the aircraft to fly along a route between any two points within the stipulated precision tolerances, not having to fly over certain ground instruments. Area navigation has been recognised by the International Civil Aviation Organization (ICAO), Future European Air Traffic Management System (ICAO FEATS), and defined as the future navigation system covering the area of Europe. The Ministers of Transport of the ECAC member states agreed in 1990 on the strategy for airspace control in Europe in accordance with ICAO FEATS. The strategy includes the requirements for obligatory RNAV equipment that will have to be fitted in the aircraft from the year 1998. Aircraft not equipped and not certified for area navigation operations will be banned from RNAV airspace.

2. BASIC AREA NAVIGATION

RNAV is a navigation method which allows aircraft operations on any of the desired flight paths within the boundaries of the reference navigation instrument positions or the capabilities of autonomous instruments, or their combination. On-board RNAV equipment determines automatically the position of the aircraft by processing the data from one or more sources and guides the aircraft in accordance with the adequate instructions about the route.

Additional navigation parameters such as distance and direction to the selected destination point can also be calculated from the position of the aircraft and destination, depending on the capabilities of the RNAV equipment. The position can be displayed to the pilot in different ways, and the most practical form is the relative position of the aircraft compared to the pre-calculated path. Most of the RNAV equipment can generate the corrective signal to the auto-pilot based on the side-deviation of the aircraft from the desired path. Other, less sophisticated equipment for RNAV provides the pilot with the possibility to undertake certain corrective actions.

Basic area navigation (BRNAV) defines the RNAV operations in Europe that meet the accuracy of maintaining the required path of ± 5 NM at least for 95 % of the flight duration. Such degree of navigation accuracy is comparable to the one that can be achieved by conventional navigation techniques on the routes defined by VOR and DME equipment, with VOR stations located at distances less than 100 NM.

The capability of reaching the required level of navigational performance in the given airspace does not depend only on the accuracy and functionality of the on-board navigation equipment, but also on the coverage by navigation equipment and the precision of the co-ordinates of the positions insured by navigation infrastructure in the given region. The adequate input data to determine the aircraft position can be obtained from the following navigation sources.

- DME/DME
- VOR/DME (within the available VOR range)
- INS (with the position correction using radionavigation, or two-hour, that is time-limited usage following the last position correction)
- LORAN C (with area limitations of usage)
- GPS (with limitations of usage)

In the ECAC airspace the primary sources of navigation information will be the DME/DME, VOR/DME and GPS systems until the year 2005 at the latest. The availability and continuity of coverage by VOR and DME instruments have been evaluated for the majority of the European territory and they are considered to be capable of satisfying the operation requirements during route flight (reference study EUROCONTROL – DEMETAR 2000).

The preparation of the necessary infrastructure for B-RNAV (navigation equipment, B-RNAV route, procedure of navigation co-ordinates, etc.) remains the responsibility of individual ECAC member states. Each state must also insure that the proper supporting services (that is communication, navigation and control) within the area of responsibility take care of the safety of operations according to the defined group of standards on route separation.

3. ADVANTAGES OF THE BASIC AREA NAVIGATION

The introduction of B-RNAV operations into the ECAC airspace will insure numerous advantages compared to the conventional navigation oriented to ground systems, at the same time maintaining the existing safety standards. These advantages and the related expected benefits include:

- improved management of traffic flow by repositioning the intersection,
- shorter flight distances resulting in fuel savings,

