Navigation Aids Transition Roadmap

Volume 3

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Version 3 dated 16 March 2006.

Based on input from industry and member airlines this document will be updated as appropriate to reflect IATA policy and position.

ACRONYMS

AAIM	Aircraft Autonomous Integrity Monitoring
ABAS	Aircraft Based Augmentation System
APV	APproach with Vertical guidance
A-SMGCS	Advanced Surface Movement Guidance and Control Systems
ATC	Air Traffic Control
ATM	Air Traffic Management
Baro-VNAV	Barometric Vertical Navigation
CAT	Category (used in conjunction with ILS)
CFIT	Controlled Flight Into Terrain
DME	Distance Measuring Equipment
FAA	Federal Aviation Administration
FAS	Final Approach Segment
FDE	Fault Detection and Exclusion
EGNOS	European Geostationary Navigation Overlay Service
GAGAN	GPS And GEO Augmented Navigation
GBAS	Ground Based Augmentation System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRAS	Ground based Regional Augmentation System
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
LAAS	Local Area Augmentation System
ILS	Instrument Landing System
MLS	Microwave Landing System
MMR	Multi Mode Receiver
MTSAT	Multi-functional Transport SATellite
NGATS	Next Generation Air Transport System
RAIM	Receiver Autonomous Integrity Monitoring
RNP	Required Navigation Performance
RNAV	Area Navigation
SBAS	Satellite Based Augmentation System
SESAR	Single European Sky ATM Research
VNAV	Vertical Navigation
VHF	Very High Frequency
VOR	VHF Omni-directional Radio Range

EXECUTIVE SUMMARY

IATA - as the industry association that represents 265 airlines comprising 94% of international scheduled air traffic - has developed the Navigation Aids Transition Road Map to help realise the industry objective of a One Sky global ATM system.

Airlines need a globally interoperable navigational infrastructure that delivers benefits in safety, efficiency and capacity. Aircraft navigation should be straight-forward and conducted to the highest level of accuracy supported by the infrastructure.

At the heart of this infrastructure is a Global Navigation Satellite System (GNSS). GNSS provides standardised positioning information to the aircraft systems to support precise navigation globally. One global navigation system will help support a standardisation of procedures and cockpit displays coupled with a minimum set of avionics, maintenance and training requirements[1].

The future navigation concept and applications shall be based on performance based navigation standards rather than technologies and equipage requirements. Performance based navigation concepts include Area Navigation (RNAV) and Required Navigation Performance (RNP). RNAV enables aircraft operation on any desired flight path allowing user preferred routings and trajectories[2]. This provides the potential to re-design a more expeditious route structure to help reduce the operating costs of airlines. RNP is a statement of the aircraft navigation performance necessary for operation in an area or necessary for a specific procedure, such as complex arrival and departure procedures and includes the attribute of on board performance monitoring and alerting.

RNAV and the application of RNP is the platform for a seamless, harmonised and cost effective navigational service from departure to final approach. This will provide significant benefits in safety, efficiency and capacity. Safety benefits will be provided by standardising and enhancing operational procedures. In particular reducing the risk of controlled flight into terrain by providing vertical guidance on approach procedures where currently no guidance exists. Efficiency benefits will be provided by improved airspace design and utilisation enabling user preferred routings and trajectories enabled by an accurate global navigation system. Capacity benefits will be provided through the increased autonomous operation of aircraft (reducing controller workload) and the reduction of separation standards in certain airspace environments[3]. In addition to safety, efficiency and capacity, economic benefit will be delivered through more direct routes, fuel savings, reduced airborne equipage requirements and a non-reliance (or reduced reliance) on ground based navigational aids particularly for en-route navigation.

[1] GNSS operations are already in use in certain regions. However, a co-coordinated global application is required to fully exploit the available benefits.

[2] RNAV is 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.

[3] This can be dependent upon the required communication and surveillance requirements being in place.

The current navigational infrastructure is a fragmented and ever expanding collection of different technologies, systems, concepts and services. If this situation continues then operating and service costs for airlines will remain high and will increase significantly over time. The future navigational infrastructure should provide a global coverage with unrestricted access to navigational position information at minimum cost. This can only be achieved if industry decides to collectively act now in a pragmatic manner therefore halting the proliferation of different navigation system solutions.

IATA is committed to ensure that the standard navigational infrastructure is safe, cost effective and efficient. This document provides details for the transition from traditional ground based navigation aids to a future navigational concept based on a cost effective Satellite based system(s) that will enhance performance and safety. Dates are identified for the de-commissioning of ground based navigation aids. IATA will now co-ordinate with Air Navigation Service Providers (ANSPs), Regulators, manufacturers and other airspace users to help establish binding agreements that can be used by airlines to plan future equipage requirements. This will be achieved through co-ordinated work initiatives at the regional and global level. This is a critical enabler to realise a true One Sky global ATM system.

01 INTRODUCTION

Currently we have a fragmented and costly navigational infrastructure. Competing technologies, political influences and different navigational concepts being introduced in isolation are pulling the infrastructure planning process in different directions. Technological solutions are being implemented nationally rather than globally. If this continues then the safety situation will deteriorate with operating costs for airlines remaining high and increasing significantly over time. The performance capabilities of the modern aircraft navigation platform are not being fully exploited and the absence of a global design authority is fueling the proliferation of differing and in some cases costly navigational systems. This must stop.

The standardised navigational infrastructure should provide an appropriate performance capability (accuracy, integrity, availability and continuity of service) to enable aircraft navigation systems to meet the navigation performance established for a more congested airspace as demand for air travel adds more aircraft into the system. The airspace evolution should provide a seamless global navigation capability with unrestricted access at minimum cost.

The future concept of operation for navigation is Area Navigation (RNAV) and Required Navigation Performance (RNP) supported by a Global Navigation Satellite System (GNSS).

Today, airlines are faced with the predicament of trying to determine their future avionics requirements without having a pragmatic and clearly communicated plan of a standardised future global navigation infrastructure. This road map identifies a performance-based concept of operation based on Area Navigation (RNAV) and Required Navigation Performance (RNP) enabled by a Global Navigation Satellite System[4] (GNSS). Within the global navigation infrastructure, the aircraft must be viewed as a standardised key component. Its navigational capabilities should be properly exploited to enhance safety and increase efficiency and capacity.

Today, the majority of the commercial airplane fleet are RNAV capable. However, IATA recognises that a significant percentage of some airlines fleet today are not GPS equipped. The addition of GPS capability will improve the navigation accuracy and we plan to co-ordinate the transition to global GNSS operations in a pragmatic, co-coordinated and cost effective manner working closely with our members.

The future navigation infrastructure should be an interoperable and seamless environment enabling airlines to standardise and reduce their avionics requirements based on a minimum set of globally agreed and harmonised standards.

[4] Additional information on the navigational applications referred to in this document is provided as an Attachment. This document states the current IATA policy. However, based on technical advancements, operational requirements and business case benefits IATA could reconsider its position on any aspect of navigation policy.

