AN ANALYSIS OF GLOBAL POSITIONING SYSTEM (GPS) AS AN AIR NAVIGATION RESOURSE TECHNOLOGY AND ITS ADOPTION IN NIGERIA

BY

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DECLARATION

I hereby declare that this project is my original work, supervised by Dr. A. A. Okhimamhe and to the best of my knowledge has never been presented by any student in any form for the award of (M.Tech) degree, but the work of others are acknowledged and referenced.

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DATE

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ABSTRACT

Civil aviation is one of the most important sectors of the Nigerian economy. Nigeria boasts of twenty (20) airports and three (3) active airstrips with twenty five (25) domestic and twenty four (24) international airlines which in 2002 collectively carried 6.3 million passengers. The demand for air transportation in the country is expected to continue to rise in future at a projected rate of between 3-6 per cent per annum. The current air navigation infrastructure and air traffic management capabilities, however present serious constraint to that projected growth.

To meet the challenge, Nigeria accepted the communication, navigation, surveillances and air traffic management [CNS/ATM] concept proposed by the international civil aviation organization [ICAO] in the early 1990s that promote the transition from conventional ground –based to satellite –based air navigation system. The opportunity to implement came when in 1993, the ICAO accepted the US global positioning system [GPS] for aircraft navigation.

Nigeria therefore developed a short term GPS implementation master plan [2000-2005] which conforms to ICAO's Africa and Indian Ocean regional implementation plan [1995-2005]. The plan consisted of a number of projects to be completed at targeted dates that would lead to the progressive approval of GPS as supplemental, primary and then sole means system for aircraft navigation and subsequent decommissioning of the current ground-based facilities in ten [10] years time.

Substantial of elements contained in this projects were successfully accomplished while many were rescheduled with few others yet to be embarked upon.

There are problems associated with the infrastructural development and implementation of the GPS navigation system in the country. Some of the constraints include the full implementation of the world geodetic survey system of 1984[WGS-84] to all airports in the country, establishment of all single EGNOS range and integrity monitoring station [RIMS], the necessity for airborne receivers to be augmented with either receiver autonomous integrity monitoring [RAIM] or aircraft autonomous integrity monitoring [AAIM], problems of certification and standardization and lack of adequate and appropriate training among user communities.

Despite these problems, GPS can be relied upon as a back up to the existing navigation aids in the event of failure and as a primary means over the country's oceanic airspace and most of the airstrips where conventional ground aids are non-existent. Other benefits include improved airspace capacity, air traffic management capabilities and increase in saving on fuel and maintenance cost.

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CHAPTER ONE

1.0. INTRODUCTION

1.1. BACKGROUND

In December 1903, two brothers from Dayton, Ohio (USA), named Wilbur and Orville Wright, were successful in flying a frail structure of metal, wood and fabric into the air. Their powered aircraft flew for twelve seconds and 120 feet above the sand dunes of Kitty Hawk, North Carolina, making them the first people to pilot a heavier – than – air machine that took off on its own power, remained under control and sustained flight.

Subsequent development of the aeroplane into a major instrument of transport has brought with it international problems. The need for safety and regularity in air transport involve the necessity for building aerodromes, for setting up navigation aids and for establishing weather reporting systems, among others.

The second world war had a major effect upon the technical development of the aeroplane, telescoping a quarter-century of normal peace – time development into six years. A vast network of passenger and freight carriage was set up but there were many problems, both political and technical to which solutions had to be found to benefit and support a world at peace. There were concerns with regard to the legal and economic conflicts that might come with peace-time flying across national borders such as how to maintain existing air navigation facilities, many of which were located in sparsely settled areas. For these reasons, the Government of United States facilitated a meeting of 52 allied and neutral states in Chicago in

November 1944. For five weeks the delegates of the 52 nations considered the problems of International Civil Aviation and came up with the Convention on International Civil Aviation (CICA) in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically. Nigeria is a signatory to this convention. The permanent body charged with the administration of the principles arising from the convention is the International Civil Aviation Organization (ICAO).

The growing Aviation industry realizes the inherent risks of air navigation and strives to lessen that risk. Earliest aviators performed nautical navigation, using longitude traversing based on a ship clock and latitude traversing based on sun or star positions. This required dedicated navigator to perform all of these duties – something the early aircraft were not equipped with or able to carry.

Technology from First and Second World Wars greatly increased the range of aircraft and the need arose to increase the accuracy of navigation. The earliest form was known as "dead reckoning" where pilots flew at predetermined magnetic compass headings at specified air speeds for specified length of time. A journey could be broken into "legs". Using simple geometry, they could pilot their expected position on a map, compare that to visual reference of actual position and correct the magnetic compass heading as they continued from leg to leg. All these presumed a constant view of the ground not possible in poor weather or darkness. With the greater range and speed of newer aircraft, better tools were needed to aid the pilot in air navigation.

The early navigation aids were the radio beacons. The Non-Directional Beacon (NDB) and the Locator Beacon (LB) provide relative bearings enabling pilots to head towards the beacons. Though fairly accurate, beacons were inexpensive to install and maintain. The basic electronic navigation system in use is the VHF Omni-directional range (VOR). VOR consists of series of radio stations that beam direction information (true bearing) to aircraft. Most VOR stations are often co-located with distance-Measuring Equipment (DME). The Instrument Landing System (ILS) provides vertical and lateral guidance for aircraft approaches. Other navigational aids include the Gyroscope – an inertial guidance system to determine precisely an aircraft's direction of flight. Precise altimeters are used not only to indicate barometric attitude but also the rate of change of that attitude; thus giving the pilot descent or climb information.

Satellites provide a better system of area navigation than ground-based radio stations. In the 1980s the US Department of Defence developed a highly accurate satellite-based navigation system known as the Global Positioning System, or GPS. GPS is a core element of International Satellite Navigation System known as the Global Navigation Satellite System or GNSS accepted by ICAO as the future means for international aviation navigation.

1.2. STATEMENT OF PROBLEM

Nigeria, a contracting state to ICAO has accepted Internationalized real-time satellite-based communication, navigation, surveillance and air traffic management (CNS/ATM) systems as the eventual and future sole systems for the development of her airspace management Infrastructure (Onasanya, 2002a).

GPS serves as a reliable and cost effective platform for air navigation payloads, thus providing a very accurate interpretations of position, velocity and time as well as enabling reduced separation between aircraft during en route flight without necessarily compromising safety. The usefulness of satellite navigation is more apparent over oceanic airspace and other regions where the provision of conventional ground-based navigation systems is practically impossible (Osunwusi, 2002).

At present, Nigeria's navigation infrastructure is driven by conventional navigation aids. Prominent amongst which include the Omni Directional range (VOR), Doppler-VOR (D-VOR), Non-Directional Beacon (NDB), Locator Beacon (LB), Automatic Direction finder (ADF), Distance Measuring Equipment (DME) and the robust Instrument Landing System (ILS). These systems though relatively accurate, lack the reliability, accuracy, integrity, global coverage and operational availability and continuity of the GPS- based navigation system.

GPS, however, cannot consistently provide the highly precise and safe information in the stable manner required for air navigation of civil aircraft, GPS performances need to be augmented in order to provide the four essential elements of air navigation: integrity, precision, availability and continuation of services.

Nigeria therefore evolves a short term master plan towards the development and implementation of GPS navigation procedures that accords with ICAO Africa Indian Ocean (AFI) CNS/ATM implementation plan. The implementation of this system would cut across a broad spectrum of the aviation industry. From the provision of air navigation and aeronautical services, to airport management, airline operations, liberalization and Open skies policy and training. These activities would be affected by the adoption and implementation of GNSS technology. There must be an appropriate coordination regulating standardization and certification of some of these activities. This would not be possible without proper articulation and stringent policy guidelines and regulations.

GPS cannot be used for aviation navigation without putting the appropriate augmentation system in place. There are different fronts of Satellite Base Augmentation Systems (SBAS) such as the US Federal Aviation Authority's wide Area Augmentation System (WAAS), Europe's European Geostationary Navigation Overlay Service (EGNOS) and the Japan's Multifunctional satellite (MTSAT) Augmentation System (MSAS), all of which satisfy the required navigation performance (RNP) of ICAO. It is therefore necessary to choose the appropriate SBAS, based on its interoperability, service availability and compatibility with the present and future airspace management infrastructure.

The necessary expertise required for the implementation of the GNSS system is inadequate. Similarly the aeronautical users expected to utilise the system lacks the basic knowledge of the equipment and its operations.

This study would therefore make an attempt to proffer solution to these problems so that the Nigerian aviation industry would derive full benefits from the GNSS technology.

1.3. AIM AND OBJECTIVES

The study aims at assessing the GPS navigation system within the context of ICAO – AFI region, CNS/ATM implementation plan. Specific objective pursued to achieve this aim are:

i. Critically appraise GPS navigation system and its implementation in the country;

ii. Evaluate the GPS augmentation systems and determine their reliability for air navigation;

iii. Highlight the necessary requirements for regulating and certifying GPS as a reliable and cost effective tool for air navigation;

iv. Determine the training required for various aeronautical users, and

v. Proffer useful suggestions and recommendations so as to derived maximum benefits for air traffic management.

1.4. JUSTIFICATION

The aeroplane is accepted as the fastest and reliable medium of public transport all over the world. To promote and facilitate air transport activities, high premium must be placed on safety, efficiency and regularity of air navigation service for unrestricted utility at all times.

In Nigeria, aircraft navigation is currently achieved through the use of a multiplicity of terrestrial – based navigation aids (VOR, NDB DME, ILS) and aircraft –based systems (inertial navigation). In addition, the southern and northern extreme parts of the country have large oceanic auspice and desert areas respectively, where no ground-based navigation aids exist or are difficult to install and maintain.

Most of the landing strips scattered across the country are not equipped for economic reasons. As regards the rates of failure of conventional ground radio-navigation equipment, the situation is quite pathetic. Many of these facilities are connected to the national grid where power supplied by the Nigerian Electrical Power Authority (NEPA) is most of the time erratic. Despite the fact there are standby generating sets to back up power supply the time taken to change the source of power supply is critical to aircraft operations.

The situation in the AFI region is not different. Information derived from the ICAO navigation aids database and the AFI air Navigation plan 7474 shows that only 70.5% of the ground radio – navigation equipment needed today is available. The missing 29.5% s consist of 12% of unserviceable equipment and 17.58%, which is not implemented according to plans.

Since the adoption of GPS by ICAO in 1993, member states have started the development and implementation of the GPS navigation technology for various phases of flight in an evolutionary manner: first by the advanced countries of US and Canada and later gradually followed by the developing world. In Africa, countries such as Senegal, Kenya, Egypt and South Africa have spearheaded the continent in the implementation for the global navigation satellite system for the benefit of the aviation sector. Nigeria is gradually treading their path.

There are however problems and difficulties associated with the development and implementation of GPS technology. This includes making the choice of the augmentation system to satisfy the country's national airspace requirement, cost implications, training and other institutional and legal considerations.

Justification for this study is embodied in the fact that there has not been an accredited information of this nature. It is the candid opinion of the researcher that the study will provide Aviators and other members of the public a reference work on the subject matter. The research work is timely and apt as the country recently began trials to test run the satellite-based navigation system.

This study would also serve as motivating research work to subsequent researches and as an information to related bodies concern with air navigation. This study will be useful to Nigerian Airspace Management Agency (NAMA), Nigerian civil Aviation Authority (NCAA), and Nigerian College of Aviation Technology (NCAT) among others.

1.5. SCOPE AND LIMITATIONS

The study would recognize safety and efficiency of global navigation satellite service technology with emphasis on navigation as a core element of communication navigation, surveillance and air traffic management (CNS/ATM) system within the context of AFI region implementation plan (1995 – 2005). The study also intends to cover the augmentation system implementation of the World Geodetic Survey (WGS-84) and GPS approach procedures for selected airports and en route stations.

The study would also cover the reliability of GPS navigation service (Supplemental, primary or sole means) for specific phase of flights namely en route, terminal and airport. The study therefore limits itself to the analysis of GPS as a navigation resource technology only, though there are host of other activities which may be affected by GPS, but cannot adequately and effectively be covered in a study of this nature. It is also envisaged that the study would be affected by financial and time constraints.

1.6. HISTORICAL BACKGROUND TO AIR NAVIGATION SERVICE IN NIGERIA

Historically, the first recorded flight on Nigeria soil was on a Polo ground in Kano where in 1925, a British royal Air Force (RAF) Bristol aircraft landed successfully. That was 22 years after the first recorded flight in 1903 by the Wright brothers. The flight was operated from Khartoum, Sudan. The Kano polo ground was therefore the first "airport" in the country. Considering the fact that there were no aerodromes, landing and navigational aids nor well-constructed runway, the pilot had to rely on known geographical features and the inertial guidance in the aircraft. This flight was clearly a hazardous operation as there were no navigational facilities, radio communication, air route or maps. Prior to independence, the British colonial government realized that if Khartoum – Kano RAF route was to be made an air routes, it was imperative to have emergency landing grounds at intervals of twenty miles. Operations of the RAF eventually evolve into an annual affair with an extension of the route and frequency to cover Maiduguri. As the annual RAF flights progressed, Nigeria increasingly became a focal point, thus the need for more aerodromes.

Against this backdrop, a representative of the Air Ministry in UK paid a fact finding mission to the country to inspect what was then describe as "landing grounds". At the end of the inspection six locations were selected.

These include Maiduguri, Oshogbo, Lagos, Minna, Kano and Kaduna. By the turn of 1950s and 60s, the colonial government embarked on an expansion programme to include Ilorin and Bida among others. These were meant to facilitate the administration of the colony. Proliferation of aviation activities is therefore a colonial heritage.

By 1964, a full pledge Ministry of Aviation was established and charged with the responsibility of air transport development particularly airport development and air navigation infrastructure. Nigeria, initiated an Airport Development Programme, shortly after the promulgation of the Civil aviation Act in 1964 aimed at upgrading the existing aerodrome facilities in the country and developing new ones. Government considered the programme vital in its effort to ensure effective communication links between all parts of the country in order to facilitate regular movement of goods and services across the nation.

The Aviation ministry and indeed the Nigerian Aviation industry have since then been undergoing significant transformation and development. Mergers and de-mergers with the ministries of Transport and communication have characterized its structural metamorphosis over the years.

Responsibility for the administration and maintenance of airports in the country was initially that of the civil Aviation Department (CAD) until the establishment of Nigerian Airports Authority (NAA) by provisions of Decree No.45 of 1976. The Nigerian College of Aviation Technology was established in 1964, the Federal Civil Aviation Authority 9FCAA) took off in March 1989 and empowered by Decree No.8 of 1990. The Federal Airports Authority of Nigeria (FAAN) came into existence on August 31, 1995. This followed the realignment of functions of the former NAA and some Directorates of the defunct FCAA by the Federal Government.

The present structure of the Nigerian Aviation Industry came into being in January 2000 in line with the directive principles of ICAO, which calls for separate autonomous bodies responsible for policy making, service provision and airport management. Thus there was the creation in 2000 of the Nigerian Airspace management Agency (NAMA) as service provider, the Nigerian Civil Aviation Authority (NCAA) as Policy maker and the Federal Airport Authority of Nigeria (FAAN) as the airport operators.

There are presently twenty (20) international and local airports scattered across the country.These are: Lagos, Abuja, Port Harcourt, Kano, Maidugiri, Kaduna, Enugu, Calabar, Yola, Jos, Benin, Minna, Sokoto, Zaria, Ilorin, Ibadan, Bauchi, Imo Akure and Katsina. In addition there are several airstrips juxtaposed in between these airports across the country. Among these are three (3) private airstrips: Osubi operated by shell Petroleum Development Company (SPDC), Eket by (Exxonmobil) and Escravos by (Chevron).

Prominent among other airstrips in the country include the following: Makurdi, Kainji, Keffi, Kontogora, Potiskum, Birnin – Kebbi, Gusau, Jalingo, Bida, Zuru, Nasko, Nguru, Azare, Magbon, Oshogbo, Ashaka, Shiroro, Mangu, Lantang, Biu, Sarti, Mubi, Ayangba, Ajoakuta, Bacita, Miango, Kaltungo, Bambur, Gboko, Lokoja and Agbera – otor (see fig. 3)

1.7 THE NIGERIAN AIRSPACE

The Nigerian airspace otherwise known as the Kano Flight Information Region (Kano FIR) laterally coincides with the political boundaries of Nigeria with two straight lines joining the Benin/Nigeria border on the coast 05°42'N 02°45'E – 0440'N 08°30'E on the Cameroun boundary. Vertically, the Nigerian airspace extent from the surface upwards – unlimited.

N'Djamena FIR to the North East, Brazzaville FIR to the South East, Niamey FIR to the North and North West and Accra FIR to the South, South West and West bound the Kano FIR (see Fig 1).

For operational reasons the Nigerian airspace is divided into two the Kano Centre and the Lagos Centre. The Lagos SUB-FIR is that part of the Kano FIR south of straight lines joining 1000.0N 0338.0E - 0903.0E – 0547.0N 0853.0E. These centres are also responsible for the provision of Area control for aircraft operating within the Nigerian airspace.

The Nigerian airspace has been divided into two Search and Rescue Regions (SRR'S) – namely Kano SRR consisting of the northern half of the country's airspace, and Lagos SRR, made up of the southern half. Two Rescue Co-ordination Centres (RCC's) at Kano and Lagos airports, respectively, are responsible for these two regions.

Immediately sub-ordinate to the RCCs are Six (6) Rescue Sub-Centres (RSCs), with three (3) in each SRR. These sub-centres are located at Abuja, Maiduguri and Sokoto (under Kano RCC), and Enugu, Ilorin and Port Harcourt (under Lagos RCC).

The last level of the organization of the organization of aeronautical SAR are known as Alerting posts consisting of all ATS units, all NAF, naval, Army and Police units. Others include Telephone Exchanges, Fire Stations, local government headquarters, Coastal Radio stations and other corporate and public organizations.

The Nigerian airspace is classified into areas based on the standard ICAO airspace classification for the provision of air traffic services. In this regard, there are two Area Control Centres (ACC) at Kano and Lagos, twelve (12) terminal control areas (TMAs) nineteen control zone areas and one aerodrome flight information area. The Nigerian Airspace Management Agency (NAMA) is responsible for managing the airspace over Nigeria.