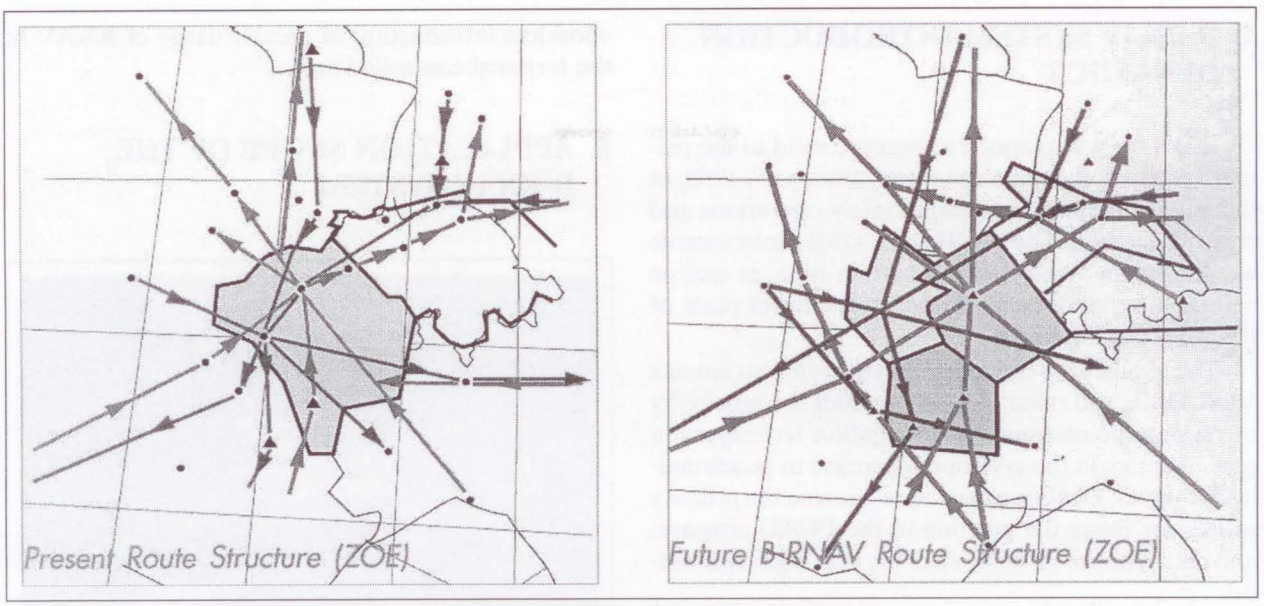

Figure 3 - Changes in the route structure

- reduction in the number of ground navigational equipment,
- more efficient usage of the available airspace, with a more flexible route structure (Figure 3) and application of FUA - Flexible Use of Airspace, which allows establishing of:
  - more direct conditioned routes (double or parallel) in order to service greater traffic flow on the route,
  - alternative or special routes, planned or ad hoc,
  - optimal locations for holding loops,
  - optimising of "feeder" routes (SID and STAR).

All this can be easily achieved, since one of the main objectives of the initial implementation of RNAV actually is to insure that in full exploitation all of the existing on-board systems are used. Many of them are adequate and can realise the required navigation performances (RNP), with greater precision than 5 NM (RNP 5). The requirements are, therefore, set in such a way that they can be met with the most of the existing RNAV equipment, thus realising the greatest advantage.

Simulations show that the increase of capacities of up to 30% can be achieved only by balanced application of B-RNAV together with the network of corrected routes and the implementation of FUA concept.