02 FUTURE OPERATIONAL CONCEPT

2.1 Area Navigation

At the heart of the future navigation system is RNAV. RNAV permits aircraft operation on any desired flight path (not restricted to paths defined by ground based aids) within the coverage of station referenced navigation aids or within the limits of the capability of self-contained aids (or a combination of these). RNAV should be applied everywhere allowing user preferred routings and trajectories providing the potential to re-design a more expeditious route structure to reduce the operating costs of airlines.

RNAV (and RNP) arrival and departure procedures introduce a more predictable and autonomous operation of aircraft. Managed airspace utilising RNAV procedures requires less tactical interaction from the controller. Therefore, controller workload is reduced providing the potential to increase sector capacity[5].

The annual fuel bill for airlines is approximately US$97 Billion[6] (based on an average price of US$57 a barrel). Therefore, an expeditious route structure will not only significantly reduce operating costs for the airline but it will also benefit the global environment by saving millions of tonnes of unnecessary CO2 emissions each year. RNAV based operations are already in use in a number of states and regions and IATA supports the expeditious extension of RNAV applications worldwide.

> RNAV applications for all phases of flight should be introduced worldwide to facilitate a global ATM system and reduce operating costs

2.2 Required Navigational Performance

RNP enables advanced navigational procedures to be designed and characterised with a specific performance level, allowing the aircraft to operate autonomously within strict navigational performance criteria whilst monitoring its own navigational performance and alerting the crew to non-compliance.

By applying the flexibility of RNAV to determine the aircrafts flight path and then, where applicable, applying RNP values to flight profiles, operations are enabled for areas that previously have been limited or precluded (e.g. paths avoiding high ground). Vertical Navigation (VNAV) further enhances flight operations by enabling the specification of a vertical flight path that can be tailored to take into consideration different aircraft performance, altitude constraints and angles of approach including arcs and curves[7].

The enhanced navigational performance parameters of RNP mean that it is a key element for the enhanced design and management of airspace. ANSP's have acknowledged both the safety and operational enhancement potential of utilising RNAV and RNP based navigation and therefore must now determine how best to introduce their application in a timely manner. RNP provides the potential to revolutionise the navigational

[5] Any increase in sector capacity for dense airspace may be reliant upon controller support tools.

[6] Fuel represents approximately 25% of the operating costs of a large airliner.

[7] Currently, the most pro-active application of RNP is for approach procedures.

RNAV should be applied everywhere and RNP where required.

infrastructure, however any application process must be harmonised to support a globally interoperable ATM system.

RNP based operations are already in use around the world. Pro-active operators have also developed their own RNP arrival and approach procedures at certain airfields to improve access, safety and efficiency[8].

Although IATA recognises the safety benefits and commercial advantage that this can provide it is concerned about the potential for the proliferation of different operational procedures for individual airlines. The development of RNP procedures must be standardised as per ICAO guidelines and should be available to all suitably qualified and authorised operators.

RNP provides the potential to revolutionise the navigational infrastructure. Service providers should be pro-active in exploiting the benefits of RNAV and RNP to deliver an enhanced cost effective service to its customers.

2.3 Global Navigational Satellite Sytem

GNSS is the ideal navigation infrastructure platform to allow full exploitation of the global benefits to be gained from RNAV capabilities and the RNP concept. GNSS provides a global time based position determination process that includes one or more satellite constellations, aircraft receivers and system integrity monitoring. GNSS provides a standardised global positioning system for air navigation whilst at the same time removing the reliance upon certain ground based navigational aids[9]. This allows an accurate, cost effective and standardised position determination on a global basis, that helps promote common airspace design and more standardised avionics, maintenance and training requirements for operators.

2.4 GNSS augmentation

Where necessary, augmentation of the GNSS core infrastructure signal is necessary to meet navigation requirements. This can be accomplished by using either a Ground Based Augmentation System (GBAS), Satellite Based Augmentation System (SBAS), Aircraft Based Augmentation Systems (ABAS) or Ground Based Regional Augmentation System (GRAS).

Having these four different augmentation options, some being developed without a credible business case or consultation with the end user, is simply unacceptable. Airlines cannot afford the extra costs of equipping their aircraft and training their crews for the various different operating systems that might be scattered around the world. The continued

GNSS allows operational transparency.

[8] RNP procedures (providing stabalised vertical guidance and significantly lower minima's than those available with non precision approaches) are being introduced at airports with insufficient or no landing aids and airports with non-precision approach capabilities only.

[9] With the introduction of any new satellite system (Galileo) co-coordinated global agreements must be established between States (service providers) and GNSS operators (owners) to guarantee the provision of service.

The continued development of augmentation systems without a credible cost benefit analysis and coordination involving all stakeholders only adds to the proliferation of different system solutions and is not supported by IATA.

development of multiple augmentation systems (some without a user driven business case) only increases costs to industry and adds to a proliferation of differing system based solutions within an already fragmented global infrastructure. For all operational developments there must be a plan that provides operation benefits to the end-users that justify the investment necessary to equip and (only if appropriate) retrofit airplanes.

2.5 Which augmentation system and why?

APproach with Vertical guidance (APV) will enhance safety and efficiency by providing guided and stabalised vertical guidance on approach procedures where currently no guidance exists (lower minima's are also enabled compared to Non Precision Approaches [NPA]).

GBAS, SBAS and GRAS are planned to provide (APV) performance levels that are similar to that of CAT I ILS (200 – 250 ft decision height). Currently GBAS is the only GNSS system that potentially will provide CAT II and CAT III performance levels. ABAS currently enable minima's in the region of 350 feet (above ground)[10]. However, it is not unreasonable, based on current operational trials, technical analysis and the planned future operation of multiple constellations, to expect that this capability may be enhanced in the future to enable ABAS performance levels near to that of CAT I ILS.

2.6 Satellite Based Augmentation System

With SBAS a network of reference stations collect the satellite signals and send them via a communication network to one or more ground processing centres usually spread over a wide area. These facilities are responsible for computing the augmentation message and sending it to one or more geostationary satellites that transmit the augmentation message to the user. SBAS is the most costly augmentation system as it is satellite based with a supporting ground based infrastructure.

There are multiple SBAS systems in development (e.g. WAAS, EGNOS, GAGAN, MTSAT). However, SBAS does not offer a global solution. No cost benefit analysis, involving all stakeholders, has been presented to support a global and interoperable SBAS. Although SBAS provides near CAT I performance accuracy levels, GBAS, GRAS and possibly ABAS will offer a similar capability at a reduced cost. Therefore, IATA does not support the continued development and implementation of SBAS. It should also be noted that both Boeing and Airbus currently have no plans to include SBAS capability in their aircraft.

IATA does not support the continued development and implementation of SBAS.

[10] Where determined by ICAO criterion for approach design procedures.

2.7 Ground Based Augmentation System

With GBAS the user receives augmentation information directly from a local ground based transmitter. GBAS currently provides CAT I type performance and eventually CAT II and CAT III performance is planned. The key challenge for GBAS is service continuity and integrity. Detailed technical investigation is on going to determine when GBAS will be able to deliver CAT II and CAT III capabilities.