FIG. 1: NIGERIAN AIRSPACE (KANO FLIGHT INFORMATION REGION)

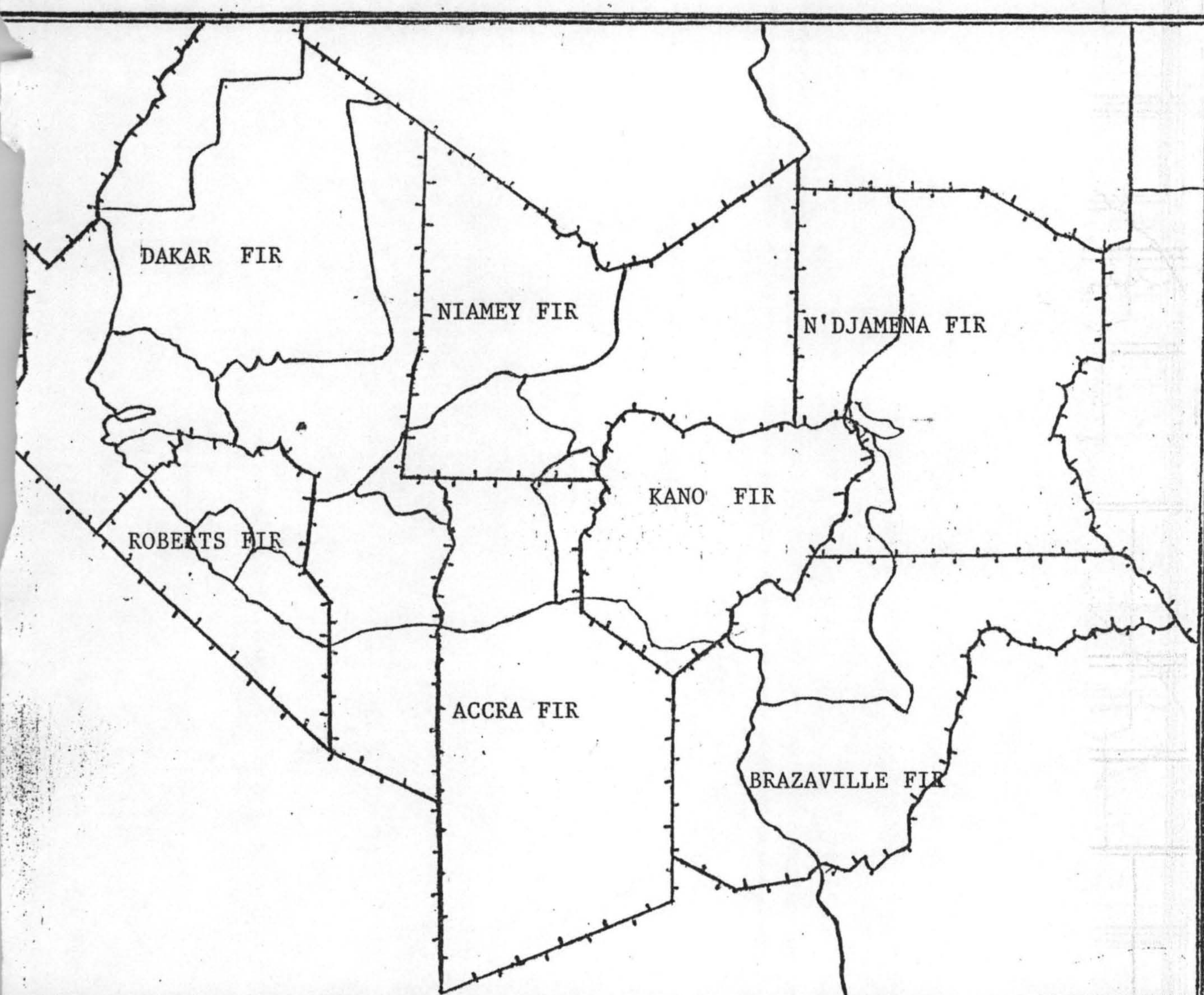

FIG. 2: THE LOCATION OF THE NIGERIAN AIRSPACE WITHIN FIRS OF WEST AFRICA.

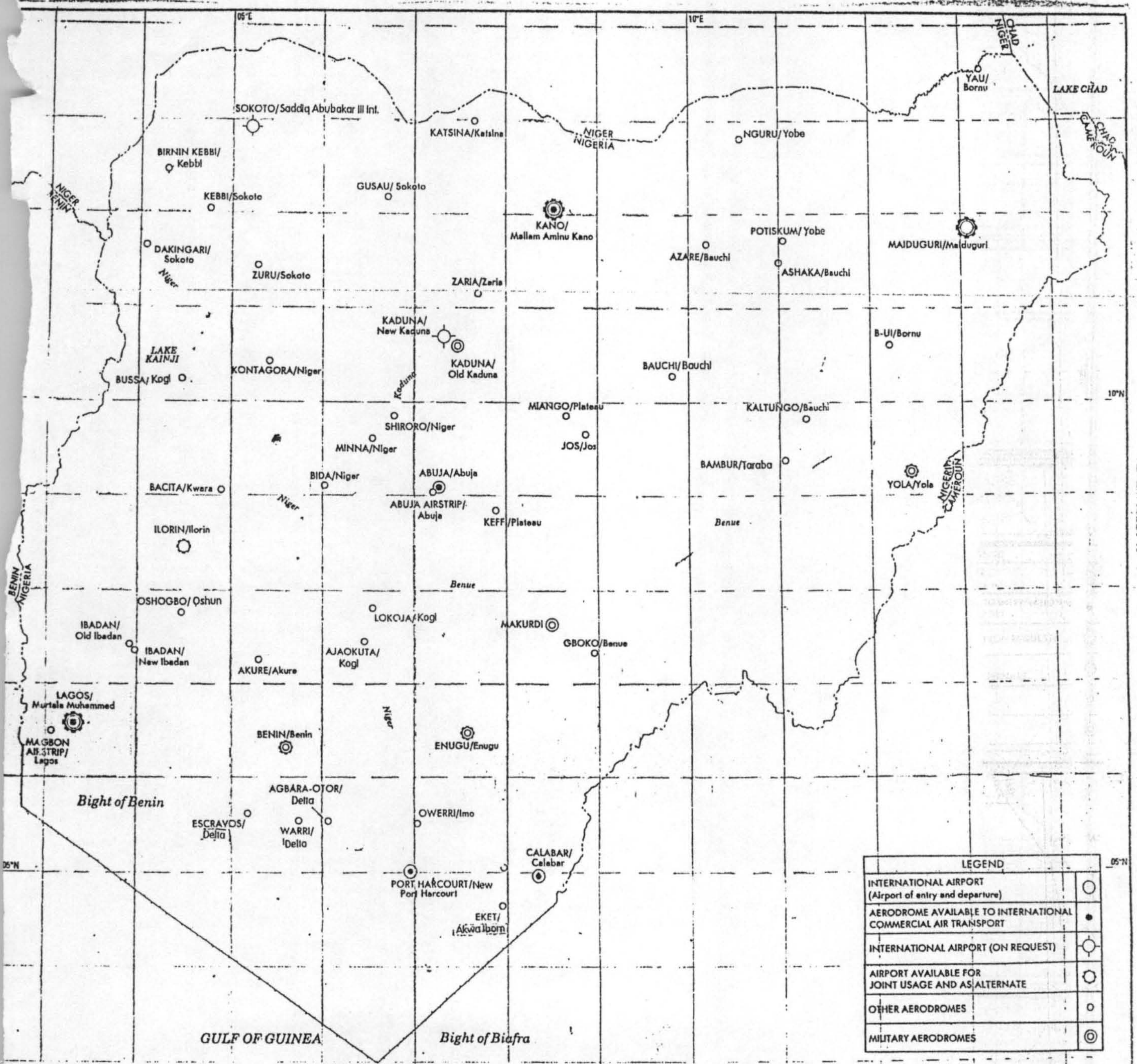

FIG. 3: AERODROME INDEX.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. THE ICAO CNS/ATM CONCEPT

To address the ever-increasing problems in air traffic management, communication deficiency and air traffic congestion, the International Civil Aviation Organization (ICAO) has formed the special Committee on Future Air navigation systems (FANS) in 1983 to take advantage of modern technologies to meet aviation's projected growth (ICAO, 1991). Working in two phases (the FANS phase I and II committees), it developed a strategy for exploiting modern satellite communications and computer technology to improve air traffic management and to bring benefits to aircraft operators around the world. The resulting global concept for communications, navigation and surveillance (CNS) and air traffic management (ATM) was endorsed by the contracting states of ICAO in September 1991, at the tenth Air Navigation Conference.

The operation of CNS/ATM systems will be in use in conjunction with traditional systems beginning 2000, and expect to reach the goal of autonomous flight known as "Free Flight" in 2015. The emphasis is now on implementation of key elements of the CNS/ATM technologies by states in an appropriate and coordinated way within each region and between regions, as part of a long-term plan to obtain full implementation.

The CNS/ATM systems refer to all air-borne and ground-based equipment such as software, hardware, operation procedures, standards, and regulations. The system is designed based on the new-generation technologies including:

COMMUNINCATION: This encompasses all technology for transferring information needed for navigation, data link and voice communication. Oceanic routes' communication will rely on satellite communication (Sat-com), instead of high frequency (HF) communication.

NAVIGATION: This term refers to all equipment that facilitates an en route navigation by aircraft along the routes they have to fly. The Global Navigation Satellite System (GNSS) in tends to replace ground-based navigation facilities (NDB, VOR/DME, ILS etc).

SURVEILLANCE: This term means all technologies that enable air traffic controllers to keep break of aircraft. The use of radar and voice communication to report an aircraft's precise location will be phased out and replaced by the Automatic Dependent Surveillance (ADS).

AIR TRAFFIC MANAGEMENT: Air traffic management with the CNS system, will replace the role of procedure control. It also redress separation requirement between aircraft resulting in the accommodation for more flights flying in the best possible flight path.

Nigeria, through the Nigerian Airspace management Agency (NAMA) has accepted ICAO's CNS/ATM concept as the foundation for the development of her airspace management infrastructure. In this respect two CNS/ATM consultants from ICAO will work with their Nigerian counterpart to put in place an Air Navigation system master plan (2006 – 2015) to complete the implementation of the airspace aspects of the new CNS/ATM system (Mohammed, 2003 and Onasanya, 2003). The benefit of the system to Air traffic control system capacity is enormous. It balances the demands of users against available capacity constrained by factors such as controller workload, airspace organization etc (Oteghile, 2003).

Highlighting the opportunities of open skies policy for Nigeria, Dr. (Mrs) Kema Chikwe, the former Hon. Minister for Aviation postulated that the implementation of the CNS/ATM system would require airlines to introduce high technology data equipment in their aircraft (an airborne requirement) to send and receive signals from ground equipment and satellites in orbit. She went further to say that though expensive, Nigerian airlines must avail themselves with the benefits of CNS/ATM system to compete favourably with global airlines.

The new CNS/ATM system of ICAO is therefore a worldwide system of high precision and reliability for application to communications, Navigation, Surveillance and Air Traffic management, based on satellite technology, independent of ground-based infrastructure (Olivera 2002, Eigl, 2002). Global Navigation Satellite System (GNSS) is a component of ICAO's CNS/ATM system. This system is based on the Global Positioning System (GPS) of USA, Global Navigation Satellite System (GLONASS) of Russia, and GALILEO of Europe. The Russian GLONASS is under development while Europe's GALILEO is at planning stage. The Americas GPS is already being used in many places in a way.

The GPS is the basic system of the GNSS. It is a worldwide radio navigation system formed from a constellation of twenty-four (24) satellite orbiting at 11,000 nautical miles above the earth (Dana, 1999). It was designed for both use for military and civil purposes, funded and controlled by the U.S. Department of Defence (DDD). GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. It remain the only available resource that permits land, sea and airborne users to determine their three dimensional position, velocity and time, 24 hours a day in all weather, any where in the world (IGEB, 2003).

GPS has three elements: the space segment consists of 24 satellites orbiting at 11,000 nautical miles above the earth. The satellites orbit the earth in 12 hours, and are placed in six orbital planes, equally spaced and inclined at about 55° with respect to the equatorial plane. The control segment consists of a system of tracking stations located around the world to ensure that the satellites are working properly. There are four unmanned stations: Hawaii and Kwajalein in the Pacific Ocean, Diego Garcia in the Indian Ocean, Ascension Island in the Atlantic Ocean and a Master control facility located at Shriever Air Force Base, in Colorado Springs, Colorado, US. The GPS user segment consists of GPS receivers and the user community. GPS receivers convert satellite signals into position, velocity and time estimates.

To satisfy the four essential elements of air navigation (integrity, precision, availability and continuation of services), GPS performances must be "augmented" to ensure safe and efficient air traffic navigation of civil aircraft.

2.2. GPS AUGMENTATIONS AND IMPLEMENTATION

Aviation is one of the core beneficiaries of satellite navigation technology but to satisfy the stringent safety requirement of the industry, the system integrity must be absolute and the standard precise (Bond 1996). There are three broad categories of GPS augmentation available. These are space – based, ground-based and aircraft based augmentation systems.

(a) Satellite-based augmentation system (SBAS) also referred to as wide area or regional augmentation provide information over large areas via satellites. SBAS makes use of a network of ground monitoring stations form which the integrity of the navigation constellation satellites and differential errors are compiled and up linked to navigation transponders on board geosynchronous communication satellites e.g. INMARSAT.

(b) Ground-based augmentation system (GBAS) also referred to as local area augmentation system consist of monitors located at or near the airport where precision operations are desired. Signals are sent directly to aircraft in the vicinity (approximately, 20nm). These signals provide corrections to increase the accuracy locally along with satellite integrity information.

(c) Aircraft-based augmentation system (ABAS) can be implemented by:

(i) Receiver Autonomous Integrity Monitoring (RAIM) whereby provided that there are five satellites in view with adequate geometry, erroneous information from one satellite can be detected. If there are six satellites in view, the faulty satellite can be rejected by the receiver; or

Aircraft Autonomous Integrity Monitoring whereby the GPS signal is integrated with other sensors e.g. inertial navigation system (INS), which can detect and reject spurious information form the GPS.

There are three different brand of satellite-based augmentation systems (SBAS): the US Wide Area Augmentation system (WAAS), Europe's European Geostationary Navigation Overlay service (EGNOS) and the Japan's Multifunctional Satellite (MTSAT) Augmentation System (MSAS) that satisfies the Required Navigation Performance (RNP)(Nelson et al, 2002).

SBAS is a system consisting of signal – in – space and a ground network to support precision navigation. The WAAS, EGNOS and MSAS augment GPS with the following three services (Vince, 2000 and Nelson et al 2002).

(i) A ranging function which improves availability and reliability,

(ii) Differential GPS correction which improve accuracy; and Integrity monitoring which improves safety.

Augmentation systems enable GPS use for local area differential systems for precision and non precision approach and surface navigation. It also promotes Oceanic, enroute and terminal non-precision approach. The WAAS signal is available over continental USA and Canada, EGNO signal is Europe, Africa and East Asia while MSAS signal is available in Asia – Pacific.

Nelson et al (2002) describe the problems that aviation nations are facing when trying to implement satellite-based CNS/ATM systems based on the Required Navigation Performance (RNP) concept adopted by ICAO. He stressed that even though GNSS/GPS is available and ready, and SBAS are almost ready for implementation, most nations have not started to implement the new satellite base CNS for the reason that it is difficult to choose the exact technology because the different SBAS all satisfy the RNP requirements but they may not be interoperable with each other. Satellite-based systems are expensive and can cover a large service volume, therefore they cannot be national systems and have to be shared between nations within a region (like Europe), or globally. The question is who controls, manages and operates the systems. The leading Aviation nations are not providing good examples as they all want to have total control over their systems since satellite-based systems are so new, nations do not know how to certify and commission them for various uses in civil aviation. Therefore, nations have to choose between different certification and commissioning processes, as there is no common set of standards. Again, since various systems can satisfy a RNP requirement, there is a major issue of being interoperable, harmonious and synchronous with contiguous neighbours and within the region. Who makes the first choice and who forces the neighbours to be interoperable with the initial selection.

The three existing SBASs have been designed to accommodate significant growth so that they can grow to become either regional or global systems. Any country therefore need only build the SBAS components that are necessary for navigation landing, and control over its own airspace.

Nelson et al (2002) recognizes four distinct levels of participation by a nation or region that wants to join a SBAS –WAAS, EGNOS or MSAS. The first level requires no separate funding by the independent nation; however, suitably equipped aircraft flying over its airspace can still use nearby SBAS and obtain benefits from the improvement in the integrity of satellite navigation. The second level requires the independent nation to install a single Reference Monitoring Station (RMS) for WAAS, a single Remote Integrity Monitoring Station (RIMS) for EGNOS, and a single MSAS Ground Monitoring station (GMS) for the MSAS. The third level is an expansion of the second level to provide sufficient accuracy for category like precision approaches through out that nation. The fourth level requires a significant level of cost as information from SBAS reference monitoring station is consolidated in one master station within the nation. The different levels of participation in a SBAS are dependent on a nation's needs and resources. The levels, however refers only to a single SBAS and not how different SBASs can be used together.

Henaku (1999) summarises the current attempts at securing the implementation of GNSS in Africa. An attempt at introducing satellite navigation technology in Africa is not merely a story of application of technologies. It is first and foremost a story of an attempt at technological leapfrogging and balancing act regional and inter-regional cooperation. With known categorized deficiencies in ground and shore facilities for aviation and maritime, coupled with the immense landmass, satellite navigation is suitable for and has been well embraced in Africa.

Perhaps taking a cue from the current impetus in the field of remote sensing, satellite navigation technology seems to be spearheading a change in focus. The change in focus is reflected in the fact that at the conference of African Ministers in charge of Air Transport held in November 1999, two of the four panels were dedicated to GNSS related issues.

A study conducted by the GNSS working Group of the AFI planning and Implementation Group (APIRG) and presented to the AFI Regional Air Navigation meeting held in Abuja, 1997, concluded that GNSS offers global coverage and harmonized performances in the region. The GNSS when combined with Ground-based Augmentation System (GBAS) and Space Based Augmentation system (SBAS) is flexible enough to cater for the regions air navigation requirement.

The study projected the installation of between 19 and 26 EGNOS Reference and Integrity Monitoring Stations (RIMS) as well as two master control stations in Africa. The study considered the fact that EGNOS and WAAS overlap over part of Africa making it inevitable to install and operate ground facilities compatible with WAAS. The type of accuracies to be assured would be in compliance with RNP5 as defined by ICAO.

Tentatively, Africa had planned the introduction of satellite navigation systems for supplementary means in 2000. It recognizes GNSS as a means of solving the Region's air navigation problems. It is clear however that Africa does not intend to rely on GPS alone, not even with WAAS and EGNOS augmentation services.

The task of GNSS implementation is enormous; Africa will need to rely on the goodwill of financial institutions and the European Union. The success of this initiative will depend, among others, on the political commitment and financial enthusiasm to be exhibited by African policy makers. Three countries Egypt, Nigeria and South Africa are leading the continent for the use of GPS for air navigation as an en route supplemental navigation aid.

Onasanya (2002a) underscores the importance of the CNS/ATM system to the development of Nigeria's airspace infrastructure. The satellite-based navigation is intended to gradually replace the ground-based systems over a period of ten years after implementation. The satellite-based Automatic Dependence Surveillance (ADS) will complement the existing radar system. Onasanya (2002a) went further to stressed that the Nigerian Airspace Management Agency will be able to save cost of procurement, installation and maintenance of present ground-based navigational facilities.

The Agency developed a short-term master Plan for the implementation of the CNS/ATM systems (1995-2005). He postulated that the overall system plan is intended to maintain and or increase the existing level of safety; increased system capacity utilization to meet traffic demand; accommodation of user- preferred three-dimensional and four-dimensional flight trajectories; accommodation of full range of aircraft types and airborne facilities; improved provision of aeronautical information to user community; improved navigation and landing capabilities to support advanced approach and departure procedures; increased user involvement in Air Traffic management (ATM) decision making including air-ground computer dialogue for flight negotiation and organise airspace in accordance with ATM provision and procedures.

The implementation plan also identifies target dates, by which individual tasks are required to be accomplished. Other components of the CNS/ATM systems such as WGS-84, and GPS approaches are being planned designed such implemented.

2.3. GPS RISK AND PERFORMANCE ASSESSMENT

GPS aviation navigation has been the subject of so much understandable enthusiasm that its limitations have been ignored (Bond, 1996). Air navigation service providers lose sleep worrying about calamitous failures. One area they need not to worry about much these days is a massive failure of the CNS system. The reason is that there is literally tens of thousands of transmitters, receivers, remote – control communications sites, primary and secondary radars flight service stations and so on. Today, must of these units and facilities are redundant, have back up power, and do not drift or go off line much. To a remarkable degree, this array of equipment and people operate separately and independently. If one element goes out, the thousands of others continue to play and provide alternative guidance. For all practical proposes, the system is invulnerable.

Bond (1996) stressed that the GPS is different. The signal strength of GPS is tiny, a small fraction of the powerful, reliable emissions in the current navigation system. It is easy to disrupt. He went further to emphasize that recently the British demonstrated that a one watt weather balloon transmitter could disrupt GPS signals for 30 miles around. And then there are electro-magnetic and particle emissions from the sun. These eruptions can damage satellites and interfere with signals transmitted from them. Solar flares could disrupt GPS signals for hours world wide.