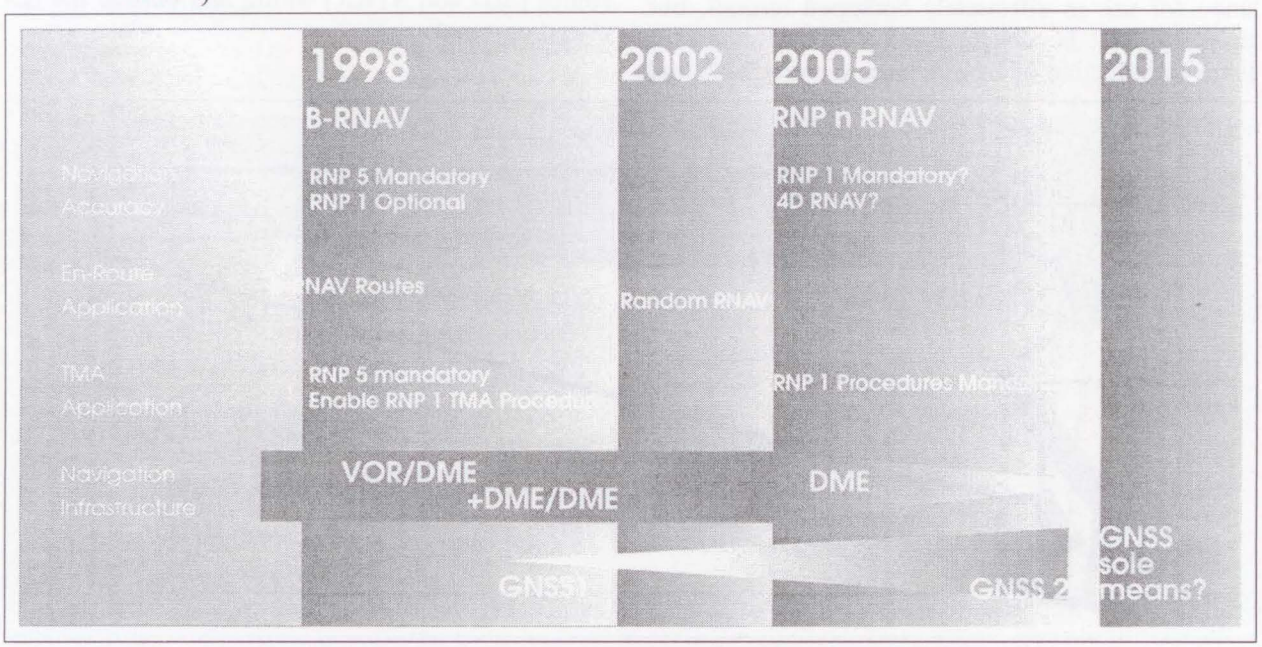

Figure 4 - Planned phases of introducing B-RNAV system

4. B-RNAV SYSTEM INTRODUCTION DYNAMICS

B-RNAV was planned to become valid as the primary navigation equipment from January 29, 1998, in the ECAC airspace, providing timely operations and costs reduction. The VOR and DME instruments would remain available for a certain time, as well as certain internal domicile routes in the lower parts of the airspace (Figure 4).

The availability of ground navigation instruments VOR/DME and radar control provides the possibility of reusing the conventional navigation techniques in case of errors in the system or decrease in functionality. However, DME is expected to become the primary source for fixing the position in the ECAC airspace, and the existence of VOR after the year 2005 is doubtful.

Government authorities can define routes for B-RNAV in the terminal control area (TCA). However, they will remain optional according to the given time scale. Conventional procedures of standard instrument approaches and departures (STAR – Standard Arrival Route; SID – Standard Instrument Departure) and holding procedures will continue to be available. The introduction of flexible area navigation (Random RNAV) and free routes is expected from the year 2002 in the selected areas with reduced availability of fixed routes, but there will be no changes in the required functionality of B-RNAV.

Besides, the required performance for the procedures in the terminal controlled area (TCA) which means precision area navigation (P-RNAV - which matches the precision of RNP 1 or better), will be defined for use in adequately equipped aircraft, but these will not be obligatory. Further development plans introduction of RNP 1 from the year 2005 and considers introduction of greater usage of RNAV in the terminal controlled area.

5. APPLICATION SCOPE OF THE B-RNAV SYSTEM

Figure 5 - Application scope of the B-RNAV system, ECAC member states

The application scope of B-RNAV covers the whole network of air traffic services routes in the ECAC area (Figure 5) including certain "feeder" routes (SID and STAR) within and outside the declared terminal areas.

