Performance Based Navigation (PBN) Operational End State 2023 – Document Status

Purpose

The New Southern Sky Working Group has expressed concern about some aspects of the PBN Operational End State document, and in particular whether the document represents a final policy position. This cover note clarifies the status of the document and explains the policy development process that will be employed

Document Status

The purpose of the PBN Operational End State 2023 is to provide a high-level 'Concept of Operations' for PBN operations in New Zealand as of 2023. It was designed to identify the system safety considerations, including safe recovery of aircraft in the event of GNSS failure. The document is also intended to be informative and to identify factors specific to the New Zealand operating environment.

It does not represent a final or agreed regulatory position, but rather a guide to a possible outcome of the PBN rules process and the navigation aspects which must be considered as part of this process.

Any future PBN-related requirements in Civil Aviation Rules will be subject to the normal rulemaking process, with the in-depth sector consultation and Ministerial oversight that entails.

Policy Development Process

The purpose of the PBN Regulatory Framework project is to develop policy to enable and support the safe and appropriate use of PBN in New Zealand's airspace. The results of the framework will include a range of outcomes, from amended guidance material to recommendations for Rule change.

In developing the regulatory framework, the CAA will be working closely with stakeholders to ensure that the impacts of possible changes are taken into account, and are part of advice given to decision-makers.

The PBN Operational End State 2023 document will assist in guiding the policy development process, but it is not binding and does not pre-judge the outcome of future work that is yet to be done. The CAA's focus will be on ensuring that the PBN Regulatory Framework creates a safe PBN environment that delivers the desired benefits, and this requires a robust, evidence-based policy development process to be followed. A key element of this is the appropriate balancing of safety risk against operational considerations.

Stakeholder involvement is essential to the policy development process, and the CAA will seek input at a number of stages, from the early formulation of policy options to formal consultation on Rule changes.

Performance Based Navigation Operational End-State 2023

A Regulatory View

Organisation	Civil Aviation Authority of New Zealand
Date of this Document	November 2018

Ministry of Transport
TE MANATŪ WAKA

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Regulatory view of Performance Based Navigation (PBN) - 2023

It is the intention for New Zealand to have a full Performance Based Navigation (PBN) environment in controlled and uncontrolled airspace by 2023[1]. The CAA is delivering a PBN Regulatory framework that will provide the necessary regulatory change to future proof existing Civil Aviation Rules (CAR), and cater for technological changes to the aviation system. Changes to the CARs will be developed through collaboration with industry (New Southern Sky Working Group) and the standard policy, rule and Notice of Proposed Rule Making (NPRM) process.

With the transition to a full PBN environment there are changes to the IFR operational requirements from a safety and systems perspective. This has an impact on training, operations, equipment and infrastructure. ***This document provides the Regulator's view of what the future PBN environment should look like in the New Zealand Domestic FIR by 2023 and should be viewed as a representative end status.***

[1] Deployment and use of ICAO PBN specifications based upon the United States Global Positioning System (GPS) navigation service as the primary means of navigation for Instrument Flight Rule navigation in the New Zealand Flight Information Region. This will not preclude IFR navigation based upon conventional ground based navigation aids, however conventional navigation operations will be limited, refer to section 5.

CONTENTS

ACRONYM	DESCRIPTION
ADS-B	Automatic Dependent Surveillance - Broadcast
A-RNP	Advanced Required Navigation Performance
ATC	Air Traffic Control – a sub-function of Air Traffic Service
ATD	Acceptable Technical Data
ATM	Air Traffic Management
ATS	Air Traffic Service – a sub-function of Air Traffic Management
Baro VNAV	Barometrical Vertical Navigation
CARs	Civil Aviation Rules
DME	Distance Measuring Equipment
FIR	Flight Information Region
FMS	Flight Management System
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
IMC	Instrument Meteorological Conditions
LNAV	Lateral Navigation
MEL	Minimum Equipment List
MON	Minimum Operational Network
NDB	Non Directional Beacon
NPRM	Notice of Proposed Rule Making
NSS	New Southern Sky
PBN	Performance Based Navigation
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP0.3 (H)	Required Navigation Performance 0.3 for Helicopters only
SBAS	Satellite Based Augmentation System
SSR	Secondary Surveillance Radar
TSO	Technical Standard Order
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VOR	VHF Omnidirectional Range. Ground based navigation aid