GPS was designed as a system for US Military. Given that the GPS signal can be used by unfriendly interests, the Defence Department can degrade and deny the signal of one or all of the satellites. Specifically, it can turn them off completely and has done so in the past. This puts other nations in a bind. Bond argued that countries with secure, successful ground-based system would not scrap their VORS, ILSs, NDBs and DMEs and rely solely on America's satellites.

He however opined that the biggest benefits of GPS is that it provides good signals where none now exists particularly over ocean, or when flying in a developing country with less infrastructure or small rural airports of the developed countries in this regard GPS is a break through.

An independent risk assessment was conducted by the Johns Hopkins University Applied Physics Laboratory (JHU/APL) to determine if the Global Positioning System (GPS) and augmented GPS can satisfy the performance requirement to be the only navigation system installed in an aircraft and the only service provided by the US Federal Aviation Authority (FAA) for operations anywhere in the US National Airspace system (Corrigan, et al, 1999). The study quantifies the ability of GPS with LAAS and WAAS to satisfy navigation performance requirements as expressed by accuracy, integrity, continuity, and availability requirements. Oceanic through Category III precision approach operations were evaluated with risks that present both normal and abnormal degrees of performance degradation. Specifically, the study considered the following risks: Intentional and Unintentional interference, interference mitigation, ionospheric propagation and scintillation.

The study concludes that GPS must be augmented to meet these requirements and that WAAS/LASS can provide the required navigation performance. The main conclusions are as follows:

(a) GPS with appropriate WAAS/LAAS configurations can satisfy the required navigation performance as the only navigation system installed in the aircraft and the only navigation service provided by the FAA:

(b) Risks to GPS signal reception can be managed, but steps must be taken to minimize the effect of international interference.

(c) A definitive national GPS plan and management commitment is needed to establish system improvements with civil aviation users and to provide greater informational access to civil aviation community.

The study finally recommended the need to develop a combined GPS and augmentations system design based on cost and performance trades among GPS system improvements, GPS operational policies, and WAAS/LAAS capabilities.

Satellite Based Augmentation Systems (SBASs) generate correction rectors for the GPS satellite clock, ephemens and ionospheric delays. El-Arini and Lejeune (2002) argued that one of the functions of WAAS is the generation of ionospheric delay estimates and an estimation of the post correction error bounds. However, ensuring with a high degree of confidence that the post-correction error bounds meet their integrity requirement has proven to be more difficult than anticipated. The initial WAAS goal is to use the ionospheric corrections only during periods of non-severe ionospheric conditions. They proposed three types of ionospheric irregularity detectors for use. These are spatial gradient, temporal gradient, and Chi-square detectors.

Abousalem et al (2002) carried a peformance analysis of GPS positioning using WAAS and EGNOS. They presented the concept of Differential GPS (DGPS) and Wide Area Differential GPS (WADGPS) by articulating GPS measurement errors. Satellite clock errors contain both systematic errors and Selective Availability (SA) effects. Satellite orbital errors, on the other hand, are caused by the imperfect modeling of physical phenomena governing the dynamics of the satellite in the sky. Ionospheric errors are however the atmospheric delay effects on the pseudo range while passing through the ionosphere, which is the layer extending from about 50 to 1000 kilometers above earth. Ionospheric delays are caused by the total electron content along the path of the GPS signal between the satellite and the receiver. Many factors affect the magnitude of these effects including sunspot number, time of the day, location on the surface of the earth, satellite elevation angle and measurement signal frequency. Tropospheric errors are the delay effects caused by the non-ionized layer of the atmosphere extending upward from the surface of the earth to about 50km above. Ionospheric and Tropospheric effects can be minimized or eliminated by differential positioning using WAAS and EGNOS and by standard modeling.

The key benefit of differential modeling is the ability to reduce or eliminate many GPS measurement errors (Satellite clock, ionospheric, tropospheric and orbital errors). Receiver noise and multipath error on the other hand are neither eliminated or reduced. Using WAAS and EGNOS corrections demonstrated horizontal and vertical positioning of better than 4 meters and better than 6 meters (95%) horizontal and vertical positioning accuracy, respectively.

Misra et al (1998) analysed the performance of GPS/LAAS augmentation with GLONASS. They proposed the augmentation of GPS/LAAAS with GLONASS and examined the incremental benefits of the additional signals from GLONASS to the availability of service for precision approaches.

GLONASS, the Russian global navigation satellite system is similar to GPS in its architecture. Some of the differences between the two systems with implications for LAAS performance is related to the status. GPS has been operational for several years, GLONASS is however under development. Other differences include difference time references, signal bandwidths, multiple access schemes and co ordinate frames e.g. GPS uses WGS-84 while GLONASS uses PZ-90. These differences can be overcome using receivers that are compatible to both systems.

When the space segment consists of the combined constellation of GPS and GLONASS satellites (GPS + GLONASS), the service available enhances the positioning performance and the differences would not degrade the system performance appreciably.

Bendicto et al (2003) argued that the current capabilities of GPS and GLONASS, although very adequate for some users, present some shortfalls. The lack of civil international control presents a serious problem from the institutional point of view. In addition, there is a need for enhanced performance. In particular, civil aviation requirements for precision and non-precision approach phases of flight cannot be met by GPS or GLONASS only.

The purpose of EGNOS is to implement a system that fulfils a range of user service requirements by means of an overlay augmentation to GPS and GLONASS based on the broadcasting through GEO satellites of GPS like navigation signals containing integrity and differential correction information applicable to the navigation signals of GPS satellites, the GLONASS satellites EGNOS own GEO overlay satellites and the signals of other GEO over lay systems.

EGNOS is a key element in the European strategy for the development of GNSS, designed to be interoperable with other satellite-based augmentation systems and aiming at contributing to a true worldwide global navigation system to benefit civil aviation.

Van Dayke (2000) evaluates the current Receiver Autonomous Integrity Monitoring (RAIM) algorithm, which provides fault detection for supplemental use of GPS. They study examined the availability of GPS integrity globally and compared the results to RAIM and fault detection exclusion (FDE) availability with "selective Availability" (SA) on the system.

Other augmentations to improve availability, such as the use of geostationary satellites for ranging and additional GPS satellites in the constellation variation of the mask angle and GPS/Galileo system, were analysed. This analysis demonstrates that there are substantial improvements in the availability of GPS integrity, both for supplemental and primary means navigation if SA is turned off. Fault detection availability approaches 100% with a 24-satellite constellation. There is significant improvement in the availability of FDE as well, though not high enough to satisfy primary means requirements, it is important to quantify the magnitude of this improvement when SA is turned off. With a 30 satellite constellation, FDE availability approaches 100% for all phases of flight.

2.4. GPS REGULATION AND RECEIVER CERTIFICATION

GPS raises technical, commercial, political, military, institutional and legal issues (O'Neil, 2000). It is not a system designed solely or specifically for civil Aviation, but it is one with very many wide ranging applications across all industrial sectors. It is also not a service provided or controlled by civil aviation. Many states are uneasy that a single satellite navigation system is controlled by US. In fact some view GPS as a military and commercial threats, even if it is currently free of charge.

GNSS also raises issues of vested interest that prompted countries like Russia and Europe to develop and launch their own system. This is to avoid those who own and operate the system to impose user requirements, standards and certification schemes. He stressed that ICAO as a forum generally accepts the certification given by member states to its own navigation system. This also translates to its registered aircraft and increased crew. ICAO therefore plays no other clearly defined role in the certification of services, equipment and people. ICAO simply set safety and interoperability standards.

He went further to state that many have assumed that GNSS would somehow be "approved" by ICAO. Yet this UN institution has no power or precedent for giving any approval that would be legally effective. ICAO is more a forum for agreeing common standards and settling relations on civil aviation matters between its members. It is not an Agency with any delegated power to carry out approvals. These are sovereign responsibility of the member states. The current ICAO institutional framework was put in place at a time when few could have envisioned a global navigation system controlled by a single nation.

Haro et al (1999) stressed that the use of GNSS in general and EGNOS in particular, for Instrument Flight Rules (IFR) operations must be authorized by the state civil aviation authorities in each European country. The aviation authorities would need to consider the development of new specific flight and air traffic control (ATC) procedures. Other important items, which need to be planned and prepared, include certification and operational approvals, ground and flight inspection, trials and demonstrations, planning and organization, training, information dissemination, and resolution of pending legal and liability issues. They agree that there is significant safety, economic and operational benefits to be achieved by using EGNOS, but, ultimately, they will only become reality if the operational environment is properly prepared in a timely manner.

Goodman (2003) focused on the potential threat the satellite navigation integrity, such as international and unintentional interference, signal in-space (satellite) and ground support infrastructure anomalies, shared spectrum issues, and multipath. His experience and other users of GPS indicate that navigation outages due to receiver software issues are great risk. He traced the historical development of the experimental, one channel, sequential receivers of the 1970s to five channel receivers in the mud 1980s and parallel "all-in-view" receivers available in the late 1990s possessing twelve or more channels.

This improvement in tracking capability and navigation accuracy, he noted was accompanied by an increasing software quantity and complexity. Current and future GPS receivers will interface with multiple systems and other satellite-based augmentation systems, sometimes in safety critical applications. These multiple radio -frequency interfaces will further increase software complexity. He therefore underscores the need to regulate, standardized and certifies GPS receivers for critical safety application in civil aviation. The ability of GNSS receivers to provide robust navigation solutions facilitated by rigorous software development, testing and certification processes will become more important as GNSS receivers replace legacy radio – navigation systems. Jospeh (2000) argued that the current certification technical standards appear to have little impact on promoting the design of standardized receiver architectures, interfaces and operating manuals – despite evidence from a variety of sources that lack of standardization many undermine safety.

The accelerated development and introduction of GPS receivers for use in airborne navigation has outs paced the capacity of international aviation authorities to fully implement regulations and guidance for the safe and efficient use of such devices (Nen dick and St. George, 1996 and Heron et al 1997). Currently there is no standard for the design of handheld GPS receivers despite their prevalence among General Aviation (GA) pilots as a supplemental aid to visual Flight rules (VFR) navigation with an approved primary means of navigation. They use system design principles to analyses existing GPS receiver interfaces and illustrated how complex receiver architectures and cumber some receiver operations can combine to impair pilot performance.

Specific observations made during FAA flight tests of terminal Instrument Procedures using IFR-approved GPS receivers concluded by Winter and Jackson (1996) illustrated instances where GPS receivers affected pilot performance because they did not support flight functions appropriately during critical flight phases. In particular, they noted increased pilot workload and delays in communication when Air Traffic control (ATC) regulated information about the distance of the aircraft from the airport. The GPS receivers did not allow easy access to such information, and pilots were forced to calculate distance manually.

Nendick (1994) developed a comprehensive questionnaire (GPS User Survey) to gather responses from 227 New Zealand pilots in an attempt to identify GPS - receiver interface design and operational issues that eroded flight safety. The survey elicited pilot perceptions of such experiences with GPS receivers by asking questions about controls and displays, operating logic, functions, operations, operating procedures navigation performance, pilot attitudes, and training. He came up with the following suggestions:

i. The design of future GPS – receiver interfaces, especially controls and displays, would benefit from strict adherence to published guidelines;

ii. Receiver operating logic could be improved through standardization of various models;

iii. Serious consideration should be given to the inclusion of receiver features that reduce and possibly eliminate over-reliance and complacency;

iv. Improvements in the content, layout and indexing of GPS operating manuals were necessary and,

v. Pilots should be required to undergo some type of formal GPS training.

The methodology he applied and the analysis adopted to arrived at these suggestions would be relevant to this study.

CHAPTER THREE

3.0. RESEARCH METHODOLOGY

3.1 INTRODUCTION

In order to achieve the aim and objective of this research, the research methodology is designed in a manner that is capable of tackling the research questions within the limit of time and resources available. These questions are articulated below.

(i) Does it benefit the country to accept global navigation satellite system (GPS) when the technology has inherent weaknesses?

(ii) Does the appropriate augmentation system required to support specific phase of flight adopted in accordance with ICAO's required navigation performance (RNP) types?

(iii) Are the GPS receivers and related avionics components certified by the appropriate regulatory body in the country?

(iv) Does the user community possess the pre-requisite knowledge and understand the basic operations of the system?

3.2. DATA COLLECTION TECHNIQUES

Three principal data collection strategies were employed in collecting relevant data for this research work. These methods include library research, interviews and questionnaire survey.

(a) LIBRARY RESEARCH

The library is the first place the researcher used in collecting data for this study. This involves reading through documentary materials available on the subject matter. Others include past student research projects, journals and other articles. This work however relied heavily on Internet resources to source for pertinent data.

The data collected is adequately supported by relevant information provided by the Nigerian Airspace Management Agency (NAMA) through its public affairs unit and Aeronautical Information Service (AIS) units in selected airports across the country.

Data extraction from available records is important to this research. Some of these records include ICAO documents particularly DOC.003, DOC.4444, DOC 7903 and ICAO circular on GPS. Others include NAMA publications such as the Aeronautical Information Publication (AIP), notice to airmen (NOTAM), Aeronautical Information Circular (AIC) Airspace news, aeronautical charts, air traffic operation statistics and other journals of the aviation industry.

These materials did not only guide the research work but also enabled the researcher to have a clear understanding and general overview of the subject matter. It also gave an indication of the viability of this study.

(b) INFORMAL INTERVIEW

This is another important strategy deployed for collecting relevant data for this study. Informal interviews were earmarked and conducted with selected personalities who are directly involved in the development and implementation of GPS technology in the country and other members of the aviation community whose schedule of duty bear relevance on the subject matter. Other persons interviewed included those that would be affected when the GPS navigation service becomes fully operational and available.

Among the first category of persons interviewed were distinguished personalities who occupy top managerial positions in federal establishments under the supervision of the Aviation Ministry.

In the Nigerian Airspace Management Agency (NAMA), the following individuals were successfully interviewed:

(i) Director, Air traffic services (ATS);

(ii) General Manager, Air Traffic Control Operations and Standards;

(iii) General manager, Airspace Design and Technical Evaluation;

(iv) General Manager, Surveillance; and

(v) General Manager, Navigation aids.

In the Nigerian Civil Aviation Authority (NCAA) the following persons were equally interviewed:

(i) General Manager, Air traffic services;

(ii) Deputy General Manager, ATS training and Licensing, and

(iii) Assistant General Manager, Air traffic regulations.

In the Nigerian college of Aviation Technology (NCAT), three head of schools were selected and interviewed. These are:

i. Head of School, Air traffic services;

ii. Head of School, Flying, and

iii. Head of School, Aeronautical Telecommunications.

It is important to note that some of these interviews were conducted directly (i.e. face-to-face) at times more than once. This is particularly applicable to those officers of NAMA and NCAA interviewed at their headquarters both at Murtala Muhammed International Airport, Ikeja, Lagos. However due to limited time and financial constraint, the three heads of schools at the Nigerian College of aviation Technology (NCAT) Zaria, Kaduna State were interviewed through the use of telephone. Also, follow up to some of these interviews was conducted by e-mail correspondence particularly with GM, Airspace Planning and Technical Evaluation.

These interviews covered significant areas and issues related to procedure development (i.e. instrument procedure design and obstacle clearance), aeronautical navigation data base, operation and certification, ground and flight inspections, trials and demonstrations, planning and organization, training and manpower development, maintenance and cost implications, information dissemination and legal and institutional issues regarding the development and implementation of the GPS technology in the country. These interviews provided the researcher the inputs necessary to make reliable inferences, analogical deductions and conclusions.

(c) QUESTIONNAIRE ADMINISTRATION

The questionnaire is the main instrument adopted for data collection in this study. A GPS user survey questionnaire was carefully designed to cover all the necessary areas on the subject matter and administered to pilots, air traffic controllers and aeronautical engineers.

The designing process involve five operations:

(a) The first logical step was to specify the information to be collected. This step was broadly categorized into four major areas: GPS implementation, augmentation, certification and training. These areas were further subdivided into subsets to cover all the important aspects of GPS technology and its implementation in the country as envisaged in the research aims and objectives.

(b) The second operations involved the making of a list of all inventory of information needed to attain the stated aims and objectives

(c) Having specified the information to be collected and making a full inventory

of all information required, the next logical step was ordering the questions, in such a manner that would suit the targeted population - pilots, controllers and engineers. The questionnaire was ordered in such a manner that the entire survey element could comfortably answer all the questions.

(d) The next important step was designing the questionnaire i.e. constructing the

questions to ensure that no relevant information is missed. The questions asked were simple and easily understandable by the respondents. The researcher is aware of the fact that the respondents work in a stressful environment and so they may not have all the time and patience to answer numerous questions.

(e) Finally, the layout of the GPS user questionaire consisted of three pages containing twenty seven (27) questions in all (see appendix3); some open ended and some controlled closed questions intended to guide against irrelevant and unexpected responses.

The simple random sampling method is used to administer copies of the questionnaires, but to ensure broad coverage, four international airports of Lagos, Kano, Abuja and Port Harcourt and six domestic airports of Minna, Zaria, Maiduguri, Enugu, Yola and Benin were chosen. The researcher utilised the ATS reporting office in these selected airports to assist in administering the questionnaire. In all one hundred and fifty one (151) copies of the questionnaire were completed and returned.

3.3 DATA ANALYSIS TECHNIQUES

The data analysis techniques adopted for this research work is that which enables the researcher to tackle the research problems sequentially and logically in order to achieve the aims and objectives of the study.

GPS implementation in the country is being carried out in an evolutionary manner, enabling improvements to be introduced gradually. The researcher therefore provides a summary outline of current attempts at securing the implementation of the GPS technology in the country. The Aviation community has identified stringent requirements and recognized the potential of satellite navigation technology to improve safety of air navigation.

In order to make critical appraisal of GPS navigation service objectively, the researcher looks into the AFI region implementation plan (1995 – 2005) as stipulated in AFI Doc. 003. This documents when compared with the implemented elements of the Air Navigation System (ANS) master plan (2000 – 2005) of the country revealed the missing links and the unsatisfactory state of affairs regarding the whole concept of satellite navigation vis-à-vis its implementation in the country. This process also revealed the desirable features necessary for the development and implementation of the GPS aviation navigation system.

This process was not oblivious of the critical elements of the AIS/AIP/Airspace design in GPS implementation in the country, especially the full WGS-84 airport/obstacle survey and analysis for the nine (9) airports and two (2) en-route stations, and the development of GPS instrument approach procedures for nine (9) airports: Lagos, Kano, Abuja, Calabar, Port Harcourt, Maiduguri, Sokoto , Kaduna and Ilorin.

Augmentations are classified in three broad categories: aircraft based, ground-based and satellite-based. This research is focused on EGNOS, which Nigeria has accepted to boost GPS, and assessed its signal availability and accuracy. This is made possible by evaluating the data provided by the flight trials conducted by the Dakar based Aviation Company ASECNA at Lagos, Kano and Port Harcourt.

The need to certify GPS receivers and other related components in such critical and safety-of-life operations cannot be overstressed. The research considered the various requirement of GPS navigation system for various phases of flight either as primary or supplement navigation system. In addition, the study considered the appropriate regulatory body saddled with the responsibility of certifying GPS navigation system.

Data collected through the use of the questionnaire was used to assess the parameters necessary for the certification and standardization of the GPS technology. The questionnaire also provided relevant information required to ascertain the level of GPS understanding among users and determine the training requirements for various users.