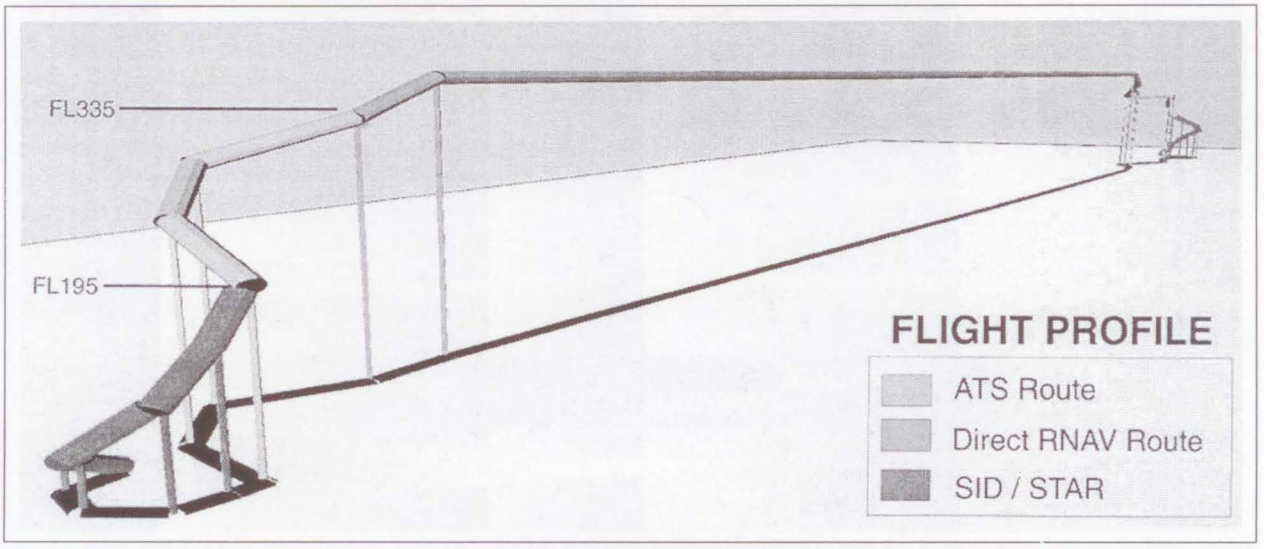

Figure 6 - Flight profile

However, the state authorities can determine domicile routes in the lower sections of airspace, that can be used by aircraft not equipped with RNAV equipment, but that can reach the navigation precision RNP 5 on these routes, i.e. routes defined by VOR and DME instruments (Figure 6).

Studies show that successful use of B-RNAV capacities requires harmonised structure of aircraft fleets (not mixed, with and without B-RNAV equipment), which operate in a harmonised airspace structure in a planned network of routes for RNAV, without dividing the airspace into the lower and upper sections.

B-RNAV includes all the instrumental flights (IFR – Instrument Flight Rules) declared as general air traffic (GAT) in accordance with the procedures stipulated by ICAO. State aircraft are excluded as defined by the Chicago Convention.

6. PLANNED SITUATION AFTER THE INTRODUCTION OF B-RNAV SYSTEM

At the beginning, the regional routes network will continue to carry the air traffic very similarly to the current structure. However, RNAV will enable the modification of the network of the up-to-now fixed routes in order to eliminate bottlenecks and to introduce additional routes, since aircraft will not have to fly over ground navigation instruments. The principles and criteria for designing networks of new routes are presented in the EUROCONTROL document "Concept and Criteria for Medium-Term European Route Network and Associated Airspace Sectorisation / ARN Version 3".

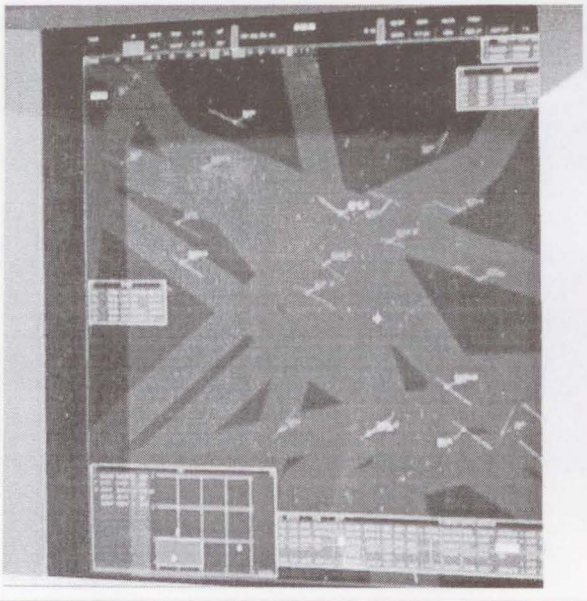

Figure 7 - Air traffic control display

Safety analysis (EUROCONTROL studies) have shown that in the ECAC space, in B-RNAV environment, the requirements for route separation will remain unchanged compared to those determined in Annex 11 ICAO for routes defined according to VOR.