Performance Based Navigation 2023

1 PBN 2023

New Zealand will be operating in a fully operational Performance Based Navigation (PBN) environment by 2023[2]. PBN will be the primary means of navigation in the New Zealand Flight Information Region (FIR). This moves navigation away from conventional ground-based to satellite-based navigation means. General Aviation and Air Transport Instrument Flight Rule (IFR) operators will require PBN capability to take advantage of the safety and efficiency benefits provided through PBN specifications in enroute, terminal and approach phases of flight.

PBN will be based upon the United States Global Positioning System (GPS) navigation service[3]. The move towards a fully operational PBN environment will result in reduced ground-based conventional navigation infrastructure and associated procedures[4].

PBN operations are driven by a combination of national, operator and user benefits[5]. These are:

- Safety
  - Lateral Guidance
  - Vertical Guidance
  - A reduction in mixed mode operations (PBN/Conventional)
- Efficiency
- Environmental
- Societal

[2] Note that PBN is already deployed in controlled airspace, system changes are underway to enhance this capability and extend to uncontrolled airspace.

[3] There are other GNSS constellations in service, however an aviation standard for multiconstellation aircraft equipment is currently not available.

[4] Conventional navigation operations will reduce, but will not cease as they will be the means for safe recovery aircraft from loss of PBN (loss of GPS) as well as contingency operations (refer sections 3 and 4). Conventional IFR navigation operations are not excluded from the system, although they will be restrictive compared to today's conventional operations, refer to section 5.

[5] A description of PBN benefits can be found in the *New Zealand PBN Implementation Plan – Revised 2017*

There are two modes of operation required for safe operations in a full PBN operating environment. These are identified below and explained in sections 2 and 3 of this document

- **PBN Operations**
- **PBN Failure – safe recovery of aircraft**

With the dependency on the GPS constellation for PBN operations, the *New Zealand PBN Implementation Plan – Revised 2017* requires Air Transport operations to continue between Auckland, Wellington, and Christchurch in the event of loss of GPS service. This operation is identified below and explained in section 4 of this document

- **Contingency Operations – Continued IFR Air Transport operations upon long-term loss of PBN**

Although Civil Aviation Rules (CARs) already partially support PBN, they will be modernised to reflect current PBN practices, and future-proofed for ongoing advances in technology and procedures. Following analysis by CAA, consultation with the sector, and the Minister's approval, the necessary changes to the Rules framework will be in place by late 2022.