The one hundred and fifty one (151) persons that responded to the questionnaire, consisting of seventy six (76) air traffic control officers, forty eight (48) pilots and twenty seven (27) aeronautical engineers. The data collected from these respondents was thoroughly appraised, updated, edited, coded and summarized separately for each target group and later combined and subjected to statistical analytical techniques using simple methods as totals, means, percentage and proportions using the following formulae:

In addition, the benefits of GPS navigation service for the period (2000 – 2005) was subjected to Cost-benefit analysis using the Net Present Value (NPV) methodology described as follows.

i. All costs and benefits are evaluated for all actors and elements involved,

ii. The NPV value defined as $\sum_{period} (\sum \text{Benefits} - \sum \text{cost})$ is calculated,

iii. The preferred scenario is the one with the highest value.

The cost involve was calculated for:

i. All equipment require maintenance and technical support service put at 10% of the equipment cost per year;

ii. Delivery cost of one (1) pre-tested RIMS;

iv. Cost of telecommunications between RIMS and MCC in Europe plus other ground segment per year for the period (2000 – 2005);

v. Project costs and engineering support;

vi. Assuming that all airlines (international and domestic) are equipped with Multi mode receivers (GPS/RAIM/AAIM Receivers) as airborne augmentation.

The costing for the aforementioned undertaking was derived from the summary report compiled on behalf of APIRG by a team of consultants from IATA, ICAO, RSA and ASECNA. The benefits for the same period was calculated from data made available by NAMA and it includes the expected savings from equipment maintenance costs and accrued revenue from enhanced safety services.

The above methodological approach to the study coupled with the numerous consultations, interviews, personal observations and experience and the extensive reading conducted by the researcher enabled the study to provide reliable answers to the research questions in addition to useful suggestions and recommendations.

CHAPTER FOUR

4.0. DATA PRESENTATION AND DISCUSSION OF FINDINGS

4.1 INTRODUCTION

This chapter provides a description of the means and methods planned or envisioned by the aviation community to improve the present situation of insufficient capacity and inadequate ground infrastructure in the air navigation system in Nigeria.

One hundred and fifty one (151) copies of the questionnaire were involved in the result presented here. The respondents consists of seventy six (76) air traffic control officers (50.3%), forty eight (48) general aviation pilots (31.8%) and twenty seven (27) flight and air traffic safety and electronic services engineers (17.9%). The result of the analysis of this survey in addition to the series of informal interviews, discussions and personal experience and observation of the researcher are as discussed in the subsequent parts of this chapter.

4.2 GPS INFRASTRUCTURAL DEVELOPMENT AND IMPLEMENTATION

From the literature review, it was discovered that the introduction and implementation of the GPS technology in Africa, including Nigeria would be hinged on certain requirements. Besides, the aviation community is of the view that the use of GPS should cater for the following:

(a) Increased navigation accuracy allowing for improved system capacity and capabilities while maintaining or increasing the level of safety;

(b) Improved situation awareness both by pilots and air traffic management system, allowing for higher flexibility in implementing area navigation leading to optimized, user preferred flight trajectories;

(c) Increased landing capabilities with adequate minima to all runways and airports for all aircraft types;

(d) Category II/III approach capability of selected locations and runways; and

(e) The consolidation of navigation functions into a single system thereby enabling the phase out of other radio navigation systems and eventually of all other navigation systems.

The AFI CNS/ATM implementation plan as spelt out in DOC. 003 specifies the required navigation performance and anticipate systems development for the period 1995/2005. These are:

(a) En-route: RNP's 10 and 5; VOR will continue to be the agreed en-route navigation aid along conventional ATS routes; GPS will be used initially as supplemental means of navigation and eventually become sole means of radio navigation allowing for the progressive withdrawal of en-route conventional navigation aids form year 2007.

(b) Terminal areas: At least up to the planning time-frame (2005), VOR/DMEs shall continue to be standard navigation aid and may only be withdrawn from 2010. GPS can be used as supplemental, primary and then sole means from 2010.

(c) Approach and Landing: ILS will be maintained at least until year 2015; trials and demonstrations shall be conducted to validate the use of GPS for precision approach and landing; GPS may be used as approach and landing aids, initially as an overlay to conventional systems.

The system requirements include the to establishment of the signal-in-space requirements defined in Table 1, that the combination of GPS elements and a fault – free GPS receiver shall meet.

TABLE I: GPS SIGNAL – IN – SPACE REQUIREMENTS. SOURCE: ICAO.

Typical Operation	Accuracy lateral 95%	Accuracy Vertical 95%	Integrity	Time to alert	Continuity	Availability	Associated RNP type(s)
En-route	2.7km 2.0NM	N/A	$1\text{-}10^{7}$/h	5minn	$1\text{-}10^{-4}$/h to $1\text{-}10^{-8}$/h	0.99 to 0.99999	20 to 10
En-route, Terminal	0.74km 0.4Nm	N/A	$1\text{-}10^{-7}$/h	155	$1\text{-}10^{-4}$/h to $1\text{-}10^{-8}$/h	0.99 t0 0.99999	5 to 1
Instrument Approach with vertical guidance (NPV I)	220m (720ft)	20 (76ft)	$1\text{-}2\times10^{-7}$ per approach	10s	$1\text{-}8 \times 10^{-6}$ in any 15s	0.99 to 0.99999	0.3/125
Instrument Approach with vertical guidance (NPV II)	16.0m (52ft)	0.0m (26ft)	$1\text{-}2 \times 10^{-7}$ per approach	6s	$1\text{-}8 \times 10^{-6}$ in any 15s	0.99 to 0.99999	0.03/50
Category I Precision Approach	16.0m (52ft)	6.0m to 4.7m (7) (20 to 13ft)	$1\text{-}2 \times 10^{-7}$ per approach	6s	1.8×10^{-6} in any 15s	0.99 to 0.99999	0.02/40

In line with ICAO and AFI region requirements, the Nigerian Airspace Management Agency (NAMA), the national air navigation service provider (ANSP) has evolved a short term national implementation plan (2000 – 2005) that accords with the AFI region implementation master plan (1995 – 2003) for the development and implementation of the necessary infrastructure for the future air navigation system.

The implementation plan identifies target dates, by which essential elements are required to be accomplished. These elements include the following.

<u>1995</u>

- Progressive reduction of longitudinal separation from 20-15 minute to 10 minute in selected airspaces as dictated by operational requirement.
- Progressive introduction of fixed RNAV routing in continental airspace initially above Flight level three hundred (FL300).

<u>1998</u>

- Implementation of World Geodetic Survey – 1984 (WGS-84);
- Data exchange between flight data processing systems in selected air traffic control centres

<u>1999</u>

- Operational Automatic Dependent Surveillance to suitably equipped aircraft in selected airspaces;

UP to <u>2000</u>

- Progressive reduction of lateral separation minima in selected airspaces as dictated by operational requirements;
- Progressive introduction of random routing in selected oceanic airspaces;
- Longitudinal Radio navigation (RNAV) separation minima of 10 minutes and for 80nm RNAV derived distance in selected airspaces;

2001

- Complete implementation of all aeronautical fixed telecommunication network (AFTN) and ATS/DS circuits;
- Progressive introduction of Controller – Pilot data link communication (CPDLC) with full capacity in 2005;
- Progressive introduction of GPS – based approach procedure;
- Progressive introduction of RNP5 in upper airspaces;

2003

- Progressive introduction of Automatic Dependent surveillance service with full ground capability by 2005;
- Progressive introduction of ATS inter-facility data communication (AIDC) to be completed by 2005.

In order to achieve the milestones contained in the plan, the Nigerian Airspace Management Agency (NAMA) embarked on the implementation of four (4) major projects, namely, the Aeronautical Information Service, Aeronautical Information Publication and Airspace Design (AIS/AIP/AIRSPACE DESIGN), Upgrading of the existing EU satellite communication (SATCOM) network, implementation of very small Aperture Terminals (VSAT) and Total Radar Coverage of Nigerian Airspace (TRACON).

These elements play key role in the development and implementation of the GPS technology, as they are crucial for the general improvement of the safety levels and airspace capacity for the country. However, many of these elements were not accomplished at the targeted dates and had to be rescheduled several times.

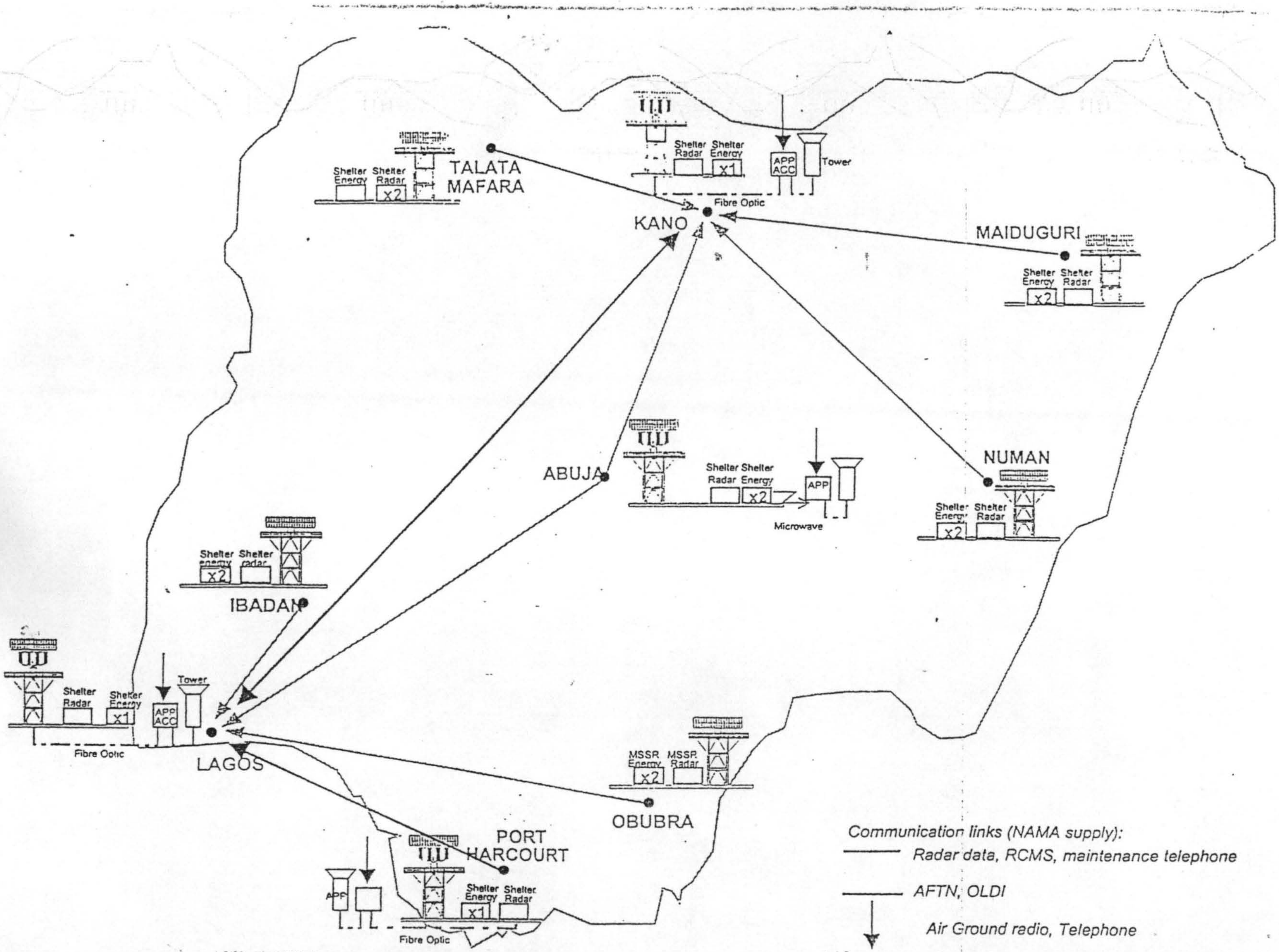

FIG. 4: SYSTEM OVER-VIEW: TOTAL RADAR COVERAGE OF NIGERIA (TRACON) PROJECT

This had actually slowed down the pace of GPS imfrastructural development in the country. For instance, the implementation of the WGS – 84 was rescheduled from 1998 to 2001. This has affected the construction of approach procedures for the selected airports in the country. This also means that up to 2001, GPS precludes the use of precision approach guidance to those selected airports.

GPS derived position information is referenced to the World Geodetic System 1984 (WGS-84) datum. This datum relates geographical co-ordinates to a mathematically defined ellipsoid that approximates the shape of the earth. The point of origin for the WGS-84 datum is the earth's centre of gravity. ICAO has adopted WGS – 84 as the only worldwide aeronautical geodetic datum to be fully implemented by contracting members by 1st January 1998.

The geographic coordinates of the country were based on the national datum inherited from the colonial period. This datum uses different ellipsoids but can be converted to the WGS – 84 datum, however inaccuracies may still prevail in the national datum. This is unsafe for critical safety-of-life operations like aviation, since GPS receivers operate on the WGS-84 global geocentric reference system. This made it mandatory for Nigeria to resurvey nine (9) airports and two en-route station for conversion into WGS-84 namely, Lagos, Kano, Port Harcourt, Abuja, Bida, Jos, Kaduna, Sokoto, Calabar and Maiduguri.

The WGS-84 airport/obstacle survey and analysis for these airports and en-route station has since been completed. This made it possible for the development of GPS approach procedures for these airports.

Other elements of the national plan supportive of the GPS air navigation system were successfully accomplished. These include the provision of area navigation service (i.e. area control) covering the national airspace through the Kano Area Control Centre (ACC) and Lagos ACC, completion of the implementation of Aeronautical fixed Telecommunication network (AFTN) and extension of the existing VHF radio coverage in the country. In addition, the terminal approach radar system (TAR) of Lagos, Abuja and Kano were refurbished as an interim measure when the total radar coverage of Nigeria (TRACON) project approved by the Federal Executive Council in April, 2003 is fully operational.

This project is designed to ensure effective surveillance of the Nigerian airspace using six (6) en-route and four (4) terminal radar and Automatic Dependence Surveillance ADS-B facilities to be installed in Talata Mafara, Maiduguri, Numan, Obubra, Ibadan, and Abuja. Also to be installed are four terminal radars in Kano, Lagos, Abuja and Port Harcourt.

The global navigation satellite system and other related elements of the CNS/ATM system contained in the national plan (2000 –2005) are implemented in an evolutionary manner to avoid serious transition problems taking into cognizance the existing technical realities on ground in order to provide cost- effective services to general aviation user groups.

4.3. GPS AUGMENTATION

The performance objectives for aeronautical application are usually characteristic by four (4) main parameters: accuracy, integrity, availability and continuity of service. The values for these parameters are highly dependent on the phases of flight if GPS is to be utilised for all phases of flight in the country, it must satisfy the requirement listed in Table 1. The present configuration of the GPS system cannot meet those requirements without system augmentation to ensure the timely availability of the necessary information on the signal integrity, accuracy, availability and continuity.

The choice of the appropriate augmentation in the country is in consideration of the medium and long-term application of GPS for operation in particular phase of flight contained within the existing implementation plan (2000 – 2005). The country is therefore implementing necessary augmentation in line with the AFI region and ICAO's proposals as contained in Table 2.

augmentation systems planned and opted for the European Geostationary Navigation Overlay service (EGNOS)

Complemented by the use of two INMARSAT III satellite navigation transponders and the ARTEMIS satellite developed by ESA (Ventura-Traveset, 2003), the EGNOS system as an augmentation to GPS, is fully interoperable with other SBASs with an inbuilt expansion capability enabling easy extension of its services areas within the Geostationary broadcast area of GEO satellite used in the system over Africa, Eastern countries and Russia.

The EGNOS architecture is based on a network of ground reference stations (RIMS: Ranging and integrity monitoring stations), that receive and monitor GPS signals. Data from these reference stations are transmitted to a master station (MCC: Master control centre) where the validity of the signals from each satellite is assessed and corrections are computed. These integrity messages and corrections are broadcast over a wide area to aircraft via geostationary communication satellites (INMARSAT), which also serve as additional sources of GPS ranging signal. Figure 5 shows the INMARSAT Geostationary footprints.

The Nigerian Airspace Management Agency in collaboration with Dakar based ASECNA (Agency for the safety of air navigation in Africa) conducted trials and demonstration of EGNOS test-bed in Nigeria on the 9th and 10th May, 2003 for approach procedures with vertical guidance (PV-1) in Lagos, Kano and Port Harcourt using four (4) RIMS in Lome, N'djamena, Bangui and Brazzaville.

TABLE 2. GPS AUGMENTATION REQUIREMENT. SOURCE: 1CAO, 1998

OPERATION/PHASE OF FLIGHT	RNP TYPE	GENERIC AUGMENTATION ARCHITECTURE		
		SUPPLEMENTAL MEANS	PRIMARY MENAS	SOLE MEANS
EN-ROUTE	RNPI and above	ABAS	ABAS	AAS OR ABAS + SBAS
INITIAL OR INTERMEDIATE APPROACH; NON-PRECISION APPROACH, DEPARTURE	RNP0.3	ABAS	ABAS or ABAS + SBAS	ABAS or ABAS + SBAS
NON PRECISION APPROACH (WITH VERTICLA GUIDANCE)	RNP 0.3/125	ABAS	ABAS or ABAS + SBAS	ABAS or ABAS + SBAS
PRECISION APPROACH DOWN TO 60 M (200FT) CATEGORY I	RNP 0.02/40	ABAS + SBAS	ABAS + GBAS	ABAS + GBAS

Nigeria working in tandem with the AFI Planning and Implementation Regional Group (APIRG) reviewed proposals for the introduction of GPS and in particular SBAS in the country. There are however problems associated with both operational and technical issues, that include whether the country needed SBAS and which type among the three existing brands (WAAS, EGNOS and MSAS) and for what phase(s) of flight. Secondly, whether local area augmentation is needed either as an additional or alternative to SBAS. At the technical level, the implementation of the augmentation systems for en-route, terminal approach and landing need to be addressed. The country having considered these issues in addition to signal coverage and cost benefit analysis of the different SBAS

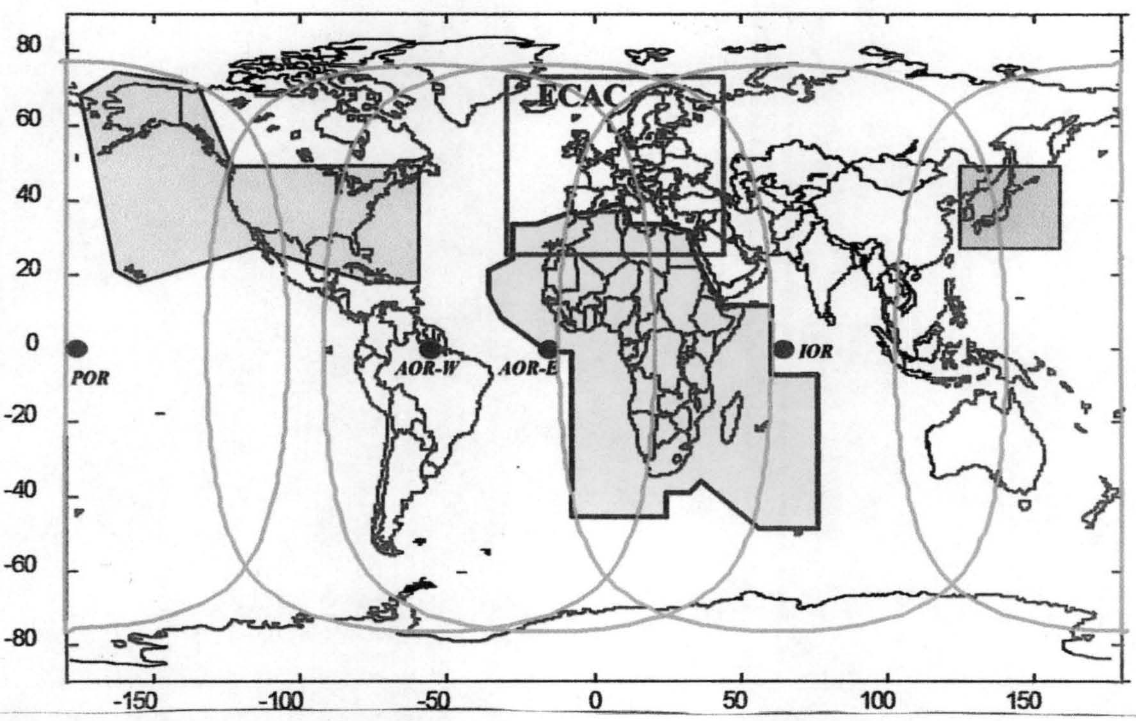

FIG.5 INMARSAT GEOSTATIONARY SATELLITE FOOTPRINTS OVER AFI REGION

The purposes of Egnos satellite test bed (ESTB) are:

i. To have a first assessment of the performance within national airspace that can be achieved with EGNOS e.g. APV-1;

ii. To analyse in dept specific critical design and operational issues or tradeoff between several options;

iii. To demonstrate the system operations and allow experimentation to the country's specific needs;

iv. To develop and validate the system test methods; and

v. To provide a representative tool for NAMA to build up SBAS practical experience.