Government administrations are required to publish the basic data, to declare the status of their navigation instruments and they require WGS-84 to become the reference geodetic system in their information regions (FIR, UIR – Flight Information Region, Upper Flight Information Region). Manufacturers, operators and suppliers of databases were obliged to insure the transfer from the RNAV system to WGS-84 by January 1, 1998 at the latest.

Specific RNAV procedures have been dealt with in the ICAO Document Doc. 7030/4 published in 1997, Para 14 – "Procedures for Area Navigation (RNAV) Operations". In case of unusual circumstances, when RNAV system could not maintain the required level of navigation performances, the pilot should request instructions from the air traffic control.

Procedures for obtaining permission for airspace operations for B-RNAV are given in the JAA Document "TGL-2 – JAA Guidance Material for the Airworthiness Approval of Navigation Systems for Use in European Airspace designated for Basic RNAV Operations. The document provides references for determining requirements according to the equipment performances that will authorise the producers, operators and national authorities to issue certificates for RNAV and operative approvals.

Aircraft operating in the RNAV airspace should be equipped minimally with B-RNAV equipment that insures system operation precision equal or better than ± 5 NM (± 9.26 km) in 95 % of the flight duration. Aircraft that satisfy the navigation precision of RNP 5,

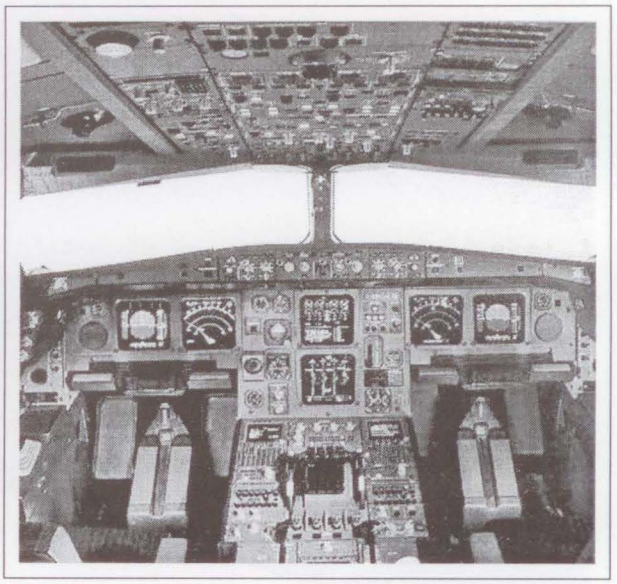

Figure 8 - Interior of an aircraft equipped for B-RNAV operations

but do not have certified equipment for B-RNAV will be banned from flying in the B-RNAV airspace. By 2005 at the latest, or until VOR, DME and NDB instruments cease to be available, operations in B-RNAV airspace will be allowed to aircraft with simple systems for RNAV which meet the precision level RNP 5, but do not meet the condition of continuity, if they possess the VOR and DME equipment.

Authorised government administrations have to insure adequate conditions for training the air traffic controllers for RNAV operations (Figure 7). From the viewpoint of air traffic control, controlling traffic on B-RNAV routes will be slightly different from controlling traffic on routes defined by VOR and DME instruments (conventional routes). It is likely, therefore, that the requirements for additional, special training will be minimal. The structure of redesigned routes will be shaped so as to insure that the working load on an air traffic controller does not increase, in fact, that it decreases wherever possible, in spite of increased traffic.

Regarding pilot training, the authorised government administrations have the responsibility to insure adequate programs for training RNAV operators (Figure 8). The programs have to enable pilots to acquire full proficiency in using the equipment and the necessary operative procedures. If the aircraft crew have reasons to believe that their RNAV equipment is not capable of maintaining the necessary level of precision and integrity, the air traffic control needs to be consulted.

Unlike conventional navigation requiring only the ability to follow the path defined by the ground navigation instruments, RNAV additionally requires the knowledge of auxiliary navigation co-ordinates and data, as well as the co-ordinates of way points that define the routes. Both parameters are crucial for completing the mission and their availability must be certified in accordance with the RTA Document Do200/EUROCAE ED76 "Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation".