Performance Based Navigation Operations

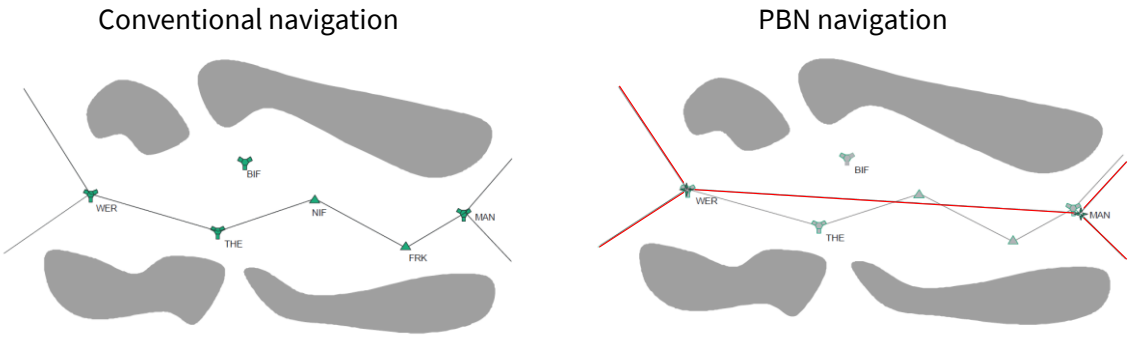
2 PBN Operations

PBN operations are based upon International Civil Aviation Organisation (ICAO) PBN specifications. There are two PBN specification types, Area Navigation (RNAV[6]) and Required Performance Navigation (RNP[7]). While New Zealand transitions to a full PBN environment there will be a mix of these specifications in use. During transition the ATS provider will consider the use of RNAV versus RNP procedures and how the existing and new users of the system continue to access the benefits of PBN[8]. However, by 2023, all PBN routes and procedures[9] will be based upon RNP specifications[10]. PBN procedures and airspace will be optimised to provide efficiency and connectivity across New Zealand.

PBN routes and procedures are not constrained by physical location of ground-based navigation aids, which provides the benefits outlined in section 1, and shown in

Figure 1.

Figure 1: Conventional versus PBN Navigation



6 RNAV enables area navigation which permits aircraft operation on any desired flight plan within the coverage of navigation aids or within the limits of self-contained aids.

7 RNP enables area navigation with an onboard system that supports on-board performance monitoring and alerting.

8 Note that during the transition to a full PBN environment not all aircraft will have RNP approvals.

9 Includes standard instrument departures, enroute, standard terminal arrivals, approach, and missed approach through RNP specifications, including use of Advanced-RNP, RNP0.3 (H) and RNP Authorisation Required specifications.

10 As NZ has opted to use GPS as the primary navigation source for PBN, all PBN users will have on-board monitoring and alerting which supports RNP and benefits operations. Consideration should be given to international operators that do not have RNP capability and are operating into NZ international airports.

PBN procedures will not be implemented based upon Distance Measuring Equipment (DME)/DME or DME/DME/Inertial means[11]. However, in the unlikely event of a long-term loss of GPS, some operators may be able to fly in certain phases of flight using this capability. This will require agreement between the CAA, ATS provider and operators on the deployment of procedures and validation of infrastructure. Refer to section 4.

PBN procedures have been implemented at controlled aerodromes and will be implemented at uncontrolled aerodromes where demand requires[12].

Through the application of PBN specifications:

- GPS provides lateral navigation (LNAV) for each of the procedures described above. Straight-in approaches where possible have been deployed, increasing approach safety[13].
- Approach with Vertical Navigation (VNAV) guidance has been implemented at aerodromes where practicable. This provides an increase in safety[14] in relation to stable approach criteria and separation from terrain. Vertical navigation requires a certified and approved barometric vertical navigation system[15].

Note: Operators with advisory[16] vertical guidance navigation capability are not permitted to conduct operations to published VNAV minima.

Note: New Zealand and Australia are assessing the viability of introducing Satellite Based Augmentation System (SBAS) to support PBN. SBAS will improve the vertical accuracy of GPS, enabling implementation of GPS/SBAS VNAV procedures. This VNAV capability can be utilised by a significant number of users with certified GPS/SBAS capability (TSO 145/146 GPS receivers) and training.

Aircraft operating PBN will be equipped with certified GPS[17] receiver(s) which are installed in accordance with acceptable technical data (ATD) (approved installation data).

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11 This was a decision supported by the New Southern Sky Working Group

12 Benefits should drive implementation of PBN at uncontrolled aerodromes, as well as consideration of medical services, national security and resilience.

13 Straight in approach is 25 times safer than circling approaches, ICAO A37-WP/148

14 VNAV approach provide an 8 times safety improvement than without vertical guidance, ICAO A37-WP/148

15 A BARO VNAV system is required as NZ does not have a Satellite Based Augmentation System (SBAS).

16 Advisory vertical guidance is only an aid provided by some manufacturers to help pilots meet altitude restrictions. It is the pilot's responsibility to use the barometric altimeter to ensure compliance with altitude restrictions, particularly during approach operations. Advisory vertical guidance is not approved vertical guidance like that found on approaches with lateral navigation (LNAV) and vertical navigation (VNAV) lines of minima.