The result of discussions and series of informal interviews conducted at NAMA headquarters indicates that the signal reception is excellent and extends well into areas that were hitherto suspected to be out of the coverage area. This demonstration rekindles the enthusiasm to use GPS as a sole means and subsequent decommissioning of VOR/DME used for en route and non-precision approaches as from ten (10) years time.

Although all respondents accepted the fact that GPS is reliable for air navigation and be approved as supplemental means to the existing conventional navigation (76%), they however do not support the idea that even with a fully operational GPS, conventional ground aid such as VOR, DME, NDB, location beacons currently in use will be decommissioned. About 85% of the respondents do not support the idea. Further analysis of the questionnaire reveal that of the 25% that subscribe to the decommissioning process only 28.5% accepted it for the next ten

(10) years, 43% opted for 20 years while 28.5% deemed it necessary only after 30 years. This implies that GPS can at best be used as an overlay or back up to the current navigational facilities which will not find diminishing utility at least in the distanced future.

The respondent view cannot be divorced form the institutional, financial and politics associated with the satellite navigation technology. In fact, the problems and sentiment are somewhat similar to that which dwarfed the regional approach to the adoption and introduction of remote sensing technology in Africa. The four (4) RIMS used in conducting the trials and demonstration of the EGNOS test bed are donated by French government hence their location in francophone countries Togo, Chad, Central Afrique and Congo.

ICAO has emphasized regional approach to the implementation of GPS in consideration of the fact that satellite systems are extensive and cover large service volume. Africa having noted her well-categorized deficiencies in ground and shore facilities coupled with the immense landmass and huge financial requirement considered the regional approach most suitable. The AFI planning and implementation group (APIRG) held a meeting in Abuja in 1997 to harmonise GPS performance by identifying set of scenarios for its implementation in the region. The study projected the installation of between 19 to 26 RIMS and two (2) master control stations in Africa. Already six countries (Egypt, Tunisia, Morocco, Canary Islands, South Africa and Reunion) have made plans for the installation for RIMS in their countries.

Nigeria is therefore encouraged to have at least a single RIMS located within her territory to assure RNP5 capability if GPS is to be used beyond non-precision approach e.g. CAT 1 and 11 precision approach with vertical guidance, or as a primary and sole means system for all phases of flight. The attempt by the country at technological leapfrogging from traditional terrestrial based systems to satellite navigation can best be appreciate under three (3) identified scenarios.

(a) ***SCENARIO A***: This scenario depicts conventional navigation aids without GPS. The current air navigation system is based on conventional navigation radio aids such as the VOR, DME, NDB, ILS and locator beacons. There are about twenty six VOR/DME 19 ILS and 28 NDB located at all airports within the country, three en-route stations, and several private and military airstrips.

These facilities are reliable and robust permitting the safety of aircraft navigation within the national airspace. The structure of the current national airspace is based on these navigation aids. Despite their dependability many of these facilities are obsolete and characterized by frequent breakdown. This situation gave rise to the blacklisting of the country by international organizations such as the International Federation of Airline Pilot Association (IFALPA), International Air Transport Association (IATA) and even ICAO. That was the situation prior to 2000, but with the advent of NAMA, the country witnessed significant improvement in the communication, navigation and surveillance system.

TABLE 3: NAVIGATION FACILITES

S/NO.	NAVIGATIONAL STATION	AIDS	IDENTIFICATION TYPE	FREQUENCY
1.	ABUJA	VOR	ABC	116.3MHz
	"	DME	ABC	CH110X
	"	NDB	AG	321KHz
	"	2ILS	N/A	N/A
2.	BENIN	VOR	BC	116.5MHz
	"	DME	BC	CH112 x
	"	NDB	BC	338kHz
	"	NDB	BE	272KHz
3.	BIDA	VOR	BDA	112.7MHz
	"	DME	BDA	CH>4 x
	"	NDB	BD	328kHz
4.	AKURE	NDB	AK	276KHz
5.	CALABAR	VOR	CAL	114.1MH
	"	DME	CAL	CH 88 x
	"	NDB	CR	317KHz
	"	1ILS	N/A	N/A
6.	ENUGU	VOR	EU	113.7MHz
	"	DME	EU	CH1044x
	"	1ILS	N/A	N/A
7.	GWASERO	VOR	GW	114.3MHz
	"	DME	GW	CH90x
8.	IBADAN	VOR	IB	112.1MHz
	"	DME	IB	CH58x
	"	NDB	IN	310KHz
	"	1ILS	N/A	N/A
9.	ILORIN	VOR	IL	112.3MHz
	"	DME	IL	CH>0 x
	"	NDB	IL	371MHz
	"	1ILS	N/A	MN/A
10.	JOS	VOR	JOS	113.1 MHz
	"	DME	JOS	CH>8 x
	"	NDB	JS	103 KHz
11.	KADUNA	VOR	KU	114.7MHz
	"	DME	KU	CH94x
	"	NDB	KD	356 KHz
	"	VOR	KDA	115.3MHz
	"	DME	KDA	CH94 x
	"	NDB	KC	310KHz
	"	2IL	N/A	N/A
12.	KANO	VOR	N/A	112.5MH$_Z$
	"	DME	IL	CH 72 X
	"	NDB	IL	260 KH$_Z$
	"	NDB	IL	376 KH$_Z$
	"	21LS	N/A	N/A

13.	LAGOS	VOR	LAG	113.75MH_Z
	"	DME	LAG	CH84 X
	"	NDB	LA	336KH_Z
	"	1ILS	LB	368 KH_Z
	"	VOR	LOS	112.9 MH_Z
	"	DME	COS	CH 76 X
	"	4ILS	N/A	N/A
	MAIDUGURI	VOR	MIU	113.7MH_Z
14.	"	DME	MIU	CH84 X
	"	NDB	MA	332KH_Z
	"	1ILS	N/A	N/A
	MINNA	VOR	MNA	115.1MHz
15.	"	DME	MNA	CH98x
	"	NDB	MN	350KHz
	OKITIPUPA	NDB	OK	345KHz
16.				
	OWERRI	VOR	OWR	114.9MHz
17.	"	DME	OWR	CH96x
	"	NDB	OW	391KHz
	PORT-HARCOURT	VOR	POT	113.5MHz
18.	"	DME	POT	CH82 x
	"	NDB	PR	385KHz
	"	2ILS	N/A	N/A
	SOKOTO	VOR	SOK	113.9mhZ
19.	"	DME	SOK	CH86 x
	"	NDB	SK	397KHz
	"	1ILS	N/A	N/A
	YOLA	VOR	YO	115.5MHz
20.	"	DME	YO	N/A
	"	NDB	YL	336KHz
	"	ILS	N/A	N/A
	ZARIA	NDB	ZA	336KHz
21.	KATSINA	VOR	N/A	N/A
22.	"	DME	N/A	N/A
	BAUCHI	NDB	N/A	N/A
23.	OSUBI	VOR	N/A	N/A
24.	ESCRAVOS	NDB	N/A	N/A
25.	EKET	NDB	N/A	N/A
26.	POTISKUM	VOR	N/A	N/A
27.	"	DME	N/A	N/A
	GBOKO	VOR	N/A	N/A
28.	"	DME	N/A	N/A

In spite of these improvements and considering the extensive national airspace, experts have insisted that the country has little or no air routes at all due to lack of essential navi aids on such routes (Lawrence, 2001). There is therefore inadequate ground-based navigation facilities to cover the whole of the national airspace. In fact, it is practically not possible to do so.

***(a)* SCENARIO B**: Conventional navigation aids with unaugmented GPS.

This is the current situation today in the country. The provision of air traffic control in the country today remains largely procedural in nature. This procedure involve the controller issuing instructions to pilot based on position reports computed by the aircraft avionics from the existing navigation facilities. GPS therefore is an essential tool for determination of position in the event of navigation aids unserviceability or over areas not adequately covered by navigation facilities. GPS can therefore be used as a supplementary means and for en-route navigation only. For aircraft operating into or out of any of the existing airstrip in the country, GPS is a breakthrough. However, GPS cannot be used for shooting approaches at all airports since final approach maneuvering as stipulated in ICAO Document 4444 (Rules of Air and Air Traffic services) is based on ILS/DME, VOR/DME and NDB only. This makes it necessary to augment GPS performance at local, national and regional levels for use in all flight phases.

***(c)* SCENERIO C:** GPS augmentation with EGNOS.

The purpose of the African strategy for the global navigation satellite system is to define an evolutionary path for the replacement of ground-based navigation aids by assuming the availability of GPS meeting specified parameters at every phase of development. Nigeria's adoption of this strategy must ensure that operational and other concerns such as positive cost-benefit are fully taken into account.

GPS with EGNOS have sufficient capabilities to meet en-route navigation requirements anywhere in the country. In order to approve GPS as a primary means for navigating in terminal areas at least a single RIMS must be located within the country. This would also provide sufficient capabilities for non-precision approaches at all selected airports resurveyed for WGS-84 conversion. GPS can also be certified as a supplementary means for precision approach category 1 (APV-1) even for busy terminals such as Lagos, Kano, Abuja and Port-Harcourt provided the analysis of historical meteorological data or traffic characteristics justifies the requirement and aircraft carries the appropriate GPS augmentation on board. The research does not find any justification for the approval of GPS even with EGNOS for precision approach category II and III in any of the airports at least for now and the near future. About 71% of all respondents accepted GPS as appropriate for non-precision approach as against 21% that opted for precision approach. Further analysis of users responses indicates that 48.3% considered GPS reliable for landing approaches in busy terminals.

For GPS to perform in all phases of flight as advocated by its owners and promoters, institutional issues such as ownership, selective degradation of its signal, vulnerability of its signal, standardization and the role ICAO is expected to play must all be squarely addressed. Nigeria must therefore tread cautiously and patiently wait for a constellation that is owned and operated by civil aviation for the enhancement of the safety of air navigation. Currently, GALILEO, the European contribution to global satellite navigation system is in the pipeline.

4.4 GPS STANDARDIZATION AND RECEIVER CERTIFICATION

There is no common set of standards on how satellite-based navigation systems can be certified for the various levels of service such as supplemental means, primary means and sole means. Therefore, each nation has to choose between different certification and commissioning processes. ICAO that is expected to provide leadership can only provide a forum to member states to discuss common standards. It is true that ICAO generally accept the certification given by a state to its own navigation services.

There are a lot of issues concerning GPS that must be addressed. This includes the status of GPS, its interoperability, safety of augmentation systems, equipment standardization, liability etc. The Nigerian airspace Management Agency (NAMA) is mandated via Decree 48 of 1999 to develop and implement the GPS air navigation service. It is responsible for providing aerodromes at all major Nigerian airports, the navigation services necessary for the operation of aircraft taking off and landing and integrate them into the overall flow of air traffic within the Nigerian airspace and procure, install and maintain adequate communication, navigation and surveillance and air traffic management (CNS/ATM) facilities at all airports in Nigeria among other functions. NAMA is therefore spearheading the country to embrace space technology for air navigation by putting the necessary infrastructure for the smooth take off of the satellite-based air navigation service in the country.

The Nigerian Civil Aviation Authority established by Decree 49 of 1999 has among many responsibilities the granting of licenses in respect of airports, aerodromes, heliports and airstrips and also certify airways, navigational approaches and landing aids in Nigeria to ensure safety of air navigation. NAMA is therefore responsible for providing air navigation equipment and facilities while NCAA must ensure that this facilities equipment and aids conform to ICAO standard and recommended practices (SARPS). In the same vein while NAMA is busily putting in place the necessary infrastructure for the implementation of the satellite system, NCAA has not deployed the necessary tools for certifying the GPS navigation services for the country. Interviews conducted at the NCAA headquarters in Lagos revealed that the agency is undergone significant reforms. It is therefore important that NCAA puts in place the necessary regulations to approve GPS as a supplemental, primary or sole means for either en route, terminal or airport flight operations, and certify GPS receivers that conform to the desired standard.

GPS receivers are essential element of the GPS architecture. These receivers convert satellite signals into position, velocity and time estimates. They operate on the WGS-84 global geocentric reference system. In Nigeria, all aircraft are mandated by the defunct Federal Civil Aviation Authority (FCAA) to carry GPS receivers on board. Most general aviation pilots have GPS handheld receivers. There are many different GPS receivers models, the most prominent among

Nigeria pilots are the Garmin 100/165, KLN 900, King KLN94, Bendix King, Allied signals, Trimble and Hilton 450.

It is observed that the introduction of GPS receivers for air navigation has out spaced the capacity of civil aviation authorities to resolve issues that concern the safe and efficient use of such devices. ICAO has adopted the Technical Standard Order (TSO) C129 A1 as the standard for certifying standalone Instrument flight Rules (IFR) GPS receivers.

Proliferation of GPS receivers and current certification standards appear to have little impact or promoting the design of standardized receiver architectures, interface and operating manual. It has been demonstrated by O'Hare and St. George (1994) and Heron et al. (1997) that complex receiver architecture and cumbersome receiver operations can combine to impair pilot performance. Evidence abound from a number of sources, that lack of appropriate certification and standardization can undermine safety (Joseph, 2000).

As stated earlier all aircraft registered in Nigeria are required to install GPS while many of the pilots have the handheld receivers. Analysis of data collected shows that only 84% of Pilot has the devices certified. There is however uncertainty regarding the appropriate regulatory authority. About 20% of those that affirmed as having their receivers certified did not indicate the certifying body. However, 10% of the respondents indicates that the receivers were certified by their operating company, while 40% by US Federal Aviation Authority (FAA) and UK's

Civil Aviation authority (CAA) and only 30% by Nigerian Civil Aviation Authority (NCAA)! There is therefore the need to harmonized and standardize the certification process in accordance with TSO C129 requirement to assure safety of air navigation in the country.

The cost of many GPS handheld receivers in the country ranges form US$500-1000 and may therefore not have a selectable datum feature and the required channels to receive the ranging signals from extra satellites as such, extra care must be taken. It is therefore important that pilots should ensure they understand the limitations of their equipment before using the output for piloting. These receivers apart from position, time and speed also incorporates such information as fuel, data, airport navigation aids, gross weight, deviation among others.

4.5 HUMAN RESOURCE DEVELOPMENT AND GPS TRAINING

The need for human resource development for economic advancement cannot be underscored. Development of human resources is the basis for all activities that involve the use of technology, the acceptance of satellite technology for improved air navigation system and its implementation in an evolutionary manner makes it necessary for the development of human resources through the transition period.

It is imperative to understand GPS operational concepts, capabilities as well as its limitation. In addition, civil aviation authorities as well as the user community must be trained on how to implement and utilized the satellite system to improve air transportation in the country to the satisfaction of its citizenry. In fact, the survival of any nation is heavily dependent on its ability to provide the basic needs of its people (Okhimamhe, 1999).

The result of the questionnaire survey indicates that 74% of all respondents did not receive any kind of formal training on GPS nor the CNS/ATM system. Only 26% showed that they received some level of training on GPS. About 91% of those trained are mostly pilots who were self trained by reading users manual and available literature. Among the very few air traffic controllers that were trained are those occupying management positions outside the realm of active control.

This implies that the civil aviation authorities in the country place emphasis on the implementation of the global navigation satellite technology without corresponding efforts to train the personnel that would be actively involved in its utilization and maintenance.

Interviews and discussions with students, recent graduates and principal officers of the Nigerian College of Aviation Technology (NCAT) Zaria, the training centre for the Nigerian Aviation industry, indicate that the training available on GPS, hardly goes beyond introducing the technology to the student. In fact, instructors at the college who are expected to impart knowledge to the students were not trained on GPS themselves.

Four basic areas requiring training is therefore identified to ensure that an appropriate and common understanding of the concept operation and limitation of the GPS technology is achieved:

(a) General overview education;

(b) Flight crew training;

(c) Air traffic services training; and

(d) Technical support system training

NAMA, NCAA and NCAT should organize an elaborate training progrmme comprising the four identified areas for persons involved in maintaining the existing system and other operational staff that would eventually use new equipment and procedures. It is also intended that the transition training should enable the civil aviation authorities achieve the required expertise by providing the relevant technical and operational personnel with the necessary training well before the full implementation of GPS approved services for the desired phase of flights in the country.

A computer-based training method in line with ICAO DOC 9758 (Human factors guidelines for Air traffic management (ATM) systems) and AFI region human resource planning and training needs of GPS implementation be pursued vigorously to successfully launch the country into the world of satellite navigation systems.

4.6 *THE BENEFITS OF THE SATELLITE-BASED AIR NAVIGATION SYSTEM*

The benefits of satellite navigation to air traffic management in the country are enormous. The present air navigation aids distribution in Nigeria is inadequate to build an efficient air traffic services network that meets the projected increase in air traffic (of 3% to 6%) for the next ten years or thereabout (Onasanya, 2002a). The challenge therefore is to generate capacity, raise safety levels and reduce costs simultaneously. The present structure of the national airspace is based on the dispersed conventional ground aids thereby making the width of the air traffic routes rather wide. This affects the utilization of airspace capacity associated with increased delays and operational cost on fuel. Figure 6 illustrates the present air traffic services (ATS) routes based on conventional ground aids.

It is envisaged that the principal benefits of GPS will clearly accrue to domestic airlines and the Nigerian Airspace Management Agency (NAMA). It is expected that airlines will have navigation capability over the whole of Nigerian airspace and should be able to take greater advantage of the most fuel efficient routes and tracks at any given point in time. Airline operators will also benefit from increased safety and airspace capacity as well as increased savings from fuel.