7. DEVELOPMENT POSSIBILITIES AFTER B-RNAV

It may be noticed that while for the operations on the route only B-RNAV conditions have to be met, the systems with minimum conditions will not be suitable for terminal operations which require P-RNAV for the majority of SID and STAR RNAV operations. It may also be expected that the simpler equipment which is today available and satisfies the B-RNAV conditions, will not be suitable for operation after the year 2005, when VOR is not used any more and when there are no possibilities of returning to conventional operations in case of RNAV equipment failure.

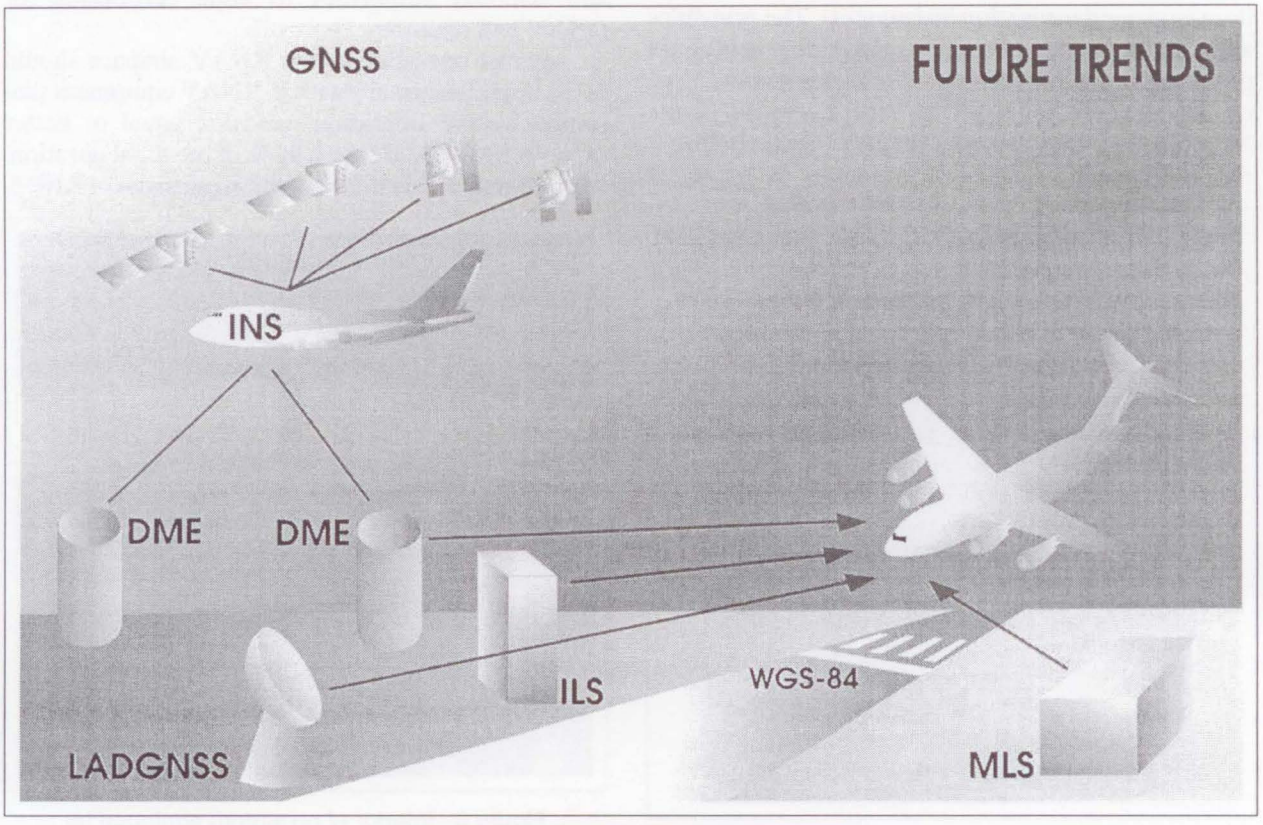

Figure 9 - Future development trends

Whereas today's applications are limited to 2D RNAV (two-dimensional RNAV), as shown by the capacities, they will be extended to 3D navigation, allowing the usage of profile management and the resulting modifications in the terminal control area structure (TCA). Finally, complete 4D (3D + time) is expected to be required in accordance with the planned development within the integrated air traffic management environment within the frames of the future European air traffic management system (EATMS).