17 Refer to CAA AC 91-21 for GPS equipage specifications. Some aircraft will have PBN capability through GPS integration with a Flight Management System (FMS).

Use of PBN LNAV or LNAV/VNAV procedures requires a CAA approval.[18]

Pilots and air traffic controllers will be competent and current in conducting and supporting PBN operations. Training and examination (to the appropriate syllabus) will consider normal and non-normal[19] operations within the Air Traffic System (ATS). Flight planning will consider the route being flown. This includes:

- RNAV specifications
- RNP specifications
- Alternate Aerodrome – Meteorological considerations
- Recovery Operations (refer to section 3)
    - Alternate Means of Navigation
    - Alternate Aerodrome – Loss of PBN capability

Pilots and air traffic controllers will have a comprehensive understanding of the operational impact of the loss of GPS[20] as this can result in:

- Loss of PBN capability – loss of IFR navigation capability for the planned route.
- Loss of ADS-B Surveillance capability[21]. If the aircraft is outside the contingency surveillance system[22], ATC will not be able to identify the aircraft through surveillance means.

Note: The aircraft may be outside of ground-based navigation aid service – there may be no immediate IFR navigation means.

Note: The current surveillance radar system reaches the end of its operational life at the end of 2021. Airways is replacing radar with Automatic Dependant Surveillance-Broadcast (ADS-B) as the primary source of surveillance data. ADS-B will be mandatory in controlled airspace from 31 Dec 2018 (above flight level 245). CAA is proposing to mandate ADS-B below flight level 245 from 31 Dec 2021. A contingency

18 Both general aviation and air transport operators require CAA approval for aircraft airworthiness and continued airworthiness of PBN capability. Private pilots require an instrument rating with GNSS endorsement. Air Transport pilots are approved for PBN operations through the aircraft type rating. Air Transport operators' PBN capability is issued through an Operational Specification.

19 Normal operations relates to a fully operational PBN system, non-normal relates to responses required upon loss of PBN capability to recover aircraft safely, refer to section 3.

20 Loss of GPS can be as a result of on-board equipment failure, or external influences affecting the GPS signal integrity and availability.

21 ADS-B also has a dependency on GPS

surveillance system[22] will provide immediate non-GNSS dependent surveillance upon loss of ADS-B capability[23]. VHF will remain the primary communication means.

As described above, the loss of GPS can affect two (navigation and surveillance) of the three PBN elements[24]. This has influenced key regulatory safety decisions on infrastructure and procedures for safe recovery of aircraft upon loss of GPS resulting in loss of PBN.

A pilot must be able to safely recover from loss of PBN capability. This requires:

- **An alternate navigation system for means of IFR navigation[25]**
- **Recovery Operations – enabling safe recovery of the aircraft**

This is discussed further in section 3.

22 The contingency surveillance system will have no dependency on GNSS in providing an operational capability when ADS-B is inoperative.

23 Contingency surveillance system coverage and service will be less than the primary ADS-B surveillance coverage and service

24 Communications, Navigation and Surveillance.

25 An alternate navigation system is required to address IFR IMC operations, this will be a minimum requirement of aircraft equipage.