With fully operational GPS, NAMA will have improved four-dimensional accuracy of aircraft position information, thereby enhancing safety especially in the seventeen airports where radar service is currently lacking. NAMA through its air Traffic Control (ATC) units: Aerodrome Control, Approach Control (procedural),

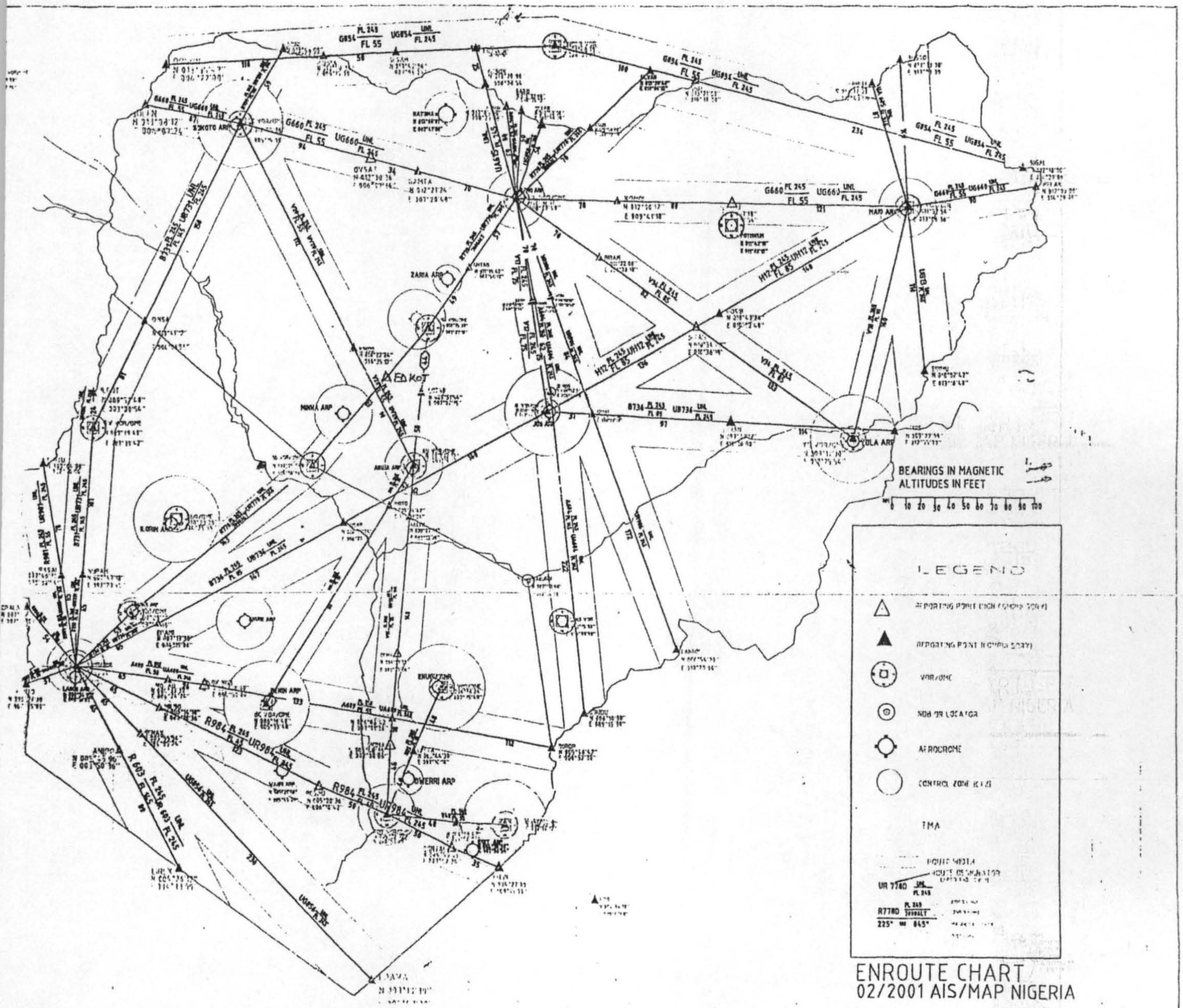

FIG. 6: EN-ROUTE CHART BASED ON CONVENTIONAL GROUND AIDS.

Terminal Approach Radar (TAR) Control and Area control should be better able to accommodate an aircraft's preferred flight profile, as well as adapt more efficiently to changes in patterns of traffic. Onasanya (2002b) postulated that GPS overall system plan will improve navigation and landing capabilities to support advanced approach and departure procedures, increase user involvement in air traffic management decision making including air-ground flight negotiation and organize airspace in accordance with ATM provision and procedures.

All respondents to the questionnaire survey and, all informal interviewees and discussant agreed that GPS is reliable for both instrument flight Rules (IFR) and Visual Flight Rules (VFR) operations in the country. Further analysis of the survey reveals that GPS is an indispensable tool for search and rescue (SAR) operations. Accurate navigation is essential for maximizing the probability of success in search operations and for determining the exact position of survivors or wreckage. Precise navigation equipment such as GPS can be helpful in covering a search area carefully or locating a datum especially over terrain or water with few navigation references.

Other benefits include efficient ground control, increased traffic flow, safety, reliability and efficiency across the national airspace. The benefit of GPS navigation service to the aviation industry is assessed using the cost-benefit analysis on the basis of GPS being used as supplemental means through non-precision approach with EGNOS serving as the satellite-based augmentation system (SBAS).

It is concluded on the basis of the cost-benefit analysis explained ealier and from the service provider's perspective that the assessed operational benefits (N250million) exceeds the cost of GPS + EGNOS implementation (N173 million) by N77million. The study accepts the analysis of IATA (International Air Transport Association) that the airlines' operational benefits will compensate their extra investment for on-board avionics (EAC, 1999). In Nigeria, most of the accruing benefits are expected from reduced delays and fuel savings by flying most economic routes. GPS would open wider possibilities by allowing aircraft the prospect of flying over the country using accurate navigation signals. The availability of such compatibility provides greater flexibility to ATM with the capability of choosing the most economic routes as shown in Figures 7 and 8.

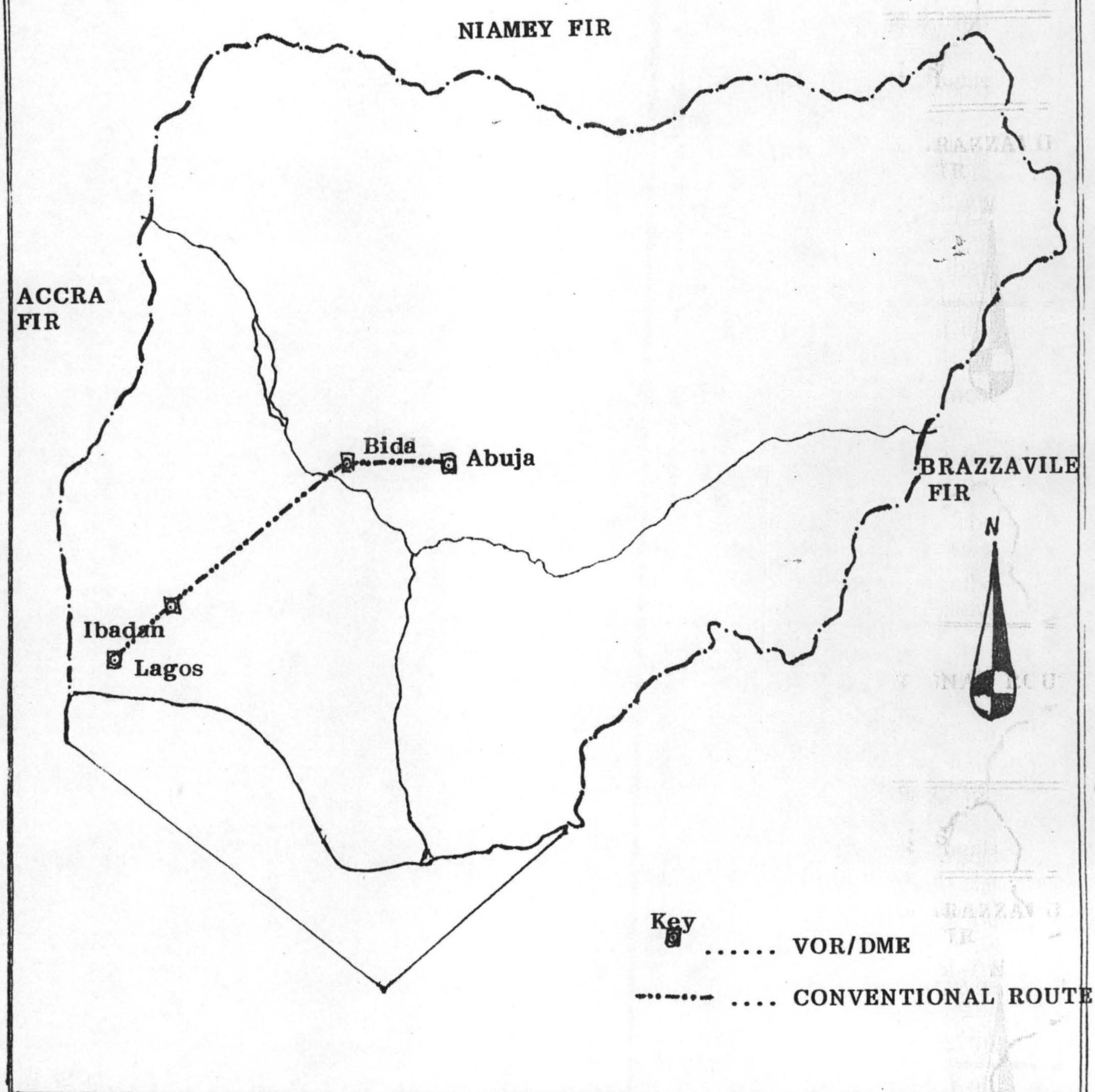

FIG.7: LAGOS-ABUJA ROUTE BASED ON CONVETIONAL GROUND AIDS

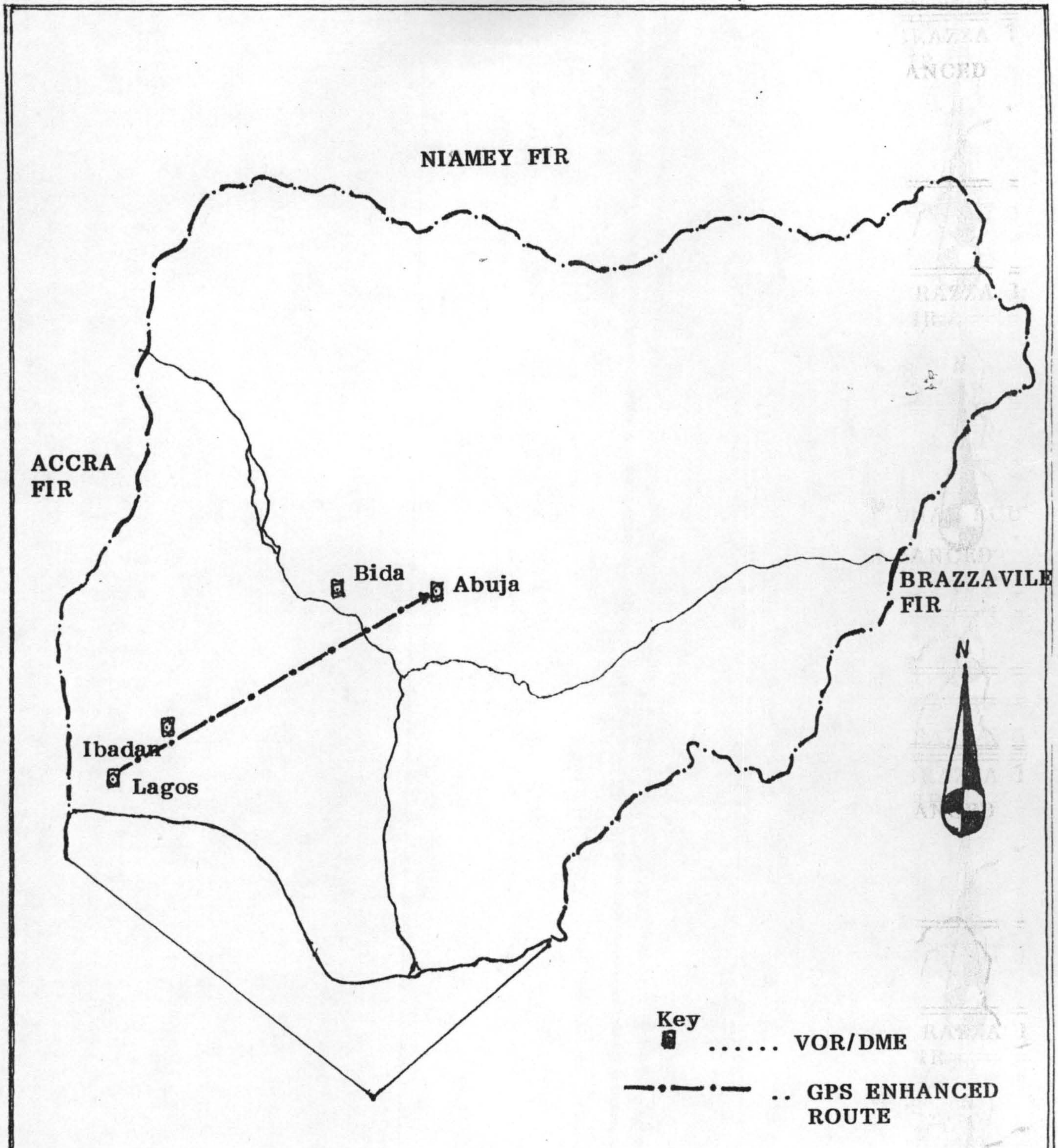

FIG.8:: LAGOS-ABUJA ROUTE BASED ON GPS NAVIGATION

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The demand for air transportation in the world is expected to continue to grow well into the next two decades. In, Africa, that growth is expected to be about 5% a year and in Nigeria the projected growth ranges from 3 to 6%. The current air navigation infrastructure and air traffic management capabilities, however present serious constraint to that projected growth.

To meet the challenge, Nigeria has accepted the concept proposed by ICAO in the early 1990s that promote the transition from conventional ground – based to satellite-based air navigation system. The opportunity came when in 1993, ICAO accepted the US global positioning system (GPS) for aircraft navigation. ICAO therefore proposed a regional approach to the implementation of the global navigation satellite system. The opportunity came when in 1993, ICAO accepted the US Global Positioning System (GPS) for aircraft navigation. ICAO therefore proposed a regional approach to the implementation of the global navigation satellite system. At the same time member states were encouraged to develop and implement the GPS navigation technology considering their needs, technical competence and financial resources.

Nigeria therefore developed a short-term master plan (2000-2005) for the implementation of the satellite navigation system. This master plan conforms with ICAO's AFI (African and Indian Ocean) region, CNS/ATM implementation plan

(1995-2005). The plan comprises of a number of projects to be completed at targeted dates that would lead to the eventual decommissioning of the current navigation aids in ten (10) years time. A substantial number of elements contained in these projects were successfully accomplished while many were rescheduled with a few others yet to be embarked upon.

To assess the role of GPS in air navigation in the country, an aggressive data collection strategies was embarked upon through the use of extensive reading, numerous interviews and discussions as well as the administration of one hundred and fifty one (151) questionnaires to seventy six (76) air traffic control officers, forty eight (48) general aviation pilots and twenty seven (27) flight and air traffic safety and electronics services engineers. The data collected was subjected to simple statistical methods to achieve the stated objectives of this study.

Nigeria as a contracting state of ICAO is obligated, and has accepted to implement the necessary infrastructure for the GPS air navigation system. An elaborate transition plan was established for this purpose and substantial improvement has been made in laying out the requirements. However, certain key elements of the master plan (2000-2005) are yet to be implemented. These include the WGS-84 for all airports, construction of GPS- based instrument approach procedures, the VSAT, TRACON and SATCOM projects.

Recently, the trials and demonstrations conducted on the 13^{th}-19^{th} of 2003 in Lagos, Kano and Port-Harcourt demonstration that EGNOS satisfies the RNP in terms of accuracy, integrity, availability and continuity of services and can therefore be relied upon as an augmentation to GPS performance.

GPS based air navigation system is yet to be certified either as a supplemental, primary, or sole means for specific phase of flights (en-route, terminal and airport). In addition many of the GPS receivers (handheld and aircraft fitted) are not certified and standardized by NCAA. This body responsible for regulating civil aviation practice in Nigeria does not have the necessary legislation and the required machinery to carry out appropriate certification in accordance with Standard And Recommended Practices (SARP) of ICAO. NCAA is also yet to acquire the class I certification status from ICAO.

Most of the personnel involved in the use of GPS are not trained on any aspect of GPS are any aspect of GPS including pilots, ATCOS and Engineers. Only pilots have some informal training on system operations usually through manuals and brochures.

5.2 CONCLUSION

The analysis of GPS as an air navigation resource technology can best be appreciated in consideration of the three application areas in the country is necessary.

a. En-Route guidance over the terrestrial airspace in the country is by the ubiquitous VOR/DME ground transmitters. This system is highly reliable, and safe.

Present distribution of VOR/DME is disperse and inadequate to accommodate future traffic growth of between 3-6%.

VOR-based navigation is laterally inaccurate and this has caused the airways to be wide thereby reducing the capacity of the air space to contain an increased traffic. GPS, a highly accurate navigation system can dramatically reduce the width of the airways. There are currently twenty six (26) VOR/DME in the country.

b. Aircraft approaching the airport are slowed down in line with other arrivals to get to final approach sequentially at specified rates. Ground transmitters such as ILSs, VOR/DMEs and NDBs support the chartered approaches. But the busiest airports of Lagos, Abuja and Kano are radar controlled and much of the maneuvering is by controller-issued vectors without the much use of navigation aids at all. Here GPS will do no more than the existing ground aids. Airport capacity is determined by the runway acceptance rate (usually 8 minutes), a fixed rate. GPS would not increase this rate but at Lagos, associated with early morning fog and closely spaced runways and other foggy airports of Calabar and Port-Harcourt, loss of capacity may be avoided.

c. Final approach is the most critical and potentially dangerous phase of flight. Low visibility instrument approaches are divided into two categories. The non-precision approaches, as the name suggests, have a lower level of accuracy and no continuous vertical guidance. Non-precision approaches in the country are made possible with the availability of VOR/DMEs and NDBs at various airports. Precision approaches, on the hand, are extremely accurate and they vastly increase the all-weather use of an airport. The standard for precision approaches at all international and busy airports in the country is the instrument landing system

(ILS), a system with two transmitters next to the runway with phenomenal accuracy and dependability.

GPS signal is vulnerable and can be tampered with intentionally or unintentionally. It is therefore not dependable. This raises a lot of institutional, military, legal, political and economic issues that must be resolved at all levels. GPS therefore can only be used to supplement the existing navigation aids that are highly reliable, safe and even in US GPS is approved only for IFR supplemental navigation system for domestic en-route through non-precision approach (NPA) phases of flight, and as a primary means system for oceanic navigation.

It is often thought that GPS can easily become a precision approach mechanism because its signal can be received right down to the ground level. Closer analysis of GPS signal has revealed that it cannot by itself meet the rigorous safety standards required for low decision heights (Bond, 1996). GPS with EGNOS will therefore not displace all the ILSs in the country and airports needing new precision approaches may well, in the future, acquire them.

However, GPS approach could prevent the installation of NDBs at airports and airstrips without a non-precision approach thereby saving a good deal of money. GPS can also be approved as an overlay to the existing system, to serve as necessary backup in the event of power failure – a frequent occurrence in the country.

Despite these problems and constraints GPS is beneficial to air navigation. GPS can be relied upon to supplemental means to the existing navigation aids in the event of failures in any of the twenty airports and as a primary means over the country's oceanic airspace and most of the airstrips where conventional ground aids is non-existent. The greatest benefit of GPS is that it provides a good signal where none now exist. Other benefits include improved airspace capacity, ATM capabilities by allowing aircraft fly the most suitable routes. Increased savings on fuel to airlines and maintenance cost to Air Navigation Service Provider – put at over a hundred million (N100m) a year.

It is important that the country's requirement be prioritized such that the characteristics and peculiarities of the air navigation system are brought to the fore as the country gradually transits from terrestrial to satellite-based navigation system. This way the full benefits of the GPS navigation service can be achieved without safety infringement.

Finally, it is important to reiterate the fear of the General Manager, Airspace Planning and Technical Evaluation (NAMA) when he posited in 2003 that "As we meander through the sea of technology, we need to determined our requirements so that we do not get lost. I can tell you that it is very easy to get lost."