The decision on obligatory equipment for RNAV that satisfies the precision requirements of RNP 1 (± 1 NM 95 % of flight duration) is expected to be accepted by the ECAC member states during 1998. The transfer is expected from ground to satellite navigation infrastructure (Figure 9). However, the introduction of RNAV of RNP 1 precision is not expected prior to 2005.

8. CONCLUSION

Continuous increase in air traffic volume requires certain actions in order to increase the capacities, reduce the delays and costs, and provide the possibility to take full advantage of the existing and future technologies maintaining the same safety standards. One of such concepts is the area navigation (RNAV) which allows the aircraft crew to freely select the route connecting two points, without having to fly over the ground navigation instruments, but within stipulated deviations. Basic area navigation (B-RNAV) is a subprogram of the wider R-NAV which defines operations in the European air traffic space on the network of ATS routes and terminal controlled areas (TCA). Care is taken to make a gradual transfer from conventional navigation to area navigation, that is, that maximum use is made of the existing resources during the initial phase of introducing RNAV.

The chronology of introducing RNAV has been developed and the authorities regarding implementation of certain segments and phases have been determined. The planned region for area navigation includes all the European ECAC member states. Maximum use of satellite infrastructure is also expected in the future phases of RNAV. By joining ECAC, the Republic of Croatia accepts also the related duties in implementing RNAV at several levels, starting from legislation all the way to the executive level. This range includes a series of links that have to act in harmony in order to achieve maximum effects in using area navigation and to reach the required level of air traffic safety.

SAŽETAK

OSNOVNA PROSTORNA NAVIGACIJA (B-RNAV - BASIC AREA NAVIGATION)

Kao potprogram šire prostorne navigacije, osnovna prostorna navigacija definira operacije u europskom zračnom prostoru na mreži ATS ruta, te završnim kontroliranim područjima, prema razrađenoj kronologiji postupne implementacije i uz jasno određene nadležnosti u njenom provođenju. Uvođenje operacija osnovne prostorne navigacije u zračni prostor Europske konferencije za civilno zrakoplovstvo direktna je posljedica značajnoga povećanja gustoće prometa i nemogućnosti njegovoga vođenja konvencionalnim metodama, a osigurati će brojne prednosti, prije svega veću protočnost prometa u odnosu na dosadašnji način vođenja navigacije, ne narušavajući pritom postojeće standarde sigurnosti.

LITERATURE

[1] *"B-RNAV Toward Tomorrow's Navigation"*, EUROCONTROL, 1997

[2] **B. Grozdanić, S. Steiner, K. Mikačić**: *"Europski B-RNAV standardi i njihov utjecaj na segmente strategije razvoja zračnog prometa RH"*, Proceedings of the Conference on Automation in Traffic'98, KoREMA, Stubičke toplice, Graz, Vienna, 1998

[3] ICAO Annex 11 *"Air Traffic Services"*, 1994

[4] ICAO Doc 9613-AN/937 *"Manual on Required Navigation Performance (RNP)"*

[5] ICAO PANS-RAC Doc 4444 *"Rules of the Air and Air Traffic Services"*, 1985

[6] ICAO Doc 7030 *"Regional Supplementary Procedures"*, 1987

[7] ICAO Doc 8168 *"Procedures for Air Traffic Services – Aircraft Operations (PANS-OPS)"*

[8] EUROCONTROL Doc 003-93 *"Area Navigation Equipment – Operational Requirements and Functional Requirements"*

[9] *ECAC Strategy for the 1990s Relieving Congestion in and around Airports"*, 1992

[10] JAA – TGL-2 *"Advisory Material for the Airworthiness Approval of Navigation Systems for Use in European Airspace designated for Basic RNAV Operations"*, 1997

[11] RTCA Do200/EUROCAE ED76 *"Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation"*, 1996