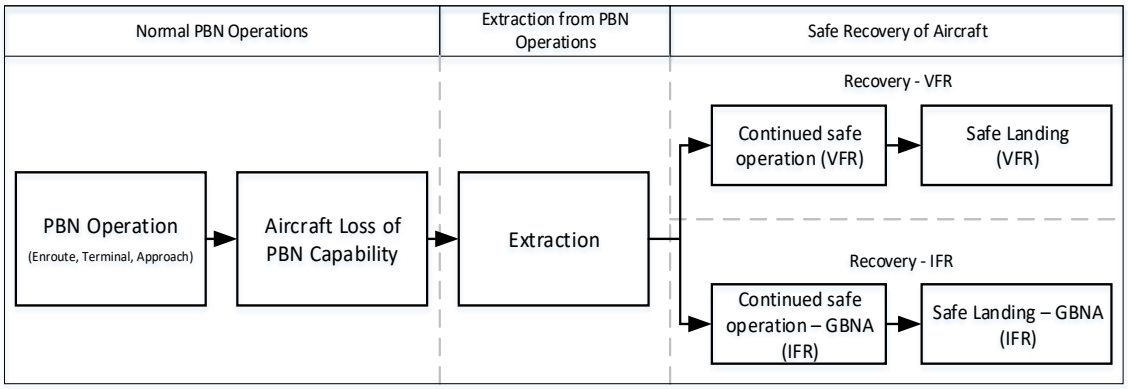
Performance Based Navigation
Safe Recovery of Aircraft

3 PBN Failure – Safe Recovery of Aircraft

Recovery operations are required when aircraft lose PBN capability through either onboard equipment failure or loss of GPS signal[26]. The pilot will extract from the PBN operation and be able to continue operations and/or land the aircraft safely. Noting that IFR can be conducted in instrument meteorological conditions (IMC), extraction and recovery will consider meteorological conditions as well as alternate aerodromes. Ground-Based Navigation aid and contingency surveillance infrastructure will also be taken into account.

The recovery response will vary depending on the operational scenario and environment. The sequence of response for recovery is outlined in Figure 2.

Figure 2: Recovery Operations Upon loss of PBN Capability



PBN operations may <u>only</u> be conducted outside of conventional ground-based navigation coverage and service **when a safe extraction procedure can be conducted.** Aircraft may be able to recover with alternate means, however this is dependent on the type of operation and capability on-board the aircraft[27].

[26] GPS signal can be lost by constellation issues, signal jamming, and signal spoofing or space weather.

[27] Alternate means could be use of inertial reference systems, weather radar with ground mapping functions, or operational techniques that provide an acceptable level of safety to the operation. This requires agreement from the regulator.

3.1 Extraction

Extraction is the immediate response to loss of PBN capability. The pilot will have considered this during flight planning. **To extract is to safely exit the PBN operation to enable recovery of the aircraft**. The CAA will provide guidance on extraction through the PBN regulatory framework project. Consideration of flight planning will include:

- The aircraft may be without immediate IFR navigation means (outside GBNA service)
- The aircraft may not be identifiable by ATC surveillance [28]
- Complexity of the PBN procedure
- Environment and terrain issues
- Dead reckoning limitations
- Traffic and separation, number of other operators (density)
- Aircraft performance
- Fuel requirements
- Meteorological conditions (IMC versus VMC)
- Availability of infrastructure[29] and air traffic service to enable safe recovery.

General Aviation and Air Transport operators will have extraction procedures that enable safe recovery operations to commence. Safe recovery can be based upon VFR or IFR operations, refer to section 3.2. Air Transport operators will require CAA approval of extraction procedures.

3.2 Recovery

Recovery occurs **once the pilot has safely extracted the aircraft from the PBN operation**. Recovery will either enable the flight to continue to the intended destination or result in a diversion to an alternate aerodrome. Recovery will be planned in conjunction with the extraction procedure. Refer to section 3.1.

There are two means to recover:

- Recovery – Visual Flight Rules (VFR) – (refer section 3.2.1)
- Recovery – Instrument Flight Rules (IFR) – (refer section 3.2.2)

[28] Loss of ADS-B due to loss of GPS, as well as outside contingency surveillance service.

[29] Specifically GBNA that support continued IFR operations

3.2.1 Recovery VFR

If the extraction concludes in VMC then the pilot may plan to recover by VFR means. Existing VFR civil aviation rules apply.

3.2.2 Recovery IFR

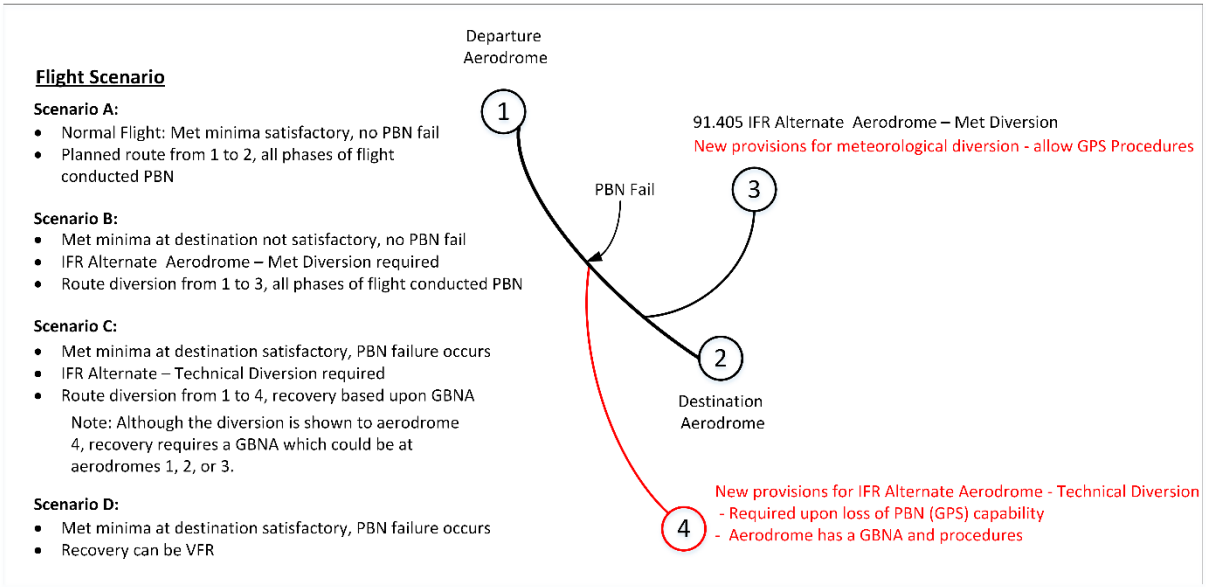
If the extraction concludes in IMC conditions or the pilot wishes to continue IFR, then an alternate navigation system[30] will be used. It may be possible to continue IFR through vectoring provided by ATC[31].

Alternate means of navigation in the event of loss of PBN capability will be based upon conventional ground-based navigation aids. To enable safe recovery, navigation aids and recovery aerodromes will include the following procedures[32]:

- Enroute
- Standard Terminal Arrival
- Approach (including missed approach)

Figure 3 provides a proposal on how aircraft can recover upon loss of GPS and how alternate navigation, alternative aerodromes and meteorological conditions are considered when planning IFR recovery.

Figure 3: Recovery Operations Upon loss of PBN Capability



[30] Alternate navigation system does not include dead reckoning as the aircraft will need to be flown within IFR procedure design tolerance.

[31] This will require the aircraft to be inside contingency surveillance service.

[32] The conventional procedures used for safe recovery will need to be designed with connectivity from enroute to arrival to approach.

Under the proposal and with consideration of meteorological alternate aerodrome navigation requirements, the CAA will allow the use of PBN procedures (GPS based) at the alternate meteorological aerodrome as opposed to conventional GBNA procedures (Scenario B in Figure 3), providing an increase in safety through use of PBN.

New provisions for PBN (GPS) failure will be introduced. An alternate aerodrome will be required to recover the aircraft safely. This is shown in Figure 3 as a technical diversion. This aerodrome will be supported by GBNA procedures. Although it has been identified as an alternate aerodrome, if safe recovery