5.3 *RECOMMENDATIONS*

The following recommendations are necessary for the introduction and implementation of GPS navigation service for improved air navigation system in the country.

a. The present GPS implementation plan (2000-2005) should be pursued vigorously with the completion and expansion of key elements specifically the WGS-84 to cover all airports in the country.

b. To assure enhanced GPS performance capabilities for all phases of flight, it is important to acquire and install at least one range and integrity monitoring station (RIMS) in the country. In addition NCAA should come up with a clear cut policy demanding aircraft registered in Nigeria to carry the necessary augmentations on board.

c. The Federal Ministry of Aviation should strengthen NCAA to acquire CLASS I certification status from ICAO. It is also expected that NCAA should put the required modalities to certify GPS navigation service for specific flight operations. In addition, the regulatory body should certify GPS receivers and recommend performance standards for critical applications.

d. Comprehensive and intensive trainings are required for plots, air traffic controllers, engineers and other stakeholders. Specifically, pilots, air traffic controllers and engineers are required to have basic knowledge and understanding of how equipment operates. It is recommended that seminars, workshops and conferences be conducted for stakeholders on all aspects of GPS.

e. Instructors at NCAT Zaria should be encouraged and supported to acquire knowledge on the global navigation satellite system with a view of imparting knowledge gained to aviation students.

f. The Federal Ministry of Aviation should take an active role in developing a road map for the future navigation infrastructure and harmonies activities of civil aviation authorities in the country.

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APPENDIX 1

ABBREVIATIONS AND ACRONYMS

CICA	Convention On International Civil Aviation.
ICAO	International Civil Aviation Organization.
VOR	Very High Frequency Omni direction Radio.
DME	Distance Measuring Equipment.
ICS	Instrument Landing System.
NDB	Non Directional Beacon.
LB	Locator Beacon.
ADF	Automatic Direction Finder
CNS/ATM	Communication, Navigation, Surveillances Air traffic Management
AFI	African And Indian Ocean
GNSS	Global Navigation Satellite System
RNP	Required Navigation Performance
RAF	Royal Air Force
CAD	Civil Aviation Department
FIR	Flight Information Region
UTC	Upper Terminal Control Area
TMA	Terminal Control Area
CTZ	Control Zone
SRR	Search And Rescue Region
SAR	Search And Rescue Region
RCC	Rescue Co-ordination Area
RSC	Rescue Sub-Center

ACC	Area Control Center
FANS	Future Air Navigation System
ATM	Air Traffic Management
ADS	Automatic Dependence Surveillance
IGEB	Intergovernmental GPS Executive Board
APRIG	AFI Planning And Implementation Regional Group
GLONASS	Global Orbiting Navigation Satellite System
GPS	Global Positioning System
SA	Selective Availability
IFR	Instrument Flight Rule
VFR	Visual Flight Rule
AIS	Aeronautical Information Service
AIP	Aeronautical Information Publication
NOTAM	Notice To Air Men
ATS	Air Traffic Service
AIC	Aeronautical Information Circular
ANS	Air Navigation System
WGS	World Geodetic Survey
IATA	International Air Transport Association
TRACON	Total Raider Coverage Of Nigeria
SATCOM	Satellite Communication
SARP	Standard And Recommended Practice
VSAT	Very Small Aperture Terminal
NPV	Non Precision Approach With Vertical Guidance
NPA	Non Precision Approach
APV	Precision Approach With Vertical Guidance

PROCEDURES FOR AIR NAVIGATION SERVICES

PART I. DEFINITIONS

Note.— Throughout the text of this document the term "service" is used as an abstract noun to designate functions, or service rendered; the term "unit" is used to designate a collective body performing a service.

When the following terms are used in the present document they have the following meanings:

Accepting unit/controller. Air traffic control unit/air traffic controller next to take control of an aircraft.

Note.— See definition of "transferring unit/controller".

Advisory airspace. An airspace of defined dimensions, or designated route, within which air traffic advisory service is available.

Advisory route. A designated route along which air traffic advisory service is available.

Note.— Air traffic control service provides a much more complete service than air traffic advisory service; advisory areas and routes are therefore not established within controlled airspace, but air traffic advisory service may be provided below and above control areas.

Aerodrome. A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

Note.— The term "aerodrome" where used in the provisions relating to flight plans and ATS messages is intended to cover also sites other than aerodromes which may be used by certain types of aircraft, e.g. helicopters or balloons.

Aerodrome control service. Air traffic control service for aerodrome traffic.

Aerodrome control tower. A unit established to provide air traffic control service to aerodrome traffic.

Aerodrome elevation. The elevation of the highest point of the landing area.

Aerodrome taxi circuit. The specified path of aircraft on the manoeuvring area during specific wind conditions.

Aerodrome traffic. All traffic on the manoeuvring area of an aerodrome and all aircraft flying in the vicinity of an aerodrome.

Note.— An aircraft is in the vicinity of an aerodrome when it is in, entering or leaving an aerodrome traffic circuit.

Aerodrome traffic circuit. The specified path to be flown by aircraft operating in the vicinity of an aerodrome.

Aeronautical fixed service (AFS). A telecommunication service between specified fixed points provided primarily for the safety of air navigation and for the regular, efficient and economical operation of air services.

Aeronautical fixed station. A station in the aeronautical fixed service.

Aeronautical ground light. Any light specially provided as an aid to air navigation, other than a light displayed on an aircraft.

Aeronautical Information Publication (AIP). A publication issued by or with the authority of a State and containing aeronautical information of a lasting character essential to air navigation.

Aeronautical mobile service. A mobile service between aeronautical stations and aircraft stations, or between aircraft stations, in which survival craft stations may participate; emergency position-indicating radiobeacon stations may also participate in this service on designated distress and emergency frequencies.

Aeronautical station. A land station in the aeronautical mobile service. In certain instances, an aeronautical station may be located, for example, on board ship or on a platform at sea.

Aeronautical telecommunication service. A telecommunication service provided for any aeronautical purpose.

Aeronautical telecommunication station. A station in the aeronautical telecommunication service.

Airborne collision avoidance system (ACAS). An aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders.

Aircraft. Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.

Aircraft identification. A group of letters, figures or a combination thereof which is either identical to, or the coded equivalent of, the aircraft call sign to be used in air-ground communications, and which is used to identify the aircraft in ground-ground air traffic services communications.

Aircraft observation. The evaluation of one or more meteorological elements made from an aircraft in flight.

Aircraft proximity. A situation in which, in the opinion of a pilot or air traffic services personnel, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved may have been compromised. An aircraft proximity is classified as follows:

Risk of collision. The risk classification of an aircraft proximity in which serious risk of collision has existed.

Safety not assured. The risk classification of an aircraft proximity in which the safety of the aircraft may have been compromised.

No risk of collision. The risk classification of an aircraft proximity in which no risk of collision has existed.

Risk not determined. The risk classification of an aircraft proximity in which insufficient information was available to determine the risk involved, or inconclusive or conflicting evidence precluded such determination.

Air-ground communication. Two-way communication between aircraft and stations or locations on the surface of the earth.

Air-ground control radio station. An aeronautical telecommunication station having primary responsibility for handling communications pertaining to the operation and control of aircraft in a given area.

AIRPROX. The code word used in an air traffic incident report to designate aircraft proximity.

Air-report. A report from an aircraft in flight prepared in conformity with requirements for position, and operational and/or meteorological reporting.

Air-taxiing. Movement of a helicopter/VTOL above the surface of an aerodrome, normally in ground effect and at a ground speed normally less than 37 km/h (20 kt).

Note.— The actual height may vary, and some helicopters may require air-taxiing above 8 m (25 ft) AGL to reduce ground effect turbulence or provide clearance for cargo slingloads.

Air-to-ground communication. One-way communication from aircraft to stations or locations on the surface of the earth.

Air traffic. All aircraft in flight or operating on the manoeuvring area of an aerodrome.

Air traffic advisory service. A service provided within advisory airspace to ensure separation, in so far as practical, between aircraft which are operating on IFR flight plans.

Air traffic control clearance. Authorization for an aircraft to proceed under conditions specified by an air traffic control unit.

Note 1.— For convenience, the term "air traffic control clearance" is frequently abbreviated to "clearance" when used in appropriate contexts.

Note 2.— The abbreviated term "clearance" may be prefixed by the words "taxi", "take-off", "departure", "en-route", "approach" or "landing" to indicate the particular portion of flight to which the air traffic control clearance relates.

Air traffic control instruction. Directives issued by air traffic control for the purpose of requiring a pilot to take a specific action.

Air traffic control service. A service provided for the purpose of:

a) preventing collisions:

1) between aircraft, and

2) on the manoeuvring area between aircraft and obstructions; and

b) expediting and maintaining an orderly flow of air traffic.

Air traffic control unit. A generic term meaning variously, area control centre, approach control office or aerodrome control tower.

Air traffic service. A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

Air traffic services airspaces. Airspaces of defined dimensions, alphabetically designated, within which specific types of flights may operate and for which air traffic services and rules of operation are specified.

Note.— ATS airspaces are classified as Class A to G as shown in Annex 11, Appendix 4.

Air traffic services reporting office. A unit established for the purpose of receiving reports concerning air traffic services and flight plans submitted before departure.

Note.— An air traffic services reporting office may be established as a separate unit or combined with an existing unit, such as another air traffic services unit, or a unit of the aeronautical information service.

Air traffic services unit. A generic term meaning variously, air traffic control unit, flight information centre or air traffic services reporting office.

Airway. A control area or portion thereof established in the form of a corridor equipped with radio navigation aids.

ALERFA. The code word used to designate an alert phase.

Alerting service. A service provided to notify appropriate organizations regarding aircraft in need of search and rescue aid, and assist such organizations as required.

Alert phase. A situation wherein apprehension exists as to the safety of an aircraft and its occupants.

Allocation, allocate. Distribution of frequencies, SSR Codes, etc. to a State, unit or service. Distribution of 24-bit aircraft addresses to a State or common mark registering authority.

Alphanumeric characters (alphanumerics). A collective term for letters and figures (digits).

Alternate aerodrome. An aerodrome to which an aircraft may proceed when it becomes either impossible or inadvisable to proceed to or to land at the aerodrome of intended landing. Alternate aerodromes include the following:

Take-off alternate. An alternate aerodrome at which an aircraft can land should this become necessary shortly after take-off and it is not possible to use the aerodrome of departure.

En-route alternate. An aerodrome at which an aircraft would be able to land after experiencing an abnormal or emergency condition while en route.

Destination alternate. An alternate aerodrome to which an aircraft may proceed should it become either impossible or inadvisable to land at the aerodrome of intended landing.

Note.— The aerodrome from which a flight departs may also be an en-route or a destination alternate aerodrome for that flight.

Altitude. The vertical distance of a level, a point or an object considered as a point, measured from mean sea level.

Approach control office. A unit established to provide air traffic control service to controlled flights arriving at, or departing from, one or more aerodromes.

Approach control service. Air traffic control service for arriving or departing controlled flights.

Approach funnel. A specified airspace around a nominal approach path within which an aircraft approaching to land is considered to be making a normal approach.

Approach sequence. The order in which two or more aircraft are cleared to approach to land at the aerodrome.

Appropriate ATS authority. The relevant authority designated by the State responsible for providing air traffic services in the airspace concerned.

Appropriate authority.

a) Regarding flight over the high seas: the relevant authority of the State of Registry.

b) Regarding flight other than over the high seas: the relevant authority of the State having sovereignty over the territory being overflown.

Apron. A defined area, on a land aerodrome, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance.

Area control centre. A unit established to provide air traffic control service to controlled flights in control areas under its jurisdiction.

Area control service. Air traffic control service for controlled flights in control areas.

Area navigation (RNAV). A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

Area navigation route. An ATS route established for the use of aircraft capable of employing area navigation.

Assignment, assign. Distribution of frequencies to stations. Distribution of SSR Codes or 24-bit aircraft addresses to aircraft.

ATIS. The symbol used to designate automatic terminal information service.

ATS route. A specified route designed for channelling the flow of traffic as necessary for the provision of air traffic services.

Note.— The term "ATS route" is used to mean variously, airway, advisory route, controlled or uncontrolled route, arrival or departure route, etc.

Automatic dependent surveillance (ADS). A surveillance technique in which aircraft automatically provide, via a data link, data derived from on-board navigation and position-fixing systems, including aircraft identification, four-dimensional position and additional data as appropriate.

Automatic terminal information service. The provision of current, routine information to arriving and departing aircraft by means of continuous and repetitive broadcasts throughout the day or a specified portion of the day.

Base turn. A turn executed by the aircraft during the initial approach between the end of the outbound track and the beginning of the intermediate or final approach track. The tracks are not reciprocal.

Note.— Base turns may be designated as being made either in level flight or while descending, according to the circumstances of each individual procedure.

Blind transmission. A transmission from one station to another station in circumstances where two-way communication cannot be established but where it is believed that the called station is able to receive the transmission.

Broadcast. A transmission of information relating to air navigation that is not addressed to a specific station or stations.

Ceiling. The height above the ground or water of the base of the lowest layer of cloud below 6 000 m (20 000 ft) covering more than half the sky.

Clearance limit. The point to which an aircraft is granted an air traffic control clearance.

Code (SSR). The number assigned to a particular multiple pulse reply signal transmitted by a transponder in Mode A or Mode C.

Computer. A device which performs sequences of arithmetical and logical steps upon data without human intervention.

Note.— When the word "computer" is used in this document it may denote a computer complex, which includes one or more computers and peripheral equipment.

Control area. A controlled airspace extending upwards from a specified limit above the earth.

Controlled aerodrome. An aerodrome at which air traffic control service is provided to aerodrome traffic.

Note.— The term "controlled aerodrome" indicates that air traffic control service is provided to aerodrome traffic but does not necessarily imply that a control zone exists.

Controlled airspace. An airspace of defined dimensions within which air traffic control service is provided to IFR flights and to VFR flights in accordance with the airspace classification.

Note.— Controlled airspace is a generic term which covers ATS airspace Classes A, B, C, D and E as shown in Annex 11, Appendix 4.

Controlled flight. Any flight which is subject to an air traffic control clearance.

Control zone. A controlled airspace extending upwards from the surface of the earth to a specified upper limit.

Cruise climb. An aeroplane cruising technique resulting in a net increase in altitude as the aeroplane mass decreases.

Cruising level. A level maintained during a significant portion of a flight.

Current flight plan. The flight plan, including changes, if any, brought about by subsequent clearances.

Note.— When the word "message" is used as a suffix to this term, it denotes the content and format of the current flight plan data sent from one unit to another.

Data convention. An agreed set of rules governing the manner or sequence in which a set of data may be combined into a meaningful communication.

Data processing. A systematic sequence of operations performed on data.

Note.— Examples of operations are the merging, sorting, computing or any other transformation or rearrangement with the object of extracting or revising information, or of altering the representation of information.

Decision altitude (DA) or decision height (DH). A specified altitude or height in the precision approach at which a missed approach must be initiated if the required visual reference to continue the approach has not been established.

Note 1.— Decision altitude (DA) is referenced to mean sea level and decision height (DH) is referenced to the threshold elevation.

Note 2.— The required visual reference means that section of the visual aids or of the approach area which should have been in view for sufficient time for the pilot to have made an assessment of the aircraft position and rate of change of position, in relation to the desired flight path. In Category III operations with a decision height the required visual reference is that specified for the particular procedure and operation.

Note 3.— For convenience where both expressions are used they may be written in the form "decision altitude/height" and abbreviated "DA/H".

Dependent parallel approaches. Simultaneous approaches to parallel or near-parallel instrument runways where radar separation minima between aircraft on adjacent extended runway centre lines are prescribed.

DETRESFA. The code word used to designate a distress phase.

Discrete code. A four-digit SSR Code with the last two digits not being "00".

Distress phase. A situation wherein there is reasonable certainty that an aircraft and its occupants are threatened by grave and imminent danger or require immediate assistance.

D-value. The amount (positive or negative) by which the altitude (Z) of a point on an isobaric surface differs from the altitude (Zp) of the same isobaric surface in the ICAO Standard Atmosphere (i.e. D-value = Z – Zp).

Elevation. The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.

Emergency phase. A generic term meaning, as the case may be, uncertainty phase, alert phase or distress phase.

Estimated elapsed time. The estimated time required to proceed from one significant point to another.

Estimated off-block time. The estimated time at which the aircraft will commence movement associated with departure.

Estimated time of arrival. For IFR flights, the time at which it is estimated that the aircraft will arrive over that designated point, defined by reference to navigation aids, from which it is intended that an instrument approach procedure will be commenced, or, if no navigation aid is associated with the aerodrome, the time at which the aircraft will arrive over the aerodrome. For VFR flights, the time at which it is estimated that the aircraft will arrive over the aerodrome.

Expected approach time. The time at which ATC expects that an arriving aircraft, following a delay, will leave the holding point to complete its approach for a landing.

Note.— The actual time of leaving the holding point will depend upon the approach clearance.

Filed flight plan. The flight plan as filed with an ATS unit by the pilot or a designated representative, without any subsequent changes.

Note.— When the word "message" is used as a suffix to this term, it denotes the content and format of the filed flight plan data as transmitted.

Final approach. That part of an instrument approach procedure which commences at the specified final approach fix or point, or where such a fix or point is not specified,

a) at the end of the last procedure turn, base turn or inbound turn of a racetrack procedure, if specified; or

b) at the point of interception of the last track specified in the approach procedure; and

ends at a point in the vicinity of an aerodrome from which:

1) a landing can be made; or

2) a missed approach procedure is initiated.

Flight crew member. A licensed crew member charged with duties essential to the operation of an aircraft during flight time.

Flight information centre. A unit established to provide flight information service and alerting service.

Flight information region. An airspace of defined dimensions within which flight information service and alerting service are provided.

Flight information service. A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights.

Flight level. A surface of constant atmospheric pressure which is related to a specific pressure datum, 1 013.2 hPa, and is separated from other such surfaces by specific pressure intervals.

Note 1.— A pressure type altimeter calibrated in accordance with the Standard Atmosphere:

a) when set to a QNH altimeter setting, will indicate altitude;

b) when set to QFE altimeter setting, will indicate height above the QFE reference datum;

c) when set to a pressure of 1 013.2 hPa, may be used to indicate flight levels.

Note 2.— The terms "height" and "altitude", used in Note 1 above, indicate altimetric rather than geometric heights and altitudes.

Flight plan. Specified information provided to air traffic services units, relative to an intended flight or portion of a flight of an aircraft.

Note.— Specifications for flight plans are contained in Annex 2. A Model Flight Plan Form is contained in Appendix 2 to this document.

Flight status. An indication of whether a given aircraft requires special handling by air traffic services units or not.

Flight visibility. The visibility forward from the cockpit of an aircraft in flight.

Flow control. Measures designed to adjust the flow of traffic into a given airspace, along a given route, or bound for a given aerodrome, so as to ensure the most effective utilization of the airspace.

Forecast. A statement of expected meteorological conditions for a specified time or period, and for a specified area or portion of airspace.

Glide path. A descent profile determined for vertical guidance during a final approach.

Ground effect. A condition of improved performance (lift) due to the interference of the surface with the airflow pattern of the rotor system when a helicopter or other VTOL aircraft is operating near the ground.

Note.— Rotor efficiency is increased by ground effect to a height of about one rotor diameter for most helicopters.

Ground-to-air communication. One-way communication from stations or locations on the surface of the earth to aircraft.

Ground visibility. The visibility at an aerodrome, as reported by an accredited observer.

Heading. The direction in which the longitudinal axis of an aircraft is pointed, usually expressed in degrees from North (true, magnetic, compass or grid).

Height. The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

Holding point. A specified location, identified by visual or other means, in the vicinity of which the position of an aircraft in flight is maintained in accordance with air traffic control clearances.

Holding procedure. A predetermined manoeuvre which keeps an aircraft within a specified airspace while awaiting further clearance.

IFR. The symbol used to designate the instrument flight rules.

IFR flight. A flight conducted in accordance with the instrument flight rules.

IMC. The symbol used to designate instrument meteorological conditions.

INCERFA. The code word used to designate an uncertainty phase.

Independent parallel approaches. Simultaneous approaches to parallel or near-parallel instrument runways where radar separation minima between aircraft on adjacent extended runway centre lines are not prescribed.