Local Area Augmentation System (LAAS) is a ground-based GPS augmentation system being developed by the FAA. However, the LAAS program slowed significantly in 2005 and is currently now only in the research and development phase. Additionally, when using satellite navigation to provide precision approach capability it has been identified that suitable redundancy (ILS) to mitigate the affect of interference with the GPS signal (due to technical error or deliberate act) will have to be in place until systems mature[11].

IATA wants to see an early transition to GNSS for all phases of flight (including precision approach CAT III type performance). Airbus and Boeing have conducted significant evaluations of approach and landing operations based on GBAS. GBAS has the potential to provide additional operational capabilities at lower cost at more places than ILS. This potential is attractive to IATA and GBAS could be a major contributor to beneficial flight operations in the future. However, IATA will only endorse the introduction of GBAS when a credible business case, involving all stakeholders, is presented showing GBAS as a cost effective alternative to current CAT II and CAT III ILS.

> IATA will only endorse the introduction of GBAS when a credible business case, involving all stakeholders, is presented showing GBAS as a cost effective alternative to CAT II and CAT III ILS.

2.8 Ground Based Regional Augmentation System

Like SBAS, GRAS uses a distributed region-wide network of reference stations for monitoring GPS signal accuracy, and a central processing facility for computing GPS integrity and differential correction information. But instead of transmitting this information to users via dedicated geostationary satellites, GRAS delivers message data to a network of terrestrial stations for local check and re-formatting. GRAS is a complementary system to GBAS and a lower cost alternative to SBAS taking advantage of equipage and networks that exist today.

The main beneficiaries of GRAS will be regional carriers and General Aviation. Although IATA recognises the benefits of GRAS, it is concerned about global proliferation of different systems. Any local or regional application of GRAS should not disadvantage non-equipped operators or

> Any local or regional application of GRAS should not disadvantage non-equipped operators or negate the introduction of global solutions. Only those operators who benefit from the system should meet the costs associated with the introduction and operation of GRAS.

[11] FAA Navigation, Landing and Transition strategy dated Aug 2002.

negate the introduction of global solutions. Only those operators who benefit from the system should meet the costs associated with the introduction and operation of GRAS.

2.9 Aircraft Based Augmentation System

ABAS are self contained on board the aircraft and rely upon avionics processing techniques or avionics integration to monitor data integrity. Considering on-going operational and technical analysis of ABAS, it is not un-reasonable to expect that ABAS will eventually enable near CAT I type performance capability[12]. ABAS are the most cost effective augmentation system as it utilises the avionics already on board the aircraft. It is the preferred option for augmenting GNSS to provide APV and thus enhance safety and efficiency at airports, particularly those currently with insufficient or no landing aids or with non-precision approach capabilities only. IATA encourages the continued technical investigation and operational analysis to enable ABAS to provide a cost effective alternative to CAT I ILS[13].

ABAS is the preferred and most cost effective systems for augmenting GNSS to provide safety and efficiency benefits.

2.10 Approaches with lateral and vertical guidance

APV can be provided in two ways. Either Barometric Vertical Navigation (Baro VNAV) where the FMS generates a continuous descent path using barometric altimeter information or geometric vertical guidance provided by an augmented Satellite based signal.

Modern air carrier airplanes have FMS vertical navigation (VNAV) modes. When this capability is combined with FMS lateral navigation (LNAV) mode, a three-dimensional approach path to the runway can be defined and flown. The primary benefit of three-dimensional approach is safety. As previously mentioned, APV (LNAV/VNAV) provides guided and stabalised vertical guidance on approach procedures where currently no guidance exists therefore reducing the risk of Controlled Flight Into Terrain (CFIT)[14]. Also RNAV (GNSS) enabled LNAV/VNAV enables the standardisation and simplification of the design and execution of approach procedures worldwide. The addition of RNP capability further enhances operational capability

2.11 APV/Baro VNAV

APV/Baro VNAV (using ABAS) is the most cost effective and quickest way of implementing APV as most of today's civil transport aircraft have navigation equipment on board that is able to support this type of approach. APV/Baro VNAV generally enables approach minima's lower than those for NPAs. Therefore, IATA encourages the widespread implementation APV/Baro VNAV as soon as possible.

IATA encourages the widespread implementation APV/Baro VNAV procedures as they will reduce the risk of CFIT and make approach procedures more efficient when compared with non precision approaches.

[12] Multiple satellite constellations will significantly enhance the capabilities of ABAS.

[13] And VOR/NDB, NDB or ILS localizer only.

[14] 9% of the 2005 accidents were classified as CFIT. (IATA Safety Report, Issued February 2006.)

03 BENEFITS OF THE FUTURE NAVIGATIONAL CONCEPT

A future global navigational infrastructure based on GNSS enabled RNAV and RNP will deliver the following benefits in safety, efficiency, capacity and economy.

3.1 Safety

The availability of stabilised vertical guidance on approaches where currently none exists will reduce the risk of CFIT. Additionally, the standardisation of the design of approach procedures and their execution worldwide will enhance the safe operation of flight and reduce training for pilots and controllers.

If a fragmented navigational system persists it will mean that additional airborne equipment, or new equipment designed to be multi compatible or functional, will be required. There will be integration required to add functionality into the airplane in a consistent way to ensure a safe and effective flight crew interface. If crews have to constantly swap between different navigational applications, with subtly different procedures and responsibilities, then the risk of safety related human error will increase.

3.2 Efficiency

Efficiency benefits will be provided by a transition to RNAV with performance enabling the expeditious navigation of aircraft using one globally accessible capability. Dynamic routings and standard approach and departure procedures based on stated user requirements and environmental considerations will be enabled. This operation will then naturally evolve into dynamic trajectories (4D) that can be used to allow a more efficient and more autonomous operation of aircraft even within high density airspace.

3.3 Capacity

A more autonomous operation of aircraft in dense airspace will reduce controller workload therefore providing the potential to increase capacity whilst maintaining or enhancing safety. Although workload may be reduced it must be recognised that in high-density airspace any increase in sector capacity will be dependent upon controller support tools for conformance monitoring, trajectory prediction and medium term conflict detection.

In remote and procedural airspace environments separation criteria will be able to be reduced making the most efficient use of available capacity. For example, when the IATA proposed RNP standard is introduced for the North Atlantic Tracks (with the associated communication and surveillance requirements) then conceivably the efficient capacity could be doubled enabling more aircraft to fly on or closer to the core route[15].

3.4 Economic

Economic benefit will be delivered through, improved safety, reduced route mileage (fuel savings), reduced flight time (crew cost), reduced airborne equipage requirements and a reduced infrastructure investment and overall maintenance costs. As the demand for air travel grows, there must be changes in the global airspace system to accommodate that growth.

[15] The core route is the most efficient track and level to cross the Atlantic being determined by the prevailing wind. When the core route is full aircraft have to fly on adjacent tracks or at different levels. This is less efficient. However, the introduction of RNP 4 will reduce separation between aircraft allowing the capacity of the core route to potentially double.

04 FUTURE PLANNING

It is unacceptable that operators do not have a pragmatic and cost effective global navigation plan to determine their future airplane systems requirements. This has been caused by a lack of "Joined-Up-Planning" between service providers and organisations responsible for providing current and future air navigation services.

A clearly communicated and pragmatic vision of the global navigation infrastructure is required. Although, individual service providers, administrations and industry organisations promote their respective view of the way forward, a lack of "Joined-Up-Planning"[16] means that the opportunity for the introduction of a credible cost effective global plan is being missed. Considering the technological investment required by the airlines and the global nature of their activity this is simply unacceptable.

It is imperative that major national and international projects looking at upgrading air traffic management infrastructure are able to agree upon and deliver a globally harmonised and interoperable ATM delivery system. In consultation, users, service providers[17], equipment manufacturers and governments should clearly and concisely determine and communicate their plan for a global navigational infrastructure and service delivery process. Aircraft manufacturers must also be involved in the planning process to ensure a minimal set of avionics requirements whilst taking note of any potential future options or developments so that due consideration can be given.

Currently, the two major industry initiatives that will significantly influence the future ATM environment are the Single European Sky ATM Research (SESAR) project and the FAA Next Generation Air Transport System (NGATS). It is imperative that SESAR and NGATS deliver the interoperable, harmonised, cost effective and efficient system that they both advertise. IATA shall provide support and expert input to help ensure this is achieved.

It is imperative that major national and international projects looking at the future ATM infrastructure are able to agree upon and deliver a globally harmonised and interoperable new service that is cost effective and practical to implement.

16 "Joined-Up-Planning" is an integrated real time planning process, using common data and forecast information, which allows a global strategy to be translated consistently in to tactical action across different functional areas.

17 The expression "Service Providers" includes ATC, GNSS providers and non-aviation or aviation consortium (public, private or both in partnership).

05 IATA POSITION

In the short and medium term certain ground based terminal navigational aids will still be an essential part of the transitional navigation infrastructure[18]. However, the immediate progressive and optimum de-linking[19] and de-commissioning of en-route navigational aids, such as NDB and VOR's is required.

There are nearly 20,000 ground based navigational aids deployed worldwide[20]. Current market forecasts indicate that the annual avionics requirements (commercial carriers, cargo operators, regional and corporate) will be in the region of 3 billion US dollars and the ATC equipment market equates to 8 billion US[21]. Decommissioning or not replacing existing ground based navigation aids, particularly those dedicated for en-route services, will significantly reduce the overheads of purchase, flight calibration, repair and maintenance costs incurred by the service provider and paid for by the airlines[22].

The introduction of new or replacement navigation aids (and the assignment of any costs) should only be done with the full agreement of airspace users.

A phased decommissioning of VORs should be completed by 2015.

5.1 VHF Omni-directional Radio Range

Globally there are approximately 3700 operational VORs. Many are over 30 years old and are not cost effective to maintain. Several service providers have already identified a reduced reliance upon these navigational aids and are starting to plan their withdrawal. The expanding operational acceptance and use of GNSS for navigation not only enables the withdrawal of VORs used for route navigation but also those aids used for NPA. NPAs are the most widely targeted area for the early deployment of GNSS based operations for approach and landing. The less stringent lateral guidance requirements for NPA and the absence of vertical guidance allow the simplest GNSS system (GPS with airborne integrity monitoring) to support these operations. It is therefore proposed that (where appropriate) the withdrawal of VORs can start immediately with full decommissioning achieved by 2015([23]).

[18] Complementing on board systems, acting as contingency and enabling integrity checking.

[19] De-linking is the process of allowing a segment[s] of the aviation user community that no longer require elements of the ground-based infrastructure to discontinue equipping, using or paying for that infrastructure.

[20] Number of nav aids worldwide: VOR 3696, DME 2877, NDB 6582, TACAN (CIV) 1161, IDME 1741, ILS Loc 3604. (Source Jeppessen.)

[21] Source: Jane's Airport review Dec 04.

[22] A significant cost associated with ground based navigational aids is the purchase or lease of the real estate to locate the facility.

[23] The use of VORs may be extended to support RNAV in the TMA.

5.2 Non Directional Beacon

Virtually all the medium frequency navigation aids, (NDB) are deemed to be obsolete and not required for safe navigation in a navigational infrastructure utilising GNSS. Globally, there are approximately 6600 NDBs in service. Several states have already started NDB de-commissioning programmes and it is anticipated that the majority of NDBs could be withdrawn from operational use by 2010.

The FAA is leading the way in reducing infrastructure costs by eliminating redundant navigational aids. The agency has announced that it will cancel 216 redundant NDB approaches from July 7 2005. For every redundant NDB approach that can be cancelled the service provider will save $14,000 annually[24].

5.3 Distance Measuring Equipment

Until the vulnerabilities of GNSS are well understood and resolved, contingency systems need to be considered during the transition to RNAV GNSS. When considering ground aids for mitigation, DME is the best and most cost effective choice to maintain near equivalent capability in case of interruption to the GNSS signal. Therefore, were identified for safety mitigation for terminal and approach phases of flight, it is expected that a minimal network of DME will need to be maintained[25].

A phased decommissioning of NDBs should be completed by 2010.

5.4 Instrument Landing System

ILS has served the industry well for over 40 years undergoing a number of safety related improvements to increase its performance accuracy and reliability. This proven capability meets user requirements today and is still considered an essential component of the required navaids infrastructure.

A phased withdrawal of CAT I ILS at major aerodromes should start with the greater use of RNAV (LNAV/VNAV) with minima's similar to those of CAT I. It is anticipated that this general process will start in circa 2012. However, it is quite reasonable to determine that the isolated withdrawal of CAT I ILS will occur before this date. To reduce the costs associated with legacy instrument landing systems the traditional Marker Beacons should be replaced with DME (with suitable required performance accuracy).

The transitional process for replacing CAT II and CAT III ILS should commence only after confirmation of efficiency and cost-effectiveness of the new navigation solutions, and after stakeholders have formalised a firm transition plan with binding commitments. Decommissioning of ILS facilities must not result in any associated degradation of currently available services related to non-visual aids for approach and landing during the transition phase.

A phased withdrawal of CAT I ILS should commence no later than 2012.

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[24] If an operator did not have to equip with NDB then they could save in the region of $30.000 on purchase equipment costs per aircraft.

[25] It is recognised that DME is at the core of the current European and US navigational infrastructure.

5.5 Microwave Landing System

The Microwave Landing System (MLS) is a credible alternative to ILS and also provides additional benefits. MLS does not suffer from broadcast interference problems like ILS and therefore allows closely spaced auto land approaches in low visibility conditions. Additionally, MLS has up to ±60 degrees of lateral coverage from the runway that enables suitably equipped aircraft to execute curved approaches. This is a key consideration when determining procedures for closely spaced parallel runway operations.

MLS services should be considered in consultation with concerned airspace users only at specific airports where ILS CAT II and CAT III cannot be maintained and where MLS operational and/or economic benefits are proven. Implementation of MLS should not have any operational impact on aircraft that are not MLS-equipped.

> Implementation of MLS should not have any operational impact on aircraft that are not MLS-equipped.

5.6 Advanced surface movement guidance and control system.

Advanced Surface Movement Guidance and Control Systems (A-SMGCS) are a key consideration for the provision of navigational guidance for surface movements within the navigational infrastructure. As airspace and airport capacity demand increases above determined threshold levels, A-SMGCS will be required to safely support the expected increases in surface movements, particularly in low visibility conditions. Where an aircraft is suitably equipped for appropriate surveillance applications delivery (e.g. ADS–B) then this technology should be considered first for delivery of potential A-SMGCS applications. This will embrace interoperability and harmonisation of technological solutions and ensure costs are minimised for operators and providers through standardisation. It should not be forgotten that the development of A-SMGCS must be closely co-coordinated with those dependent and non-dependent surveillance systems being considered for approach, landing and departure. If this is not the case then benefits will potentially be lost and development costs increased.

> IATA endorses the application of A-SMGCS using existing technology where able.

06 NAVIGATIONAL AIDS TRANSITION ROADMAP

The following transitional roadmap provides dates for a structured transition from ground based to satellite based navigation service delivery. Industry should aim to de-commission or de-link the most obsolete or obsolescent navigational aids first and then reduce the numbers of other navigational aids in successive phases as users are introduced to performance based navigation services. Navigational aids that provide RNAV and navigational aids that provide vertically guided instrument approach services have the highest priority for retention. Figure 1 shows the proposed integrated phase out of ground based navigational aids (information is also provided on parallel work related to future Communication and Surveillance).

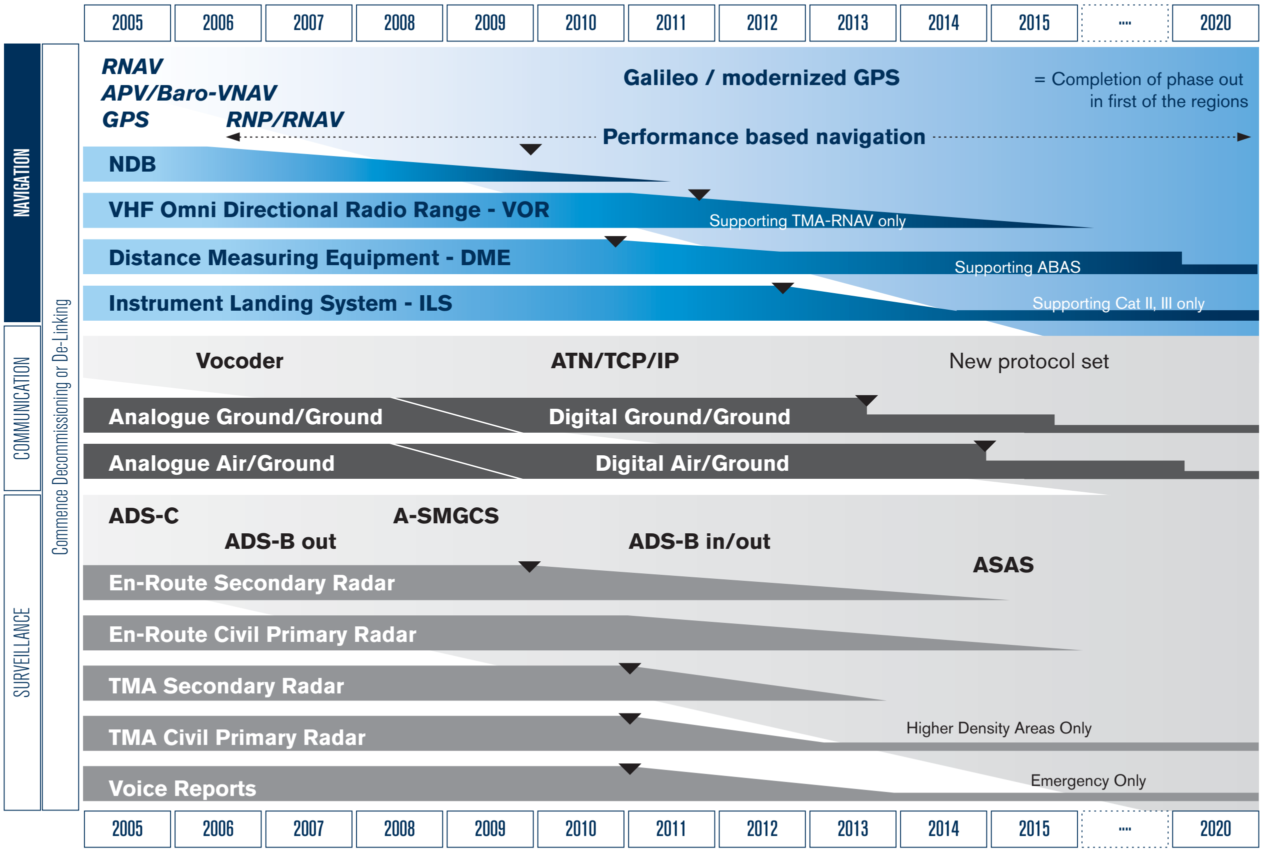

Figure 1: Proposed Integrated Phase-Out of Main Infrastructure - NAVIGATION

1. NOTICE PERIOD: Whilst no specific guidance is provided, it is generally accepted that 7 years notice should be given before significant infrastructure is decommissioned. Proper consultation is essential to ensure a smooth transition in identified time frames.

2. PRIMARY RADAR: It is anticipated that Enroute Primary Radar will no longer be required to provide civilian ATM services – however it may be required to ensure national security. Where it is required for national security, or non-civil aviation services, the infrastructure costs should be absorbed as a State function. It is accepted that Primary Radar may be needed as safety mitigation in terminal areas – this should not be taken as a blanket requirement – each TMA should be assessed on safety and cost merit.

3. SECONDARY RADAR: It is anticipated that secondary radars will be phased out as ADS is expanded. It is also anticipated that where consideration is being given to additional en-route surveillance, ADS will be the preferred option.

4. NDB, VOR and DME: The use of traditional ground based aids – NDB, VOR and DME – for en-route navigation will be replaced by area navigation capabilities including FMC, INS/IRS and GNSS. Traditional approach will be TMA RNAV, RNP and VNAV procedures, reducing – then eliminating – reliance on ground based infrastructure.
The de-commissioning date for NDB has been discussed for many years. The 2010 time frame could be achieved through expeditious and pro-active work initiatives.

5. COMMUNICATIONS: Communications infrastructure is gradually being digitized, and capabilities enhanced. Inter-unit ground-ground communications are being phased to Internet protocols. New protocols for communication are indevelopment with action targets of 2012-2015.

ATTACHMENT TO:

This attachment provides a high level overview of current and future navigational technology. It is designed for information only and includes extracts from the Civil Air Navigation Services Organisation (CANSO) publication Demystifying GNSS dated Jan 05([26]).

[26] For the full document see CANSO's website: www.CANSO.org.

IATA NAVIGATION AIDS TRANSITION ROADMAP:
HIGH LEVEL EXPLANATION OF CURRENT AND FUTURE NAVIGATIONAL CONCEPTS

A1. Global Navigation Satellite System

GNSS provides a global position and time determination system that includes one or more satellite constellations, aircraft receiver and system integrity monitoring. There are currently two core constellations. The US military Global Positioning System (GPS) and a Russian military system called GLONASS. GPS is fully operational and GLONASS has a planned operational date of 2010. In addition to these two military constellations a new civilian constellation, suitable for aviation use, is planned for circa 2012 called Galileo.

A1.1 GALILEO

Galileo will be Europe's own civilian global navigation satellite system and IATA recognises the potential benefits that this new system will bring. However, it must be compatible and interoperable with other satellite navigation systems (avionics compatibility) and its operational introduction must be supported by a clear business and safety case.

The aviation community has been targeted as a potential major source of financing for the Galileo system. Today GPS is provided free of charge to the end users therefore, the aviation community expects that similar services from Galileo will be free as well.

Moderised GPS

Enhancements are planned to GPS under the GPS moderisation program. Accuracy and integrity will be improved and operational implementation is planned for 2013. The planned modernisation of GPS and the development of the European Galileo system will substantially increase the signals available to the GNSS user community. This will bring numerous benefits for the advanced navigational application of performance-based navigation.

A1.2 GNSS for all phases of flight

GNSS provides the potential to enhance the safety and efficiency of navigation in all phases of flight resulting in a seamless global navigation infrastructure that is cost effective for both the aircraft operator and the service provider. GNSS provides accurate guidance in remote and oceanic areas where it is impractical, too costly, or impossible to install traditional navaids. The availability of accurate, GNSS-based, guidance on the departure and arrival phase of flight supports efficient procedures. It allows greater flexibility in routings where terrain is a restricting factor, providing the possibility of lower climbing gradients and higher payloads. GNSS can improve airport usability through lower minima, without the need to install a traditional navigation aid at the airport. With the introduction of any new Satellite constellation (Galileo) co-coordinated national, international and global agreements must be established between States (service providers) and GNSS operators (owners) to guarantee the provision of service. The basic GNSS satellite signal should continue to be free of charge to all user as is the case today with GPS.

A1.3 Augmentation

To meet the required performance for advanced navigational application, such as final approach, augmentation of the GNSS signal is required to improve accuracy and monitor data integrity. Only basic information on augmentation is provided in the main text. Therefore, more detailed information is provided on ABAS, SBAS, GBAS and GRAS in the following paragraphs.

A1.4 ABAS

ABAS are self contained on board the aircraft and rely upon avionics processing techniques or avionics integration. Receiver Autonomous Integrity Monitoring (RAIM) provides integrity monitoring of GPS for aviation applications. In order for a GPS receiver to perform RAIM a minimum of 5 visible satellites with satisfactory geometry must be visible to it. The RAIM function performs consistency checks between position solutions obtained with various subsets of the visible satellites. The receiver provides an alert to the pilot if the consistency checks fail. Because of geometry and planned maintenance RAIM is not always available. In this situation pre warning is given to users of 'RAIM outage'.

An enhanced version of RAIM employed in some receivers is known as Fault Detection and Exclusion (FDE). It uses a minimum of 6 satellites to not only detect a possible faulty satellite, but to exclude it from the navigation solution so the navigation function can continue without interruption.

A1.5 Aircraft Autonomous Integrity Monitoring

With Aircraft Autonomous Integrity Monitoring (AAIM), the integrity of the GPS solution is validated using other on board information sources, such as the Inertial Platform, in addition to those used in RAIM. A barometric ("baro") altimeter may be used as an additional measurement so that the number of ranging sources required for RAIM and FDE can be reduced by one. Baro-aiding can also help to increase availability when their geometry is not adequate to perform integrity function, even though there are enough satellites visible.

Depending on the different additional measurement introduced to aid the GNSS receiver, the following sub-types of AAIM can be identified:

- AAIM/ Baro using the barometric altimeter information;
- AAIM/ MS using Multi-Sensor information based on ground navaids signals (VORs, DMEs, ILS/LOCs);
- AAIM/ INS using the inertial sensor information.

As discussed in the main text ABAS is the preferred and the most cost effective system for augmenting GNSS to provide safety and efficiency benefits.

A1.6 SBAS

With SBAS a network of reference stations collect the satellite signals and send them via a communication network to one or more ground processing centres usually spread over a wide area. These facilities are responsible for computing the augmentation message and sending it to one or more geostationary satellites that transmit the augmentation message to the user. The augmentation message consists of differential corrections (ranges, satellite clocks, and orbits), ionospheric corrections and integrity information. The integrity information indicates whether a specific satellite should be used or not. A user receives both the core constellation signals and the SBAS augmentation message through one or more geostationary satellites on the GPS L1 frequency.

SBAS are currently being implemented in Europe with the European Geostationary Navigation Overlay Service (EGNOS), in the United States with the Wide Area Augmentation System (WAAS), in Japan with the Multi-functional Transport SATellite (MTSAT) Satellite-based Augmentation System and in India with the GPS And GEO Augmented Navigation (GAGAN)[27]. As you can see from Figure A1 SBAS is not a global system.

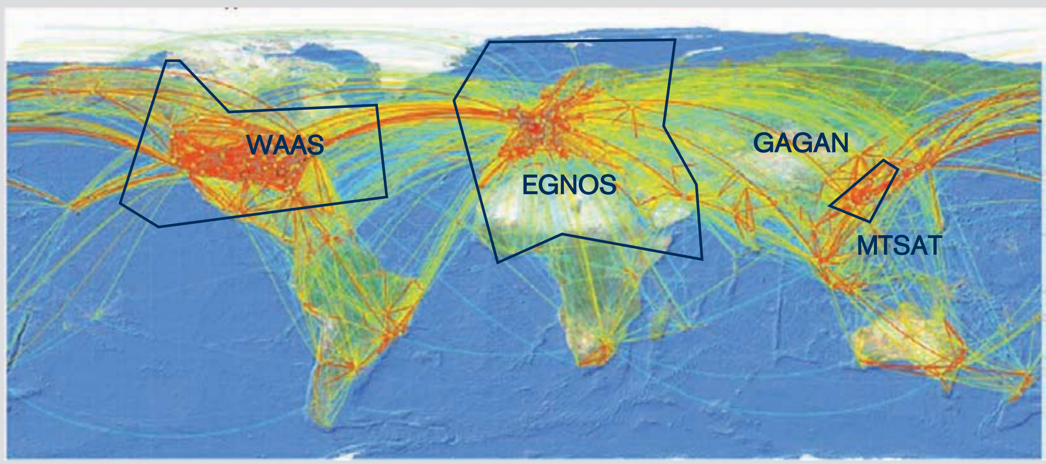

Figure A1. Different SBAS around the world.

A1.7 EGNOS

The two most advanced SBAS are EGNOS and WAAS. EGNOS is due to enter operational service in circa 2008-2010. Airspace users have long opposed paying for EGNOS, which has not satisfactorily demonstrated tangible operational benefits and for which all attempts to build a credible business case have failed. IATA does not expect that airspace users will be charged for services (either directly or indirectly) in the future.

A1.8 WAAS

In the United States, the FAA commissioned WAAS for instrument flight use in July 2003 providing en route navigation across the entire National Airspace System. Avionics are now certified to perform operations from en-route to approach with vertical guidance so that WAAS-based instrument approaches (similar to CAT I) can be performed at airport runways with little or no ground-based landing capability.

SBAS is the most costly augmentation option because it is satellite based. No credible business case, involving all stakeholders, has

[27] Other SBAS systems are in development. The Quasi-Zenith Satellite System [QZSS) is a constellation of at least three Japanese satellites and research in China has been underway for many years to introduce a military system called Beidou.

been presented to support SBAS. Although SBAS provides near CAT I performance accuracy levels, GBAS, GRAS and possibly ABAS will offer the same capability at a much reduced cost. Therefore, IATA does not support the continued development and implementation of SBAS.

A1.9 GBAS

The Ground-Based Augmentation System (GBAS) [Figure 2] is composed of the satellite constellation that produces ranging signals, the ground subsystem and the aircraft subsystem. The GBAS ground sub-system collects pseudo ranges for all GNSS satellites within view and then computes and broadcasts differential corrections for them based on its own surveyed position. For the initial implementation it is anticipated that GPS will be the only satellite constellation declared operational for civil use. Additional ranging sources from geostationary satellites (SBAS) may also be available. The computed corrections are transmitted from the ground system via a Very High Frequency (VHF) Data Broadcast (VDB) system, together with GBAS ground system related data and the FAS data within a nominal range of 23NM (depending on line-of-sight).

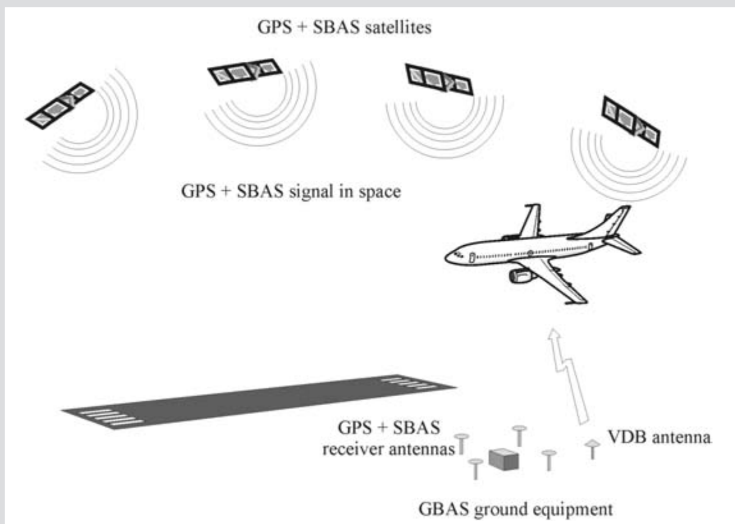

Figure A2: Ground-based Augmentation System

Aircraft sub-systems within the area of coverage of the ground station use the broadcast corrections to compute their own measurements. After selection of the desired Final Approach Segment (FAS) for the landing runway, the differentially corrected position is used to generate navigation guidance instructions. These are lateral and vertical deviations as well as distance to the threshold crossing point of the selected FAS and an integrity flag. As is the case for SBAS, the resulting guidance information will be output from a Multi-Mode Receiver (MMR) that is consistent with ILS requirements, i.e. looks and performs like an ILS, to minimise the impact upon current aircraft design and thereby certification effort.

A1.10 GBAS CAT II and II

The key challenge for GBAS is integrity. Detailed technical investigation is on going to determine when GBAS will be able to deliver Cat II and III performance capabilities. When using Satellite Navigation to provide CAT II and CAT III precision approach capability it has been identified that suitable redundancy (ILS) to mitigate the affect of interference with the GNSS signal (due to technical error or deliberate act) will have to be in place until GBAS has matured.

A1.11 LAAS

LAAS is a ground-based GPS augmentation system (GBAS) being developed by the FAA that provides differential corrections to aviation users via a localised VHF data broadcast. LAAS is expected to provide the required accuracy, availability, integrity, and continuity to initially support Category I precision approaches and eventually Category II and III precision approaches at LAAS-equipped airfields. However, the LAAS program slowed significantly in 2005 and is currently now only in the research and development phase. The main task is the completion of the integrity analysis activity for CAT I operations. Various organisations are working closely with the manufacturers to develop GBAS technology. In particular Air Services Australia, DFS in Germany and AENA in Spain which have already established and funded programs and or /GBAS prototype systems installed. IATA will only endorse the introduction of GBAS when a credible business case, involving all stakeholders, is presented showing GBAS as a cost effective alternative to CAT II and CAT III ILS.

A1.12 GRAS

GRAS is SBAS like in using a distributed network of reference stations for monitoring GPS, and a central processing facility for computing GPS integrity and differential correction information. But instead of transmitting this information to users via dedicated geostationary satellites, GRAS delivers SBAS message data to a network of terrestrial stations for local check and re-formatting. The benefits of GRAS are limited to General Aviation and regional carriers and therefore non-users should not be charged for the implementation and operation of the system.

A1.13 GNSS for Approach and Landing Operations

The present ICAO definitions identify several operational concepts available for GNSS-based approaches:

- Non-Precision Approach (NPA), with lateral guidance only.
- APproach with Vertical guidance (APV), where lateral and vertical guidance are delivered. There are two different possibilities for the vertical guidance:
  - Barometric vertical guidance (BaroVNAV)
  - GNSS vertical guidance with two levels of performance (APV1, APV2)
- Precision Approach (PA) with lateral and vertical GNSS guidance.

APV1 and APV2 based operations consist of very precise geometric, vertical guidance with an independent cross check and a lateral precision equivalent to ILS CAT I. The superior integrity for the vertical guidance, where descent trajectories with reduced operational minima are expected, is expected to be provided through the use of SBAS. It is anticipated however, that other systems, such as GBAS, GRAS and Galileo, will also be able to provide APV1 and APV2 based operations in the future.

A1.14 Non-Precision Approach

The relaxed (relative to APV1, APV2 and PA operations) lateral guidance performance requirements along the approach path and the absence of requirements for vertical guidance allow the simplest GNSS systems, such as a GNSS receiver with ABAS/RAIM/AAIM, to support NPA operations. GNSS NPA may be introduced on runways where no terrestrial-based navaids are available and there are some additional safety benefits in using of RNAV GNSS NPA operations in lieu of conventional NPAs such as NDB or VOR.

It must be remembered that airport access under instrument flight conditions is determined by a number of factors including the lighting infrastructure. Research is underway looking at the use of systems such as Heads Up Guidance and Synthetic Vision to enable approach approval.

A1.17 Micro-wave Landing System

MLS is an alternative to ILS. ILS has a number of basic limitations. The physical location of the ILS is site sensitive and there is a high installation cost. The ILS provides only a single approach path and the ILS signal received by an aircraft following another on final approach can reflect of the aircraft ahead resulting in false guidance. In low visibility this can create a potentially hazardous condition therefore appropriate mitigation must be applied.

MLS does not suffer from broadcast interference problems or affected by adverse weather. MLS all-weather coverage is available up to ±60 degrees from runway centerline, from 0.9 degree to 15 degrees in elevation, and out of 20 nautical miles (NM). This enables a more flexible and efficient approach paths especially in dense restricted airspace.

A2 Benefits of RNAV

RNAV routings and RNP approach and departure procedures introduce a more predictable and autonomous operation of aircraft. Managed airspace utilising RNAV and RNP procedures requires less tactical interaction from the controller[28]. Therefore, controller workload is reduced that provides the potential to increase capacity.

In high density airspace utilising RNAV and RNP the role of the controller will be more of strategic planning and monitoring. As long as controllers are provided with the appropriate support tools (may include ground based conformance monitoring) then the potential increases in sector capacities enabled by RNAV and RNP can be realised.

A2.1 Guidance on the implementation of performance based navigation.

IATA is in the process of producing guidance material for the introduction of RNAV in terminal airspace. The guidance material will identify the required processes for the

[28] Today, in dense airspace, the sheer amount of tactical control instructions issued by ATC means that controller workload is high. High controller workload restricts sector capacity.

introduction of RNAV including system description, reference documentation, certification, controller guidance and operator approval. This work is being done in close co-operation with ICAO to ensure a globally harmonised introduction and will complement and support the ICAO Performance Based Navigation manual (RNAV and RNP) that is currently being produced.

A2.2 Required Navigation Performance

Required Navigation Performance (RNP) is a statement of navigation performance defined in terms of accuracy, integrity, availability and continuity of service necessary for operations within defined airspace. The RNP defines the total navigation system error that is allowed in lateral, longitudinal, and, in some cases, vertical dimensions within particular airspace. RNP is naturally associated with the design and infrastructure of the airspace. The key element of RNP is the requirement for on board navigational performance monitoring and alerting.

IATA members support global implementation of the RNP concept originally developed by ICAO and amplified by the aviation industry, in order to provide a seamless environment and standard aircrew procedures. RNP will allow the most efficient operations based on navigation performance of available sensors rather than assumed worst-case performance. The choice by a State or Region of ICAO specified RNP route or airspace values/requirements must, in all cases, be benefit driven. States and regions should only select RNP values in accordance with those promulgated in Annex 11 or the PANS-ATM.

The choice of navigation mix to meet a specified RNP value/requirement should be at the discretion of the aircraft or operator, subject to assessment of the availability and continuity thereof. States and/or regions should not unnecessarily restrict the use of navigation solutions. Notification of the ability of an aircraft or operator to meet the prescribed navigation performance will be provided in the appropriate flight notification. RNP can be presently met using either GNSS, the current ground based navigation infrastructure, airborne self-contained systems or a combination of these. Table A1 provides a list of equipment required to support GNSS-based operations for the various phases of flight .

[29] Chart extracted from CANSO document.

	GNSS-based Operation	Minimum Airborne Navigation Equipment/Capability Required (for the Operation)	Remarks
1	RNAV enroute (remote area primary or oceanic navigation)	GNSS receiver with ABAS/RAIM/AAIM including FDE	Fault Detection and Exclusion (FDE) required in addition to preflight FDE/RAIM prediction
2	RNAV enroute and TMA (supplemental navigation)	GNSS receiver with ABAS/RAIM/AAIM meeting TSO C129 or equivalent	GNSS navigation is supplemental to terrestrial-based navigation aids
	RNAV enroute and TMA (primary navigation)	SBAS receiver meeting TSO C145a/146a or equivalent) or GNSS receiver with ABAS/RAIM/AAIM/ BaroVNAV meeting TSO C129 or equivalent	SBAS allows primary navigation using GNSS (The US still requires a VOR to be carried in Class B airspace)
	RNP RNAV enroute and TMA	GNSS receiver & FMS with ABAS/RAIM/AAIM (Most RNP aircraft are equipped with an FMS, but the FAA has indicated that a TSO C129/C145a/146a will meet the requirements of RNP 0.3 and above. However, nothing to this effect has been published yet.)	RNP certified aircraft navigation performance considering installed equipment. RNP may be based on GNSS/ABAS, GNSS plus SBAS, or GRAS, or IRS/INS, VOR and/or DME. In cases of non-satellite navigation appropriate avionics onboard as well as conventional terrestrial-based navaids are required.
3	Non-precision Approach (NPA) (supplemental navigation)	GNSS receiver with ABAS/RAIM/AAIM meeting TSO C129 or equivalent	GNSS navigation is supplemental to Ground Based Navigational Aid (GBNA). Alternate airport must have approach supported by installed GBNAs.
	Non-precision Approach (NPA) (Primary navigation)	GNSS receiver with ABAS/RAIM/AAIM or SBAS receiver (meeting TSO C145a/146a or equivalent) or GBAS Receiver	ABAS, SBAS, or GRAS supports primary navigation using GNSS. Depending on national legislation the alternate airport may require ground based navigation aids.
4	Approach with vertical guidance APV BaroVNAV	GNSS receiver with ABAS/RAIM/AAIM and BaroVNAV or SBAS receiver (meeting TSO C145a/146a or equivalent) or GBAS Receiver	Barometric Altimetry system must meet requirements for BaroVNAV.
5	Approach with vertical guidance APV1	SBAS receiver (meeting TSO C145a/146a or equivalent) or GBAS Receiver	LPV is currently the US APV1 service. LNAV/VNAV can also be flown with SBAS receivers
6	Approach with vertical guidance APV2	SBAS receiver meeting TSO C145a/146a or equivalent) or GBAS Receiver	WAAS does not currently provide this service.
7	Precision Approach CAT I	GBAS Receiver or Galileo+GPS/SBAS Receiver	ICAO SARPs include requirements for SBAS CAT I, however currently implemented SBASs do not provide this service.
8	Precision Approach CAT II	GBAS Receiver	Standards for GBAS supporting CAT II operations are under development now. It is expected that avionics will be ready after 2010.
9	Precision Approach CAT III	GBAS Receiver	Standards for GBAS supporting CAT III operations are under development now. It is expected that avionics will be ready after 2010.

Table A1: Required equipment to support GNSS

Notes: A variety of standards have been or are being developed for GNSS, SBAS, GRAS, and GBAS receivers. At present, stand-alone and MMR receivers are being produced or are envisioned for GNSS, SBAS, GRAS, and GBAS.

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