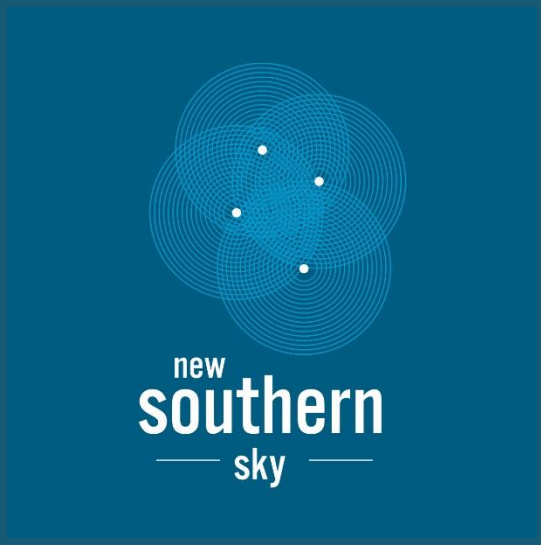

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Glossary

Term	Definition
ADF	Auto Direction Finder
ANP	Air Navigation Plan
ANSP	Air Navigation Services Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
APNT	Alternate Position and Navigation Timing
BARNZ	Board of Airline Representatives New Zealand
Baro-VNAV	Barometric - Vertical Navigation
CAA	Civil Aviation Authority
DME	Distance Measuring Equipment
DND	Dunedin
FIR	Flight Information Region
FIS	Flight Information Service
GBNA	Ground Based Navigation Aid
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IRU	Inertial Reference Unit
LNAV	Lateral Navigation
MEL	Minimum Equipment List
MON	Minimum Operating Network
MoT	Ministry of Transport
MSA	Minimum Safe Altitude
NAANP	National Airspace and Air Navigation Plan
NDB	Non Directional Beacon
NPE	Napier
NSN	Nelson
NSR	National Security and Resilience
PBN	Performance Based Navigation
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP APCH	Required Navigation Performance Approach
RPAS	Remotely Piloted Aircraft System
SBAS	Satellite Based Augmentation System
SID	Standard Instrument Departure
STAR	Standard Instrument Arrival
VFR	Visual Flight Rules
VOR	VHF Omnidirectional Range

Executive Summary

The National Airspace and Air Navigation Plan[1] (NAANP) identifies Performance Based Navigation (PBN), based on the use of GNSS, as the means for modernisation of navigation in New Zealand, enabling safety, environment and economic benefits. With the implementation of PBN, it is important that the current Ground Based Navigation Aid (GBNA) infrastructure is reviewed to ensure it supports safety criteria while achieving efficiencies. These efficiencies will be realised through GBNA rationalisation. This document provides the aviation industry of New Zealand with a strategy for the rationalisation of the GBNA infrastructure to support PBN.

A requirement of PBN use in domestic airspace is to have an alternate means of navigation, in order to recover IFR aircraft in the event of loss of GPS navigation capability. In the case of New Zealand, the *recovery* of aircraft will be enabled through conventional navigation using a GBNA network. The GBNA infrastructure that supports the recovery of aircraft will be known as the Minimum Operational Network (MON).

This Strategy also introduces a process for a collaborative approach to GBNA rationalisation, which includes the Ministry of Transport (MoT), Civil Aviation Authority (CAA), Airways (Air Navigation Services Provider (ANSP)), airports and operators; this process will be used to define the MON.

The NAANP identifies the need for a contingency network that enables air transport operations on the “main trunk”, as well as international operations into and out of these aerodromes. The main trunk is currently defined as flights between Auckland – Wellington – Christchurch this will be referred to as main trunk for the purposes of this strategy. The purpose of this contingency network is to provide social connections and economic benefits between these aerodromes in the event of short or long term loss of GPS navigation capability. The contingency network will be provided by a GBNA infrastructure that supports conventional IFR navigation between these aerodromes. In addition to the GBNA infrastructure required to meet recovery and contingency operations, the available GBNA infrastructure must consider national security and resilience needs.

MON development will be accomplished by the NSS Working Group (NSSWG) initiating a GBNA infrastructure review panel, including airport representatives and operators. The process for change must be established without delay. Terms of reference for the GBNA infrastructure review panel will be developed by the NSSWG. The panel will deliver a definition of the GBNA infrastructure required to provide a MON, a refined rationalization plan agreeing time frames for

[1] National Airspace and Air Navigation Plan, June 2014

decommissioning, replacement or installation of GBNA infrastructure as required and an agreed ‘business as usual’ process for managing future change.

1 Introduction

The National Airspace and Air Navigation Plan (NAANP) identifies Performance Based Navigation (PBN), based on the use of GNSS, as the means for modernisation of navigation in New Zealand, enabling safety, environment and economic benefits. With the implementation of PBN, it is important that the current Ground Based Navigation Aid (GBNA) infrastructure is reviewed for safety and efficiencies. These efficiencies will be realised through GBNA rationalisation. This document provides the aviation industry of New Zealand with a strategy for the rationalisation of the GBNA infrastructure to support PBN.

The Strategy for rationalisation has been considered as follows:

ICAO document 9613[2] provides States with guidance for PBN implementation. This document provides a means to assess the navigation specifications that are best suited for implementation. It also identifies the options for infrastructure and the aircraft and pilot requirements to support these navigation specifications.

In accordance with the NAANP and the Global Navigation Satellite System (GNSS) Sole Means Report[3], New Zealand has opted to implement PBN based on the use of the GNSS technology. The New Zealand aviation system currently uses the United States Global Positioning System (GPS). GPS will provide the primary navigation capability to support Area Navigation (RNAV) and Required Navigation Performance (RNP). The transition to a full PBN environment is being delivered as part of the New Southern Sky (NSS) programme.

A requirement of PBN use in domestic airspace is to have an alternate means of navigation, in order to recover IFR aircraft in the event of loss of GPS navigation capability. In the case of New Zealand, the *recovery* of aircraft will be enabled through conventional navigation using a GBNA network. This enables PBN deployment across the whole of NZ, however when operating outside of GBNA coverage will drive requirements such as the need for a pre-planned recovery to an airfield served by a GBNA procedure or the ability to continue the flight under VFR conditions.

The need for Recovery Operations is an outcome of the establishment of Safety Criteria[4]. The need to meet these Safety Criteria will be a fundamental element of decisions regarding GBNA rationalisation. The GBNA infrastructure that supports the recovery of aircraft will be known as the Minimum Operational Network (MON). It continues to be the operator's responsibility to assess their

[2] ICAO Performance Based Navigation Doc 9613, issue 4
[3] 'The GNSS Sole Means Report', Civil Aviation Authority, NZ (2015) Issue 2.
[4] 'Establishment of Aviation System Safety Criteria', Navigatus Consulting, 2016, Page B-4

operations against PBN requirements, including the safe recovery of aircraft in the event of the loss of GPS navigation capability.

This Strategy also introduces a process for a collaborative approach to decision making in regard to GBNA rationalisation, which includes MoT, CAA, ANSP, airports and both commercial and private operators; this process will be used to define the MON.

A secondary benefit of the GBNA MON is that aircraft with an approved RNAV capability based on GBNA (DME/DME and DME/DME/IRU) may be able to continue operations or recover using PBN RNAV standards in the event of the loss of GPS navigation capability.

The NAANP identifies the need for a contingency network that enables air transport operations on the “main trunk”, as well as international operations into and out of these aerodromes. The main trunk is currently defined as flights between Auckland – Wellington – Christchurch this will be referred to as main trunk for the purposes of this strategy. The purpose of this contingency network is to provide social connections and economic benefits between these aerodromes in the event of short or long term loss of GPS navigation capability.

The contingency network will be provided by a GBNA infrastructure that supports conventional IFR navigation between these aerodromes. There may be a secondary benefit of the contingency network in that it enables PBN RNAV operations, based upon the coverage provided by DMEs.

Where the MON and contingency infrastructure provide for ground based RNAV operations, this will retain the safety, environmental and economic benefits provided by PBN. The rationalised GBNA infrastructure may also enable a significant proportion of operations to continue between regional controlled aerodromes using conventional IFR navigation.

Rationalisation of the GBNA infrastructure may allow for optimisation of conventional navigation ATS routes and instrument flight procedures. Operators will also need to consider this in their operational planning.

This Strategy considers the above with respect to the GBNA infrastructure today. Future infrastructure changes will be considered from the perspective of safety in developing the MON and the needs of the contingency network. Changes to the GBNA infrastructure will follow the same collaborative decision making process. This Strategy requires the development of a plan to manage GBNA rationalisation.

2 Scope

This Strategy describes the requirements for a GBNA infrastructure needed to support PBN operations in the New Zealand domestic FIR. In addition, this Strategy also considers the relevant recommendations of the GNSS Sole Means Report[5], Conditions for the use of PBN (GPS) segments outside the coverage of a GBNA and Safety Criteria[6] which have a dependency on a rationalised GBNA network.

The primary navigation capability for all IFR operations is PBN based on GNSS. ICAO PBN guidance and the Aviation System Safety Criteria have determined a need for a GBNA infrastructure to support safe operations in the event of a failure of GNSS navigation capability. The GBNA infrastructure is detailed in this Strategy as the requirements for a MON and any additional requirements to support contingency operations on the main trunk.

The Strategy provides a process for the rationalisation of conventional navigation aids. There may be GBNA that are not required to meet the safety requirements of the MON and the process needs to enable this assessment.

For the purposes of the Strategy, GBNA infrastructure is considered to be the NDB, VOR and DME installations in New Zealand that are operated under Part 171.

In addition to aviation safety, a focus has been placed on the main trunk routes as they have the highest concentration of passenger traffic and therefore potential for significant disruption to social connections and impact on the New Zealand economy.

[5] 'The GNSS Sole Means Report', Civil Aviation Authority, New Zealand (2015) Issue 2.

[6] 'Establishment of Aviation System Safety Criteria', Navigatus Consulting, 2016, Page B-4

2.1 In scope

For clarification, the following have been considered in scope in the development of this strategy:

- NDB, VOR and DME installations
- National Security and Resilience (NSR) requirements
- MON
- Contingency Operations on the main trunk, as defined in section 1.
- All IFR flights within the New Zealand Domestic FIR including arrival and departure phases of international flights

2.2 Out of scope

For clarification, the following have been considered out of scope in the development of this strategy:

- ILS installations (except their continued existence as noted)
- Remotely Piloted Aircraft Systems (RPAS) operating IFR
- any detailed assessment of any reduction in GBNA coverage due to “line-of-sight” issues associated with low flight levels and terrain
- VFR operations

Note: Assessment of “line-of-sight” issues will form part of the review panel’s task when identifying the MON.

2.3 Objectives

The Strategy will:

a) Develop a process for the rationalisation of GBNA. This will optimise the GBNA infrastructure required to facilitate the implementation of PBN in New Zealand.

b) Ensure that a suitable conventional GBNA infrastructure exists that can support Recovery Operations[7] for IFR users in the event of the loss of GNSS navigation capability. This capability has been defined as a MON.

c) Meet relevant Safety Criteria and any associated conditions.

d) Take account of social connections and the economy of New Zealand. This will ensure that a suitable conventional ground based navigation aid infrastructure exists that can support Contingency Operations[8] for air transport operations on the main trunk in the event of a prolonged loss of GNSS navigation capability.

e) Encourage airspace users to equip with a PBN capability.

f) Be consistent with the proposed ICAO Annex 10 Volume I Attachment H"Strategy for rationalization of conventional radio navigation aids and evolution toward supporting performance based navigation", effective November 2016.

g) Maintain global interoperability.

h) Maintain flexibility; as the aviation system changes the Strategy will remain dynamic ensuring optimisation of GBNA without maintaining unnecessary infrastructure.

i) Provide guidance for the removal, replacement, installation or retention of conventional navigation aids that are not part of the MON and are not required for Contingency Operations.

j) Enable stakeholder engagement in the change process.

[7] 'Establishment of Aviation System Safety Criteria', Navigatus Consulting, 2016, Page B-4

[8] 'Establishment of Aviation System Safety Criteria', Navigatus Consulting, 2016, Page B-4

2.4 Benefits

The following benefits are delivered by this Strategy:

a) A reduction in operating costs from a reduction in GBNA.

b) A reduction in ‘conventional’ ATS routes and instrument flight procedures may provide additional cost savings through reduced cyclic maintenance.

c) Greater confidence in infrastructure planning, as this paper will provide evidence that the GBNA structure outlined in the NAANP (a VOR at every controlled airport) will adequately support Recovery and Contingency Operations.

d) A collaborative process for GBNA rationalisation which ensures that all stakeholders have awareness of proposed changes and their impact.

3 Navigation in New Zealand

IFR operators in New Zealand currently navigate using several methods, including conventional means, GPS IFR and PBN.

Conventional means relies entirely on a network of GBNA to allow IFR aircraft to operate safely. In New Zealand, this can be a combination of NDB and VOR GBNA providing tracking information. At times VOR and NDB installations are supplemented by DME which can provide along track distance and the ability to fly fixed distance 'arcs'. These navigation aids are used by pilots to navigate along fixed routes directly between navigation aids (enroute navigation) and to make instrument approaches, arrivals and departures at aerodromes.

GPS based RNAV can be described as the use of GPS to provide an area navigation capability to conduct enroute navigation that is not defined by GBNA. It is also used to conduct GNSS instrument approaches, arrivals and departures.

PBN is a means of area navigation that has defined performance criteria allowing for enhanced safety and efficiency. PBN is applicable to all phases of flight. In the future, the primary means of navigation for IFR operations in New Zealand will be PBN based on GNSS (in effect GPS). Both enroute airway structures and instrument procedures will be optimised to take full advantage of PBN.

PBN implementation based on GPS is not without challenges. GPS is known to be susceptible to a number of issues that need to be taken into consideration when assessing its use for navigation. These issues include unintentional interference, intentional interference (jamming), spoofing, ionospheric scintillation, on-board equipment failure and GPS system issues. Although for individual flights the likelihood of these issues affecting navigation can be considered to be remote, they do mean that GPS may only be used as a primary means navigation system in conjunction with additional independent navigation capability. Therefore there is a need to provide a GBNA network to ensure continuity of navigation. The GBNA infrastructure will be optimised to support Recovery and Contingency Operations and not all IFR operations will be achievable using conventional means; e.g. some aerodromes will have PBN procedures only, as Masterton and Wanaka do currently.

Whilst some conventional means navigation capability will remain and will be available to be utilised for conventional IFR operations, it is important to note that this will be as a secondary effect of an optimised GBNA infrastructure which is primarily designed to support PBN.

3.1 Performance Based Navigation

PBN in New Zealand will be primarily based on GNSS, provided by the GPS constellation. PBN will provide for IFR operations throughout the Domestic FIR both within and outside the coverage of the remaining GBNA infrastructure.

There are two types of navigation performance specifications in PBN, RNAV and RNP. The key difference between RNAV and RNP is that RNP requires on-board performance monitoring and alerting so that the pilot is notified early of any reduced satellite coverage or navigation uncertainty. A GNSS with Receiver Autonomous Integrity Monitoring (RAIM) meets the required standards for RNP. In the context of NZ, to support PBN operations outside of GBNA coverage and future ADS-B surveillance service, GNSS receivers will require Fault Detection and Exclusion (FDE).

New Zealand is planned to adopt the following standards for IFR operations in the Domestic FIR:

- RNAV2 for enroute operations where there is ATC surveillance service
- RNAV1 for terminal operations (SID/STAR) where there is ATC surveillance service
- RNP2 for enroute operations without ATC surveillance service
- RNP1 for terminal operations (SID/STAR) without ATC surveillance service or where partial surveillance service is provided (i.e. not 24/7)
- RNP APCH (labelled RNAV (GNSS)) for instrument approach procedures

Note: Approach with vertical guidance based on Barometric Vertical Navigation (Baro-VNAV) criteria will be included on instrument approach procedures at airfields served by public transport aircraft capable of utilising this.

3.2 Recovery Operations

As discussed above, within the NZ FIR, GPS does not meet the continuity requirements for a navigation solution and therefore a GBNA infrastructure will remain in New Zealand to enable safe recovery. *See section 5*, for the process for determining the MON infrastructure.

The need for safe recovery requires that for all phases of flight an aircraft operator must have a pre-planned response to support safe navigation in the event of a failure of GPS navigation capability. The pre-planned response to a failure of GPS will take many forms dependent on operational needs and capability; the following are two possible examples:

- Operating Auckland to New Plymouth on RNAV2 airway Y244, the flight is within coverage of VOR and can plan to continue to New Plymouth for an instrument approach based on VOR.
- On approach to Masterton flying an RNAV (GNSS) approach to runway 06, climb tracking 055 degrees using dead reckoning based on forecast winds until above 25nm MSA sector altitude of 5,200’ at which stage aircraft should be within GBNA coverage. Divert using conventional navigation to an aerodrome served by a conventional instrument approach.

In particular, where the flight is operating based on GNSS outside the coverage of GBNA for some portion of the flight, the pre-planned response will need to include an extraction procedure to recover the aircraft to an area/altitude where it is possible to continue based on conventional navigation. Extraction procedures would be required during any phase of flight when below the relevant MSA (SID, STAR, Approach, Missed Approach and Holding) and any enroute phase when operating below the transition level.

Note: For cruise above the transition level, all flights will be within coverage of VORs. VORs will remain at all controlled aerodromes and as loss of GNSS navigation capability may result in a requirement to obtain a revised clearance to track via GBNA to destination or a suitable diversion aerodrome. (See coverage diagram below)

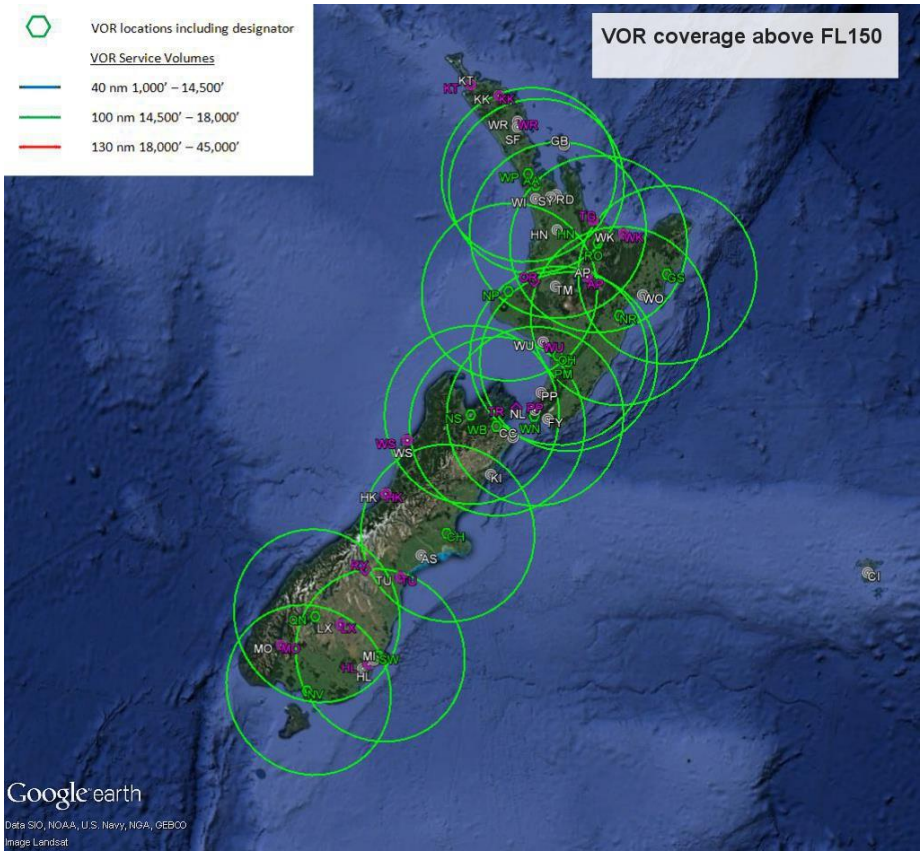


Figure 1. VOR coverage above 15000' in NZ

All extraction procedures should consider the following, including but not limited to:

- advise Air Traffic Control (ATC) when in controlled airspace. Outside of controlled airspace, advise Flight Information Service (FIS) on the appropriate radio frequency (Note: ATC/FIS may or may not be able to provide guidance).
- forecast weather conditions, in particular; cloud base, visibility and wind
- sufficient fuel for suitable destination in addition to mandatory reserves
- the suitable destination must allow the aircraft to land independent of GPS
- performance capability of aircraft
- heading system (compass as a minimum including any magnetic variation corrections)
- knowledge of terrain from GPS independent source (e.g. charts)
- knowledge of GBNA infrastructure
- knowledge of airspace and other users
- if required, make a distress or urgency call
- Minimum Equipment List (MEL) limitations

3.3 Contingency Operations

In addition to the safety focussed requirements of Recovery Operations, there is a need to take account of social connections and the effect on the New Zealand economy. This approach ensures that a suitable GBNA infrastructure exists that can support Contingency Operations.

Contingency Operations define the need to continue scheduled air transport operations operating on the main trunk in the event of a prolonged loss of GPS navigation capability.

All scheduled air transport aircraft are capable of conventional means navigation with reference to VOR installations. VOR installations will continue to be supported as part of the optimised GBNA infrastructure.

However, some air transport category aircraft are not equipped with ADF and therefore cannot navigate with reference to NDB installations. This is an important distinction between the VOR and NDB networks.

In addition, a significant proportion of air transport category aircraft are capable of continuing to fly PBN based on DME/DME and DME/DME/IRU.

This capability is dependent on DME coverage and these aircraft may be able to continue to operate RNAV2 enroute and RNAV1 terminal without GPS. The PBN manual[9] and existing RNAV approvals provide for this mode of operation.

PBN (RNAV – based upon GBNA) capability is a secondary effect of the existence of the optimised GBNA infrastructure needed to support Contingency Operations.

3.3.1 Conventional navigation

VOR installations will be maintained at controlled aerodromes, this will enable all scheduled air transport operations on the main trunk. These operations will be less efficient, with increased track mileage due to indirect routes and less optimised altitudes due to ATC separation requirements.

GBNAs will also allow for a significant level of flight operations between other aerodromes, this is however a secondary effect of the GBNA required for Contingency Operations.

3.3.2 PBN RNAV operations (secondary effect)

The PBN manual[10] has criteria which allow for both RNAV1 and RNAV2 operations using DME/DME and DME/DME/IRU. Suitably equipped and approved aircraft may be able to continue to operate in a PBN environment without GNSS. This would retain the safety and efficiency benefits of PBN if the Air Traffic Management (ATM) system can support mixed mode operations of PBN and conventional means navigation. This PBN capability is a secondary effect of the existence of the optimised GBNA infrastructure needed to support Contingency Operations.

[9] ICAO Doc 9613
[10] ICAO Doc 9613

4 Current GBNA infrastructure

Conventional navigation in New Zealand has traditionally relied on a combination of ground based installations that include the VOR, NDB and DME networks. These are identified individually in Table 1 and shown in Figure 2.

The main drivers for optimisation of GBNA infrastructure are the implementation of PBN and aging GBNAs. The GBNA infrastructure needs to move from enabling conventional navigation to supporting PBN.

The 3 networks (NDB, VOR and DME) that make up the GBNA infrastructure have different applicability in a PBN environment. These are described as follows:

4.1 VOR

- VORs do not support any of the PBN navigation specifications planned for use in New Zealand
- the VOR network provides a suitable recovery capability and can provide for Contingency Operations
- for enroute operations, the coverage provided by the current VOR network is almost seamless above 15000’
- VOR supports conventional SIDs and STARs
- VORs support non-precision approaches

4.2 NDB

- NDBs do not support any PBN operations, the NDB network has become redundant and serves only a very limited role in supporting some IFR users

4.3 DME

- DME/DME supports PBN operations, RNAV2 enroute and RNAV1 terminal without GPS for suitably equipped aircraft
- a secondary effect of the DME network is to support the use of PBN in Contingency Operations
- RNAV2 can be achieved on the main trunk with DME/DME updating utilising the current DME network

Note: Many DME installations are co-located with NDBs and VORs. Careful consideration will need to be given to the reduction in NDB/DME sites and the risk to benefits in removing both NDB and DME installations.

4.4 NAANP considerations

The ability to conduct a non-precision approach will be retained at all controlled aerodromes. With the exception of Tauranga (NDB/DME), this requirement will be met by VOR/DME installations. As described above NDB does not support PBN and consideration should be given to upgrading Tauranga to a VOR/DME installation.

4.5 GBNA installations

List of current NZ Ground Based Navigation Aids (GBNA)

NDB/DMEs	NDBs	DMEs	VOR/DMEs
Alexandra (LX)	Ashburton (AS)	Mt Mary (RY)	Auckland (AA)
Henley (HL)	Berridale (BE)	Ohura (OR)	Christchurch (CH)
Hokitika (HK)	Cape Campbell (CC)	Tory (TR)	Gisborne (GS)
Kaitaia (KT)	Chatham Islands (CI)		Hamilton (HN)
KeriKeri (KK)	Ferry (FY)		Invercargill (NV)
Manapouri (MO)	Great Barrier (GB)		Napier (NR)
Paraparaumu (PP)	Hamilton (HN)		Nelson (NS)
Taupo (AP)	Kaikoura (KI)		New Plymouth (NP)
Tauranga (TG)	Miranda (RD)		Ohakea (OH)
Timaru (TU)	Mosgiel (MI)		Palmerston North (PM)
Westport (WS)	Newlands (NL)		Queenstown (QN)
Whakatane (WK)	Springfield (SF)		Rotorua (RO)
Whanganui (WU)	Surrey (SY)		Swampy (SW)
Whangarei (WR)	Taumaranui(TM)		Wellington (WN)
	Waiuku (WI)		Whenuapai (WP)
	Wairoa (WO)		Woodbourne (WB)

Legend	
	Operational and owned by Airways
	Whenuapai and Ohakea operational and owned by RNZAF
	Operational and owned by Chatham Islands
	Wairoa NDB is to be withdrawn 10 Nov 2016

Table 1: NZ Conventional Navigation Infrastructure

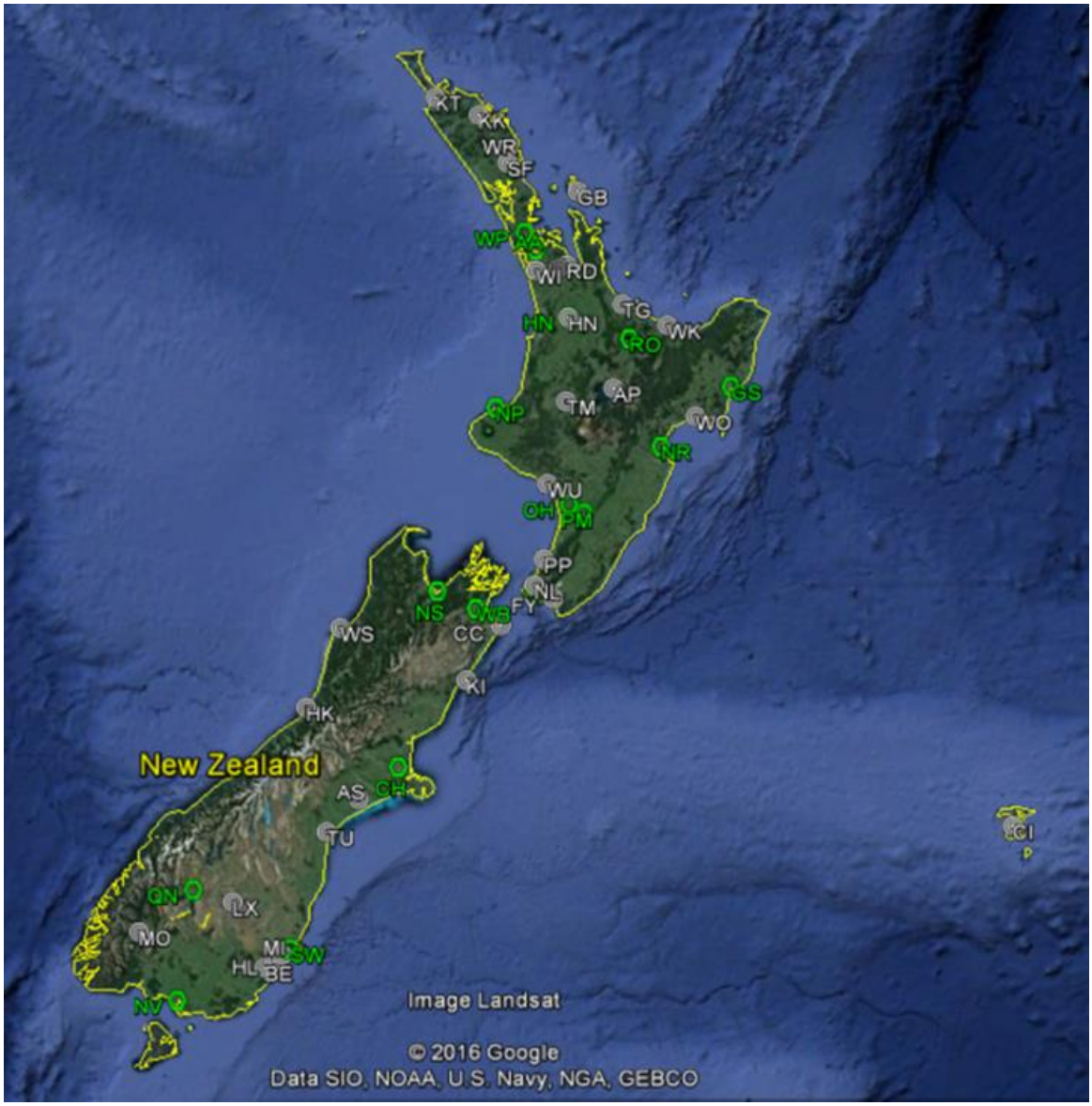


Figure 2: VOR and NDB locations

5 Minimum Operation Network - Recovery Operations

The MON is described in the Safety Criteria[11]. The MON is the minimum GBNA infrastructure necessary to support safe Recovery Operations. Recovery Operations are required whenever there is a loss of GPS navigation capability. In the New Zealand context, this is primarily based on the existence of coverage provided by GBNA. In regions outside GBNA coverage, a pre-planned extraction procedure is required to allow a safe transition of the aircraft from GNSS to another navigation system.

The current structure (*see section 4*) provides a starting point for the evolution to a MON. Rationalisation of the existing GBNA infrastructure to one that supports PBN operations will be conducted in accordance with this Strategy and in particular the change process defined in section 9.

Note: There will be other criteria that influence the GBNA infrastructure that remains such as Defence, NSR and IFR training needs; however the fundamental determinant is the ability to provide safe recovery of aircraft.

5.1 Safety criteria related to MON

The Safety Criteria Report[12] contains a number of criteria relevant to the development of a MON, these are summarised below:

- GBNA will exist at all 17 controlled aerodromes with associated instrument approach (in addition to ILS where applicable), arrival and departure procedures. Where practicable these should exist for each runway end. Currently, 16 of these aerodromes have VOR/DME installations, with the exception of Tauranga which is served by NDB/DME.
- All IFR aircraft are to be equipped with non-GNSS navigation capability sufficient to allow safe navigation to an appropriate recovery aerodrome following the loss of GNSS navigation capability.
- Aircraft flying outside of GBNA coverage are to be able to continue safe flight in order to re-establish their navigation capability following loss of GNSS navigation.

[11] 'Establishment of Aviation System Safety Criteria', Navigatus Consulting, 2016, Page B-4

[12] 'Establishment of Aviation System Safety Criteria', Navigatus Consulting, 2016, Page B-4

The Safety Criteria[13] was based upon a number of agreed assumptions, some of these must also be considered as part of a GBNA Strategy and they are described here.

- ILS installations will be retained at those aerodromes where it is currently fitted (Auckland, Christchurch, Ohakea, Wellington and Dunedin).
- The primary navigation capability for all IFR operations is PBN employing GNSS.
- The only alternative navigation capability available to most users will be conventional navigation utilising GBNAs.
- The current VOR/DME infrastructure may be sufficient to retain RNAV capability in some regions for suitably equipped aircraft operating using DME/DME and DME/DME/IRU.

5.2 Conditions for the use of GNSS based segments outside the coverage of GBNA relevant to the MON

When an IFR flight is operating utilising GNSS for some portion of its flight outside of the coverage of GBNA, the flight will be subject to a number of conditions to ensure safety can be maintained in the event of any loss of GNSS navigation capability. These conditions require that a pre-planned response be developed which will include an extraction procedure to recover the aircraft to an area/altitude where it is possible to continue based on conventional navigation. The considerations for developing extraction procedures were discussed in section 3.2.

Note: Air Transport Operations will require CAA approval for their proposed responses to meet the conditions associated with utilising GNSS outside the coverage of GBNA.

The requirement that all IFR flights are capable of developing a safe extraction procedure that allows them to recover to an aerodrome served by GBNA is one of the key drivers to be used in defining the MON.

[13] 'Establishment of Aviation System Safety Criteria', Navigatus Consulting, 2016, Page B-4

5.3 Recovery Operations – Conventional GBNA navigation

The following sections describe how Recovery Operations may be achieved using conventional GBNA navigation.

5.3.1 Enroute

All enroute operations remaining above the transition level (FL150) can utilise the GBNA that are installed at controlled aerodromes. This infrastructure provides complete coverage to all aerodromes except in the region of Kaitaia. (*See* Figure 1) and therefore no specific Recovery Operations are required.

For enroute operations below the transition level, a MON based solely on the GBNA at controlled aerodromes will not always provide coverage and an extraction procedure may be required. For example, a flight from New Plymouth to Nelson operating at 8,000', on the standard route H499 MEVAX H438, is likely to leave coverage of the New Plymouth VOR before it is in range of Nelson VOR. One option for this flight would be to plan to continue on a heading determined at flight planning (dead reckoning) until within coverage of the Nelson VOR. In a different example, it might be appropriate to divert off the planned track to attain coverage of a GBNA.

5.3.2 Terminal (Departure/Arrival) and approach

At aerodromes served by PBN procedures only, e.g. Wanaka, Greymouth and Masterton, an IFR flight will need to evaluate the coverage provided by other GBNA and have a planned response to any loss of GNSS navigation capability. This is especially important for phases of the flight when the aircraft will be operating below the relevant Minimum Safe Altitude (MSA). An extraction procedure will be required to allow the IFR flight to safely get above terrain and also attain coverage from GBNA. In many cases this will require some form of dead reckoning and may replicate the track of the missed approach or another track away from terrain.

Note: Operating with weather conditions that assure the ability to continue an approach visually may be an acceptable “extraction”.

The above mentioned flight will also need to ensure that appropriate fuel is carried to allow flight to an aerodrome served by a conventional procedure with any required reserves.

5.3.3 International operations

The Board of Airline Representatives New Zealand (BARNZ) assisted in contacting foreign operators to discuss the need for NDB installations. Six airlines (LATAM Airlines, Air New Zealand, Emirates Airlines, Fiji Airways, Qantas and Singapore Airlines) responded and they have all confirmed that NDB does not have a role to play in their recovery or contingency operations.

A number of jet aircraft are not equipped with ADF.

Recovery Operations for these aircraft will be a combination of PBN based on GBNA *(see section 5.4)*, VOR terminal procedures and VOR or ILS approaches and terminal procedures at destinations and alternates.

5.4 Recovery Operations - PBN RNAV

The following describes how Recovery Operations may be achieved by means of PBN. A number of aircraft have the capability and approval to conduct some PBN operations utilising DME/DME or DME/DME/IRU, currently these are to both RNAV1 and RNAV2 standards. A PBN enabled Recovery Operation would retain some efficiency and safety benefits. These RNAV operations will need to be considered with Surveillance service in mind, or an appropriate safety case.

5.4.1 Enroute

Airways in New Zealand that have a surveillance service provided will be designed and published as RNAV2. When operating on these airways, the loss of GNSS navigation will not restrict suitably equipped aircraft from continuing on the planned route so long as there is sufficient DME coverage. The anticipated coverage for DME/DME updating to an RNAV2 standard is depicted in Figure 3.

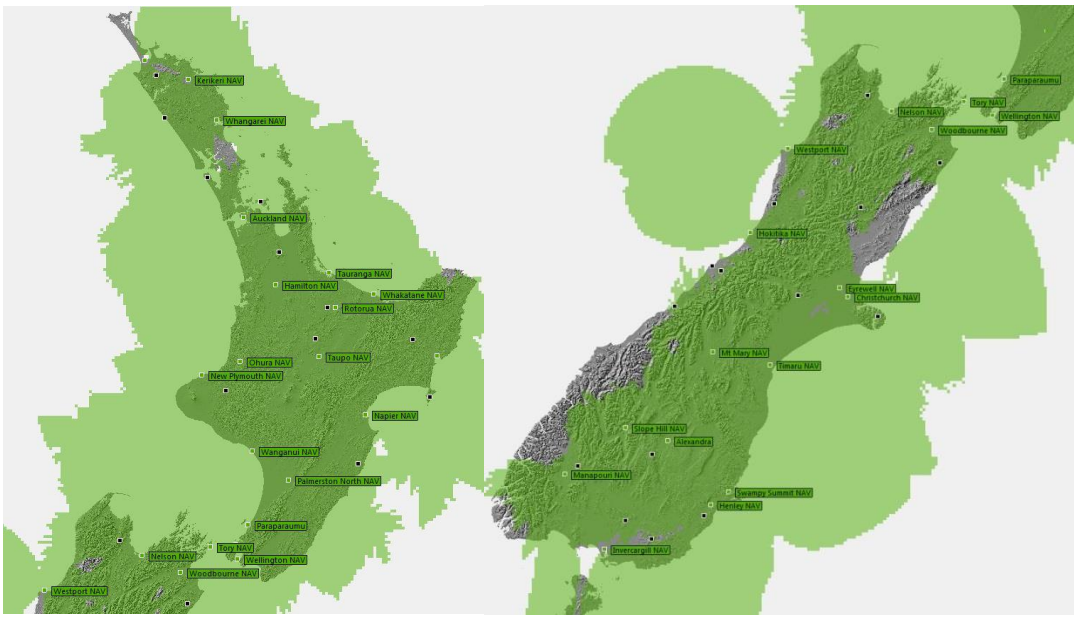


Figure 3: DME coverage on the North and South islands

DME/DME/IRU allows for the ability to “coast” between DME/DME updates using the IRU for navigation reference. This allows equipped aircraft an approved time between updates and therefore has the effect of extending PBN capability beyond the DME/DME coverage depicted.

5.4.2 Terminal (Departure/Arrival)

At some aerodromes where DME/DME updating coverage exists, suitably equipped aircraft can maintain RNAV1 capability. If RNAV1 SIDs and STARs are published for that aerodrome, they could be flown.

5.4.3 Approach

There are no PBN navigation specifications for approach that are independent of GNSS, so the conventional applications stated above in section 5, will apply.

Note: IFR aircraft that do have PBN RNAV capability generally operate to controlled aerodromes and will therefore have a VOR based instrument approach available.

6 Contingency Operations

Contingency provides the surety for continued economic and social benefits in the event of loss of GPS navigation capability. The primary aim of a GBNA network is to provide both Recovery Operations and conventional means Contingency Operations to allow air transport operations to continue on the main trunk.

6.1 Contingency Operations - conventional navigation

The GBNA infrastructure at controlled aerodromes will be sufficient to support main trunk Contingency Operations. The following sections describe how Contingency Operations may be achieved using conventional navigation.

6.1.1 Enroute

There are currently several airways that can be used to transit between Auckland, Wellington and Christchurch. These are based on the use of existing published conventional airways tracking VOR to VOR, for example:

- AA H384 NP H252 NS H267 WN
- WN H267 NS H110 CH
- AA H384 NP H252 NS H110 CH

These routes are less efficient, but provide the contingency to support main trunk operations in both directions. Therefore in addition to any MON requirements, for Contingency Operations the AA, NP, WN, NS and CH VORs must be retained.

Efficiencies could be gained by an optimised enroute structure that published direct routes between Auckland, Wellington and Christchurch to be used in the event of loss of GPS navigation capability. These could be included in future editions of the AIP. For example:

- NZAA DCT AA H384 NP new airway1 WN DCT NZWN
- NZWN DCT WN new airway1 NP H384 AA DCT NZAA
- NZWN DCT WN new airway2 CH DCT NZCH
- NZCH DCY CH new airway2 WN DCT NZWN

Note:

1. new airway 1 defined as direct between NP and WN
2. new airway 2 is defined as direct between WN and CH replacing H221 which overheads KI (Kaikoura).

Users may be required to operate at suboptimal flight levels to ensure ATC separation on conventional routes.

It is expected that the majority of air transport traffic on the main trunk can be sustained by flying these routes.

6.1.2 Terminal (Departure/Arrival)

Conventional SIDS and STARS exist and must be retained at AUCKLAND, Wellington, and Christchurch. These procedures must connect to the enroute conventional network.

6.1.3 Approach

ILS approaches will be retained at those aerodromes where it is currently fitted, (Auckland, Christchurch, Ohakea, Wellington and Dunedin) these will support main trunk operations as precision approaches for destinations and some alternate aerodromes.

VOR/DME approaches to both runway ends will be maintained at all main trunk aerodromes. These conventional procedures meet the requirements for Contingency Operations. This ensures that a straight-in approach, and its associated safety benefits, will be available in all but the most severe meteorological conditions.

6.1.4 International Operations

International operations into main trunk aerodromes will operate using conventional procedures as referred to in section 6.1.2 and 6.1.3.

ATC will need to develop processes to ensure connectivity from international airways to connect SIDs and STARs at main trunk aerodromes.

Diversion to an alternate aerodrome will be in accordance with 6.1.

6.2 Contingency Operations - PBN RNAV

As discussed in section 5.4, RNAV2 and RNAV1 can be supported by suitably equipped users (DME/DME or DME/DME/IRU). Several air transport operators already have this capability including Jetstar, Air New Zealand, Air Nelson and Mt Cook.

6.2.1 Enroute

Domestic RNAV2 routes are currently available to non-GNSS equipped aircraft and this will continue to provide PBN RNAV Contingency Operations,

for example: Auckland to Wellington(Y127,Y277) and Wellington to Christchurch(Y393)

6.2.2 Terminal (Departure/Arrival)

At main trunk aerodromes, if DME/DME updating coverage exists, suitably equipped aircraft can maintain RNAV1 capability. RNAV1 SIDs and STARs that are published for that aerodrome could be flown.

An evaluation needs to be completed to establish the capability to retain RNAV1 with current infrastructure for suitably equipped DME/DME and DME/DME/IRU operators.

6.2.3 Approach

There are no PBN navigation specifications for approach that are independent of GNSS, so the conventional applications stated above in section 6.1.3 will apply.

7 Operator considerations

This section discusses criteria that each type of operator would need to consider in their individual operations.

7.1 General aviation IFR

General aviation operators will have some additional considerations. These include having pre-planned extraction procedures whenever their flight contains GNSS based segments outside the coverage of GBNA, appropriate pilot training and approvals for PBN operations and ensuring fuel requirements to divert to a suitable aerodrome with conventional infrastructure are met.

Those general aviation IFR users choosing to operate via conventional means will need to assess the benefits of GPS equipage in light of any reduction in conventional GBNA infrastructure.

7.2 Transport operations

Air transport operations need to consider their specific operations, relevant equipage and route. Relevant equipage such as dual on-board navigation aids for dispatch as well as DME/DME or DME/DME/IRU which may provide continuity of service in the event of a loss of GPS navigation capability.

Air Transport operations will need to ensure flight crew are appropriately trained in the procedures that have been developed and approved by the CAA to meet the conditions associated with operating on GNSS based segments outside the coverage of GBNA. These procedures will need to be published in appropriate exposition manuals, e.g. Route Guide.

7.3 Training operations

It is anticipated that several aging NDBs will require investment decisions in 2018 increasing to 2023. It is likely that sufficient NDBs will remain for flight training in the short to mid-term. Provision for flight training will need to be assessed in any case for removal or replacement. This assessment must include engagement with training users.

7.4 National Security & Resilience (NSR)

In addition to the GBNA infrastructure required to meet recovery and contingency operations, the available GBNA infrastructure must consider NSR needs. Considerations include but are not limited to the following:

7.4.1 Lifeline

Lifelines are the essential services that support our community. They are identified by the Ministry of Civil Defence & Emergency Management and include transportation network links, aerodromes and other basic infrastructure. An objective of Lifeline organisations is to ensure outages to services and restoration times are both minimised.

A number of organisations operate Lifeline flights providing emergency and non-emergency medical transportation.

These organisations need to be considered to ensure that lifeline services continue to operate day to day and in times of disaster.

7.4.2 State

Police and other state aircraft operate missions within the New Zealand domestic FIR. Some of these missions may be IFR flights and it needs to be understood whether or not there any additional requirements for this sector that are not already captured by section 7.1.

7.4.3 Defence

The Defence Force has already identified that there may be requirements for retention of GBNA to support some of their regular aircraft operations. In particular Kaikoura and Taumaranui (or alternatives) may be required to provide enroute coverage to support military flight operations.

7.4.4 ICAO Air Navigation Plan

Hokitika and Kaitaia NDBs are included within the ICAO Air Navigation Plan (ANP) as a requirement for international navigation to New Zealand.

Hokitika is listed in the ANP as a required international navigation aid, however there is currently no international airway utilising the Hokitika NDB. Kaitaia NDB is listed as part of the definition of international airway G591.

Regardless of other considerations these GBNA must be retained until such time that they are no longer required by the ANP. Continued inclusion in the ANP should be considered by the CAA and changes to the ANP requested if deemed appropriate.

8 Optimisation of routes and procedures

This Strategy describes a GBNA infrastructure that will be optimised to support PBN based on GNSS. That infrastructure will result in the optimisation of enroute airways and connected terminal and instrument approach procedures.

8.1 PBN plan

The PBN plan states that an RNAV (GNSS) instrument approach will be designed and published for every IFR runway end, where practicable. These procedures must be published prior to any GBNA being removed from that aerodrome.

Where an air transport operation occurs with aircraft capable of Baro-VNAV then the procedures will be designed and published with both LNAV only and LNAV/VNAV minima.

PBN arrival and departure procedures will also be published for each IFR aerodrome.

8.2 Instrument procedure optimisation

Where a GBNA is retained at an aerodrome for recovery and/or contingency purposes there must be conventional instrument approach procedures published for each runway end, where practicable. This will enable approaches in all but the most severe meteorological conditions.

In accordance with the Aviation System Safety Criteria these procedures should be straight-in approaches wherever possible as there are significant safety benefits associated with straight-in approaches.

Arrival and departure procedures will be published based on the GBNA at the aerodrome. As these procedures are provided for Recovery and/or Contingency Operations, then it is expected that the number of procedures available may be able to be rationalised. This may impact efficiency if the procedures are actually used but may reduce maintenance costs.

8.3 Enroute airways

PBN RNAV2 airways will be promulgated to support IFR flights. This will allow for optimisation of existing enroute airways designed using GBNA.

For contingency operations, enroute airways based on GBNA will be promulgated for the main trunk routes.

Where GBNA are retained for recovery and/or contingency operations, consideration should be given to promulgation (charted or not) of enroute

airways between these navaids. This will assist in providing safe recovery operations through the calculation of route MSA.

9 Changes to the GBNA infrastructure

This Strategy outlines the requirements for a GBNA infrastructure to provide a MON which ensures the safe recovery of aircraft in a PBN environment (*see section 3.2*) and a GBNA infrastructure that will support main trunk contingency operations in the event of the loss of GNSS navigation capability supporting PBN operations in a short to long term outage *(see section 3.3).*

The development of the MON will be through a collaborative approach, taking account of operational and safety needs, ANSP considerations, airport needs CAA regulatory requirements and the MoT from a national security and resilience perspective. This will be accomplished by the NSS Working Group (NSSWG) initiating a GBNA infrastructure review panel. The process for change must be established without delay. Terms of reference for the GBNA infrastructure review panel will be developed by the NSSWG.

The panel will deliver:

Stage 1

- A definition of the GBNA infrastructure required to provide a MON.
- A refined rationalization plan agreeing time frames for decommissioning, replacement or installation of GBNA infrastructure as required.

Stage 2

- An agreed “business as usual” process for managing future change.

The GBNA infrastructure to support Contingency Operations are clearly defined in this strategy; however any changes proposed by MON development that affect the contingency infrastructure will also need to be considered by the GBNA infrastructure review panel.

The MON and contingency requirements will be considered side by side in order to gain efficiencies in both networks, utilising infrastructure that can be used for both purposes wherever possible.

The strategy for managing change is presented in the following subsections.

9.1 Process for change

Changes to the current GBNA Infrastructure will follow a two stage process which builds on the existing process managed by Airways. This process will be based on a specific value proposition that will provide a lens through which change will be managed and considered. This value proposition considers the needs of all stakeholders and comprises:

A transparent process. A transparent process will be enabled by using the current NSSWG structure to establish the GBNA infrastructure review panel.

All relevant operators involved. The GBNA infrastructure review panel will endeavour, as far as is practicable, that all of the relevant operators, stakeholders and affected parties are informed and involved.

National Security & Resilience. National security and resilience input from the paper entitled 'Maintaining security and resilience in New Zealand's modernised aviation system' will be an input for consideration.

Safety. The GBNA infrastructure must continue to provide safe IFR operations.

Conditions for the use of GNSS based segments outside the coverage of GBNA. The ability of the GBNA infrastructure to support the conditions described in the GNSS sole means recommendation report will be included.

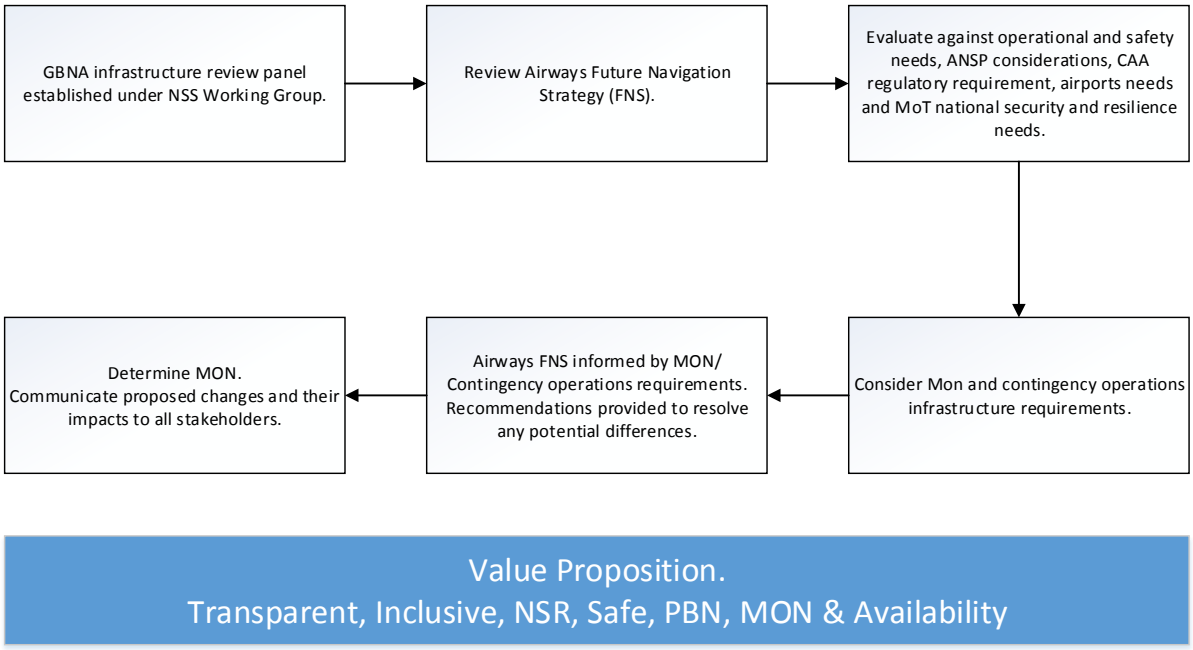
Minimum operating network (MON). The existence of a MON sufficient to support PBN operations.

Navaid availability. The impact of planned temporary unavailability of navaids on the MON and contingency operations must be considered and effectively managed.

9.1.1 Stage 1 – Determine the MON

The Airways Future Navigation Strategy (FNS) dated 06 December 2013 outlines the GBNA Infrastructure changes that are proposed to be made between now and 2018. The GBNA infrastructure review panel will lead a review of this plan based on the value propositions discussed above to determine the MON and GBNA infrastructure to support contingency operations.

The Airways FNS and associated navaid decisions will be informed by the MON and the decisions of the review panel. The review panel will provide recommendations to resolve any potential differences.



9.1.2 Stage 1 – Agree a rationalization plan.

The GBNA infrastructure review panel will develop a rationalization plan that considers navaid life-cycles and the requirements of all other parties. The review panel will agree a timetable for rationalization of GBNA infrastructure.

9.1.3 Stage 2 – The Continual Change Environment

The nature of air navigation continues to change and the GBNA infrastructure will need to adapt. As multi-constellation GNSS and other technologies are deployed, the MON and the GBNA infrastructure to support contingency operations may require revision in response. The current infrastructure change regime is aligned to the 3 year Airways pricing review cycle. This

cycle will be maintained to provide confidence, stability and predictability to industry, however consideration should be given to establishing a longer term indicative view as was done in the Airways Future Navigation Strategy.

It is important that the value proposition is applied to all future GBNA infrastructure changes, permanent and temporary. The impact of proposed changes will be considered and communicated to affected stakeholders. The GBNA infrastructure review panel will be utilised to oversee planned and proposed navaid infrastructure changes until the agreed 'business as usual' process has been established.

10 Future navigation technologies

New Zealand continues to transition into a PBN environment. It is expected that this transition will be complete by 2021. The key technology selected in New Zealand for PBN is GNSS (GPS) supported by a ground based conventional navigation network enabling recovery in the event of a GPS loss.

NSS will continue to monitor technologies that support and enhance PBN further; the current focus is in this area is outlined below:

10.1 Satellite Based Augmentation System (SBAS)

NSS is currently assessing the viability of SBAS to support approaches with vertical guidance. The use of SBAS already exists in other ICAO states in a PBN environment. In other parts of the world the aviation technology to support SBAS exists today, comprising of geostationary satellites, ground monitoring and control stations, and airborne receivers. The airborne receivers are currently GNSS receivers with TSO-C145/146 functionality.

Status of SBAS adoption will be provided through the NSS programme.

10.2 GNSS multi-constellation

There are several GNSS constellations providing a navigation service today. Aviation standards are being developed for airborne systems that can utilise multiple constellations to provide navigation capability. NSS will continue to monitor progress of the development of these standards and availability of multi constellation GNSS equipment. The use of multi constellation GNSS may enable further review of the required GBNA infrastructure; this will require an assessment with respect of viability and safety.

10.3 Alternate Position and Navigation Timing (APNT)

ICAO States such as the USA and Europe are in the early stages of researching technology that would support PBN operations to a similar accuracy to GNSS. Currently the research is focused on ground based systems. NSS will monitor developments in this field. It is likely that this technology will be 10-15 years away from wide aviation use. Use of the technology developed under APNT may have an impact to GBNA infrastructure.