Independent parallel departures. Simultaneous departures from parallel or near-parallel instrument runways.

Initial approach segment. That segment of an instrument approach procedure between the initial approach fix and the intermediate approach fix or, where applicable, the final approach fix or point.

Instrument approach procedure. A series of predetermined manoeuvres by reference to flight instruments with specified protection from obstacles from the initial approach fix, or where applicable, from the beginning of a defined arrival route to a point from which a landing can be completed and thereafter, if a landing is not completed, to a position at which holding or en-route obstacle clearance criteria apply.

Instrument meteorological conditions. Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, less than the minima specified for visual meteorological conditions.

Note 1.— The specified minima for visual meteorological conditions are contained in Chapter 4 of Annex 2.

Note 2.— In a control zone, a VFR flight may proceed under instrument meteorological conditions if and as authorized by air traffic control.

Landing area. That part of a movement area intended for the landing or take-off of aircraft.

Level. A generic term relating to the vertical position of an aircraft in flight and meaning variously, height, altitude or flight level.

Location indicator. A four-letter code group formulated in accordance with rules prescribed by ICAO and assigned to the location of an aeronautical fixed station.

Manoeuvring area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons.

Meteorological information. Meteorological report, analysis, forecast, and any other statement relating to existing or expected meteorological conditions.

Meteorological office. An office designated to provide meteorological service for international air navigation.

Meteorological report. A statement of observed meteorological conditions related to a specified time and location.

Missed approach procedure. The procedure to be followed if the approach cannot be continued.

Mode (SSR). The conventional identifier related to specific functions of the interrogation signals transmitted by an SSR interrogator. There are four modes specified in Annex 10: A, C, S and intermode.

Movement area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s).

Near-parallel runways. Non-intersecting runways whose extended centre lines have an angle of convergence/divergence of 15 degrees or less.

Non-radar separation. The separation used when aircraft position information is derived from sources other than radar.

Normal operating zone (NOZ). Airspace of defined dimensions extending to either side of an ILS localizer course and/or MLS final approach track. Only the inner half of the normal operating zone is taken into account in independent parallel approaches.

NOTAM. A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

No transgression zone (NTZ). In the context of independent parallel approaches, a corridor of airspace of defined dimensions located centrally between the two extended runway centre lines, where a penetration by an aircraft requires a controller intervention to manoeuvre any threatened aircraft on the adjacent approach.

Obstacle clearance altitude (OCA) or obstacle clearance height (OCH). The lowest altitude or the lowest height above the elevation of the relevant runway threshold or the aerodrome elevation as applicable, used in establishing compliance with appropriate obstacle clearance criteria.

Note 1.— Obstacle clearance altitude is referenced to mean sea level and obstacle clearance height is referenced to the threshold elevation or in the case of non-precision approaches to the aerodrome elevation or the threshold elevation if that is more than 2 m (7 ft) below the aerodrome elevation. An obstacle clearance height for a circling approach is referenced to the aerodrome elevation.

Note 2.— For convenience when both expressions are used they may be written in the form "obstacle clearance altitude/height" and abbreviated "OCA/H".

Operational control. The exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of the flight.

Operator. A person, organization or enterprise engaged in or offering to engage in an aircraft operation.

Pilot-in-command. The pilot responsible for the operation and safety of the aircraft during flight time.

Precision approach radar (PAR). Primary radar equipment used to determine the position of an aircraft during final approach, in terms of lateral and vertical deviations relative to a nominal approach path, and in range relative to touchdown.

Note.— Precision approach radars are designated to enable pilots of aircraft to be given guidance by radiocommunication during the final stages of the approach to land.

Pressure-altitude. An atmospheric pressure expressed in terms of altitude which corresponds to that pressure in the Standard Atmosphere.*

Primary radar. A radar system which uses reflected radio signals.

Primary surveillance radar (PSR). A surveillance radar system which uses reflected radio signals.

Procedure turn. A manoeuvre in which a turn is made away from a designated track followed by a turn in the opposite direction to permit the aircraft to intercept and proceed along the reciprocal of the designated track.

Note 1.— Procedure turns are designated "left" or "right" according to the direction of the initial turn.

Note 2.— Procedure turns may be designated as being made either in level flight or while descending, according to the circumstances of each individual procedure.

Profile. The orthogonal projection of a flight path or portion thereof on the vertical surface containing the nominal track.

PSR blip. The visual indication, in non-symbolic form, on a radar display of the position of an aircraft obtained by primary radar.

Radar. A radio detection device which provides information on range, azimuth and/or elevation of objects.

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* As defined in Annex 8.

Radar approach. An approach in which the final approach phase is executed under the direction of a radar controller.

Radar clutter. The visual indication on a radar display of unwanted signals.

Radar contact. The situation which exists when the radar position of a particular aircraft is seen and identified on a radar display.

Radar control. Term used to indicate that radar-derived information is employed directly in the provision of air traffic control service.

Radar controller. A qualified air traffic controller holding a radar rating appropriate to the functions to which he is assigned.

Radar display. An electronic display of radar-derived information depicting the position and movement of aircraft.

Radar identification. The situation which exists when the radar position of a particular aircraft is seen on a radar display and positively identified by the air traffic controller.

Radar map. Information superimposed on a radar display to provide ready indication of selected features.

Radar monitoring. The use of radar for the purpose of providing aircraft with information and advice relative to significant deviations from nominal flight path, including deviations from the terms of their air traffic control clearances.

Radar position indication (RPI). The visual indication, in non-symbolic and/or symbolic form, on a radar display of the position of an aircraft obtained by primary and/or secondary surveillance radar.

Radar position symbol (RPS). The visual indication, in symbolic form, on a radar display, of the position of an aircraft obtained after automatic processing of positional data derived from primary and/or secondary surveillance radar.

Radar separation. The separation used when aircraft position information is derived from radar sources.

Radar service. Term used to indicate a service provided directly by means of radar.

Radar track position. An extrapolation of aircraft position by the computer based upon radar information and used by the computer for tracking purposes.

Note.— In some cases, information other than radar-derived information is used to assist the tracking processes.

Radar unit. That element of an air traffic services unit which uses radar equipment to provide one or more services.

Radar vectoring. Provision of navigational guidance to aircraft in the form of specific headings, based on the use of radar.

Receiving unit/controller. Air traffic services unit/air traffic controller to which a message is sent.

Note.— See definition of "sending unit/controller".

Repetitive flight plan (RPL). A flight plan related to a series of frequently recurring, regularly operated individual flights with identical basic features, submitted by an operator for retention and repetitive use by ATS units.

Reporting point. A specified geographical location in relation to which the position of an aircraft can be reported.

Required navigation performance (RNP). A statement of the navigation performance accuracy necessary for operation within a defined airspace.

Rescue co-ordination centre. A unit responsible for promoting efficient organization of search and rescue service and for co-ordinating the conduct of search and rescue operations within a search and rescue region.

Rescue unit. A unit composed of trained personnel and provided with equipment suitable for the expeditious conduct of search and rescue.

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 per cent of the total flying time.

Example.— RNP 4 represents a navigation accuracy of plus or minus 7.4 km (4 NM) on a 95 per cent containment basis.

Runway. A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft.

Runway visual range. The range over which the pilot of an aircraft on the centre line of a runway can see the runway surface markings or the lights delineating the runway or identifying its centre line.

Secondary radar. A radar system wherein a radio signal transmitted from the radar station initiates the transmission of a radio signal from another station.

Secondary surveillance radar (SSR). A surveillance radar system which uses transmitters/receivers (interrogators) and transponders.

Segregated parallel operations. Simultaneous operations on parallel or near-parallel instrument runways in which one runway is used exclusively for approaches and the other runway is used exclusively for departures.

Sending unit/controller. Air traffic services unit/air traffic controller transmitting a message.

Note.— See definition of "receiving unit/controller".

Shoreline. A line following the general contour of the shore, except that in cases of inlets or bays less than 30 nautical miles in width, the line shall pass directly across the inlet or bay to intersect the general contour on the opposite side.

SIGMET information. Information issued by a meteorological watch office concerning the occurrence or expected occurrence of specified en-route weather phenomena which may affect the safety of aircraft operations.

Signal area. An area on an aerodrome used for the display of ground signals.

Significant point. A specified geographical location used in defining an ATS route or the flight path of an aircraft and for other navigation and ATS purposes.

Slush. Water-saturated snow which with a heel-and-toe slap-down motion against the ground will be displaced with a splatter; specific gravity: 0.5 up to 0.8.

Note.— Combinations of ice, snow and/or standing water may, especially when rain, rain and snow, or snow is falling, produce substances with specific gravities in excess of 0.8. These substances, due to their high water/ice content, will have a transparent rather than a cloudy appearance and, at the higher specific gravities, will be readily distinguishable from slush.

Snow (on the ground).

a) *Dry snow.* Snow which can be blown if loose or, if compacted by hand, will fall apart upon release; specific gravity: up to but not including 0.35.

b) *Wet snow.* Snow which, if compacted by hand, will stick together and tend to or form a snowball; specific gravity: 0.35 up to but not including 0.5.

c) *Compacted snow.* Snow which has been compressed into a solid mass that resists further compression and will hold together or break up into lumps if picked up; specific gravity: 0.5 and over.

Special VFR flight. A VFR flight cleared by air traffic control to operate within a control zone in meteorological conditions below VMC.

SSR response. The visual indication, in non-symbolic form, on a radar display, of a response from an SSR transponder in reply to an interrogation.

Surveillance radar. Radar equipment used to determine the position of an aircraft in range and azimuth.

Taxi-holding position. A designated position at which taxiing aircraft and vehicles may be required to hold in order to provide adequate clearance from a runway.

Taxiing. Movement of an aircraft on the surface of an aerodrome under its own power, excluding take-off and landing.

Taxiway. A defined path on a land aerodrome established for the taxiing of aircraft and intended to provide a link between one part of the aerodrome and another, including:

a) *Aircraft stand taxilane.* A portion of an apron designated as a taxiway and intended to provide access to aircraft stands only.

b) *Apron taxiway.* A portion of a taxiway system located on an apron and intended to provide a through taxi route across the apron.

c) *Rapid exit taxiway.* A taxiway connected to a runway at an acute angle and designed to allow landing aeroplanes to turn off at higher speeds than are achieved on other exit taxiways thereby minimizing runway occupancy times.

Terminal control area. A control area normally established at the confluence of ATS routes in the vicinity of one or more major aerodromes.

Threshold. The beginning of that portion of the runway usable for landing.

Total estimated elapsed time. For IFR flights, the estimated time required from take-off to arrive over that designated point, defined by reference to navigation aids, from which it is intended that an instrument approach procedure will be commenced, or, if no navigation aid is associated with the destination aerodrome, to arrive over the destination aerodrome. For VFR flights, the estimated time required from take-off to arrive over the destination aerodrome.

Touchdown. The point where the nominal glide path intercepts the runway.

Note.— "Touchdown" as defined above is only a datum and is not necessarily the actual point at which the aircraft will touch the runway.

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).

Traffic avoidance advice. Advice provided by an air traffic services unit specifying manoeuvres to assist a pilot to avoid a collision.

Traffic information. Information issued by an air traffic services unit to alert a pilot to other known or observed air traffic which may be in proximity to the position or intended route of flight and to help the pilot avoid a collision.

Transfer of control point. A defined point located along the flight path of an aircraft, at which the responsibility for providing air traffic control service to the aircraft is transferred from one control unit or control position to the next.

Transferring unit/controller. Air traffic control unit/air traffic controller in the process of transferring the responsibility for providing air traffic control service to an aircraft to the next air traffic control unit/air traffic controller along the route of flight.

Note.— See definition of "accepting unit/controller".

Transition altitude. The altitude at or below which the vertical position of an aircraft is controlled by reference to altitudes.

Transition layer. The airspace between the transition altitude and the transition level.

Transition level. The lowest flight level available for use above the transition altitude.

Uncertainty phase. A situation wherein uncertainty exists as to the safety of an aircraft and its occupants.

Unmanned free balloon. A non-power-driven, unmanned, lighter-than-air aircraft in free flight.

Note.— Unmanned free balloons are classified as heavy, medium or light in accordance with specifications contained in Annex 2, Appendix 4.

VFR. The symbol used to designate the visual flight rules.

VFR flight. A flight conducted in accordance with the visual flight rules.

Visibility. The ability, as determined by atmospheric conditions and expressed in units of distance, to see and identify prominent unlighted objects by day and prominent lighted objects by night.

Visual approach. An approach by an IFR flight when either part or all of an instrument approach procedure is not completed and the approach is executed in visual reference to terrain.

Visual meteorological conditions. Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, equal to or better than specified minima.

Note.— The specified minima are contained in Annex 2, Chapter 4.

VMC. The symbol used to designate visual meteorological conditions.

Way-point. A specified geographical location used to define an area navigation route or the flight path of an aircraft employing area navigation.

Definitions

For the purpose of this AIC, the following definitions apply:

"accuracy"	is the degree of conformance between the estimated or measured position and/or velocity of a platform at a given time and its true position and/or velocity.
"availability"	is the ability of the total system to perform its function at the initiation of the intended operation.
"integrity"	is the ability of a system to provide timely warnings to users when the system should not be used for navigation.
"continuity"	is the ability of the total system to perform its function without interruption during the intended operation.
"primary-means navigation system"	is a navigation system approved for a given operation or phase of flight that must meet accuracy and integrity requirements but need not meet full availability and continuity of service requirements. Safety is achieved by limiting flights to specific periods, and through appropriate procedural restrictions.
Note	*There is no requirement to have a sole means navigation system on board to support a primary means system.*
"Receiver autonomous integrity monitoring (RAIM)"	is a technique whereby an airborne GNSS receiver/processor autonomously monitors the integrity of the navigation signals from GNSS satellites.
"Sole-means navigation system"	is a navigation system approved for a given operation or phase of flight that must allow the aircraft to meet, for that operation or phase of flight all four navigation system performance requirements: accuracy, integrity, availability and continuity of service.
Note	*This definition does not exclude the carriage of other navigation systems. Any sole-means navigation system could include one (stand-alone installation) or several sensors, possibly of different types (multi-sensors installation).*
"Supplemental-means	

navigation system" is a navigation system that must be used in conjunction with a sole-means-navigation system. Approval for supplemental-means for a given phase of flight requires that a sole-means navigation system for that phase of flight must be on board. Amongst the navigation system performance requirements for a given operation or phase of flight, a supplemental-means navigation system must meet the accuracy and integrity requirements for that operation or phase of flight; there is no requirement to meet availability and continuity requirements.

Note: *Operationally, while accuracy and integrity requirements are being met, a supplemental-means system can be used without any cross-check with the sole-means system. Any navigation system approved for supplemental-means could involve one (stand-alone) installation) or several sensors, possibly of different types (multi-sensor installation).*

APPENDIX 3: STRUCTURED QUESTIONNAIRE

FEDERAL UNIVERSITY OF TECHNOLOGY,

DEPARTMENT OF GEOGRAPHY

MINNA, NIGER STATE

Sir/ Madam,

I am an ATCO and a postgraduate student of the above named university currently undertaking a research: AN ANALYSIS OF GPS AS AN AIR NAVIGATION RESOURCE TECHNOLOGY AND ITS ADOPTION IN NIGERIA for my Masters' thesis.

Please, kindly go through the questionnaire and either fill or tick the appropriate answer(s). All information supplied is confidential and will be used only for academic exercise.

Thank you.

GPS USER SURVEY

1. Kindly indicate your profession.
   (a) Pilot (b)ATCO (c) Engineer
2. Experience in years.
   (a) Less than 5yrs (b) 5-9yrs (c) 10-19yrs (d) 20yrs and above.
3. o you know what is GPS?
   a) Yes (b) No
4. ı have a GPS receiver (either handheld or installed in aircraft)?
   's (b) No
   at type?..
   ? cost of the handheld receiver?
   (b) $200-400 (c) $500-1000 (d) above $1000
   ls are there in your receiver?
   (c) Four (d) Five

lays,

18. Do you think that with a fully operational GPS conventional ground aids (VOR/DME, NDB, ILS, etc) will be decommission?

(a) Yes (b)No (c) 1 don't know

19. IF yes, when?

(a) next 10 years (b) 20 years (c) 30 years and above

20. Do you think that using GPS would reduce your workload?

(a) Yes (b) No (e) 1 don't know.

21. Do you know that presently GPS infrastructure is being put in place?

(a) Yes (b) No

22. Have you been trained on GPS?

(a) Yes (b) No

23. If yes, indicate duration and by who?..

24. If no, indicate the type of training required?..................................

25. In your opinion, do you think GPS is beneficial to air traffic management?

(a) Yes (b) No (e) 1 don't know

26. If yes, kindly enumerate the benefits

....

....

....

27. In what ways would GPS affects the present air traffic scenarios in (lie country?..

....

....

APPENDIX 4

Passenger Movement

AIRPORTS	1999	2000	2001	2002
MMA (DOM)	1,205,487	1,404,527	1,563,483	1,879,164
INT	944,968	1,053,572	1,234,160	1,263,326
TOTAL	2,150,455	2,458,099	2,797,643	3,142,490
ABJ (DOM)	673,535	892,748	1,082,981	1,334,873
INT	13,931	55,100	68,234	106,861
TOTAL	687,466	947,848	1,151,215	1,441,734
PHG (DOM)	444,007	219,938	294,420	667,422
INT	39,230	37,834	42,908	52,769
TOTAL	483,237	257,772	337,328	720,191
KANO (DOM)	236,224	132,647	112,238	103,346
INT	208,276	163,272	154,984	123,940
TOTAL	444,500	295,919	267,222	227,286
KAD (DOM)	127,120	114,967	141,827	146,050
ENUGU	46,696	68,405	103,107	140,247
MAID (DOM)	28,660	55,438	80,312	73,802
INT	0	4,298	16,912	5,304
TOTAL	28,660	59,736	97,224	79,106
CAL (DOM)	45,567	60,017	71,939	83,613
INT	1,960	3,992	5,832	9,357
TOTAL	47,527	64,009	77,771	92,970
SOK (DOM)	11,495	11,589	12,947	9,053
INT	0	9,585	21,096	21,983
TOTAL	11,495	21,174	34,043	31,036
YOLA	16,388	34,893	27,769	45,660
JOS	41,727	47,278	58,009	35,978
BENIN	2,385	1,4246	19,953	36,317
OWERRI	3,374	6,149	7,979	24,640
IBADAN	461	637	3,467	6,988
ILO (DOM)	2,969	759	4,429	5,164
INT	0	2,843	4,469	0
TOTAL	2,969	3,602	8,898	5,164
MAKURDI	856	670	543	466
MINNA	1,664	711	313	1,062
KATSINA	700	325	941	913
AKURE	288	242	298	1,224
TOTAL	4,097,468	4,396,682	5,135,541	6,279,416

8 What information does the GPS receiver gives you?

(a) Position (b) Time (c) Speed (d) Weather (e) Others indicate...

9. Is your GPS receiver certified?

(a) Yes (b) No

10. If yes by whom?..

11. Do you think GPS is reliable for air navigation?

(a) Yes (b)No (c) 1 don't know

12 If yes, in what areas?

(a) en-route (b) terminal (c) airport (d) all areas.

13. In your opinion GPS can be approved for:

(a) primary navigation

(b) supplement

(c) both primary and supplemental .

14. Do you consider GPS reliable for landing approaches in busy terminals?

(a) Yes (b) No (c) 1 don't know

15. If yes, do you think it is appropriate for:

(a) precision approach

(b) non-precision approach

(c) both approaches

16. Under what conditions can GPS be best used?

(a). VFR flight

(b). 1FR flight

(c). both

17. Do you agree that GPS increases airspace capacity (reduce delays, separation minima etc)?

(a) Yes (b)No (c) I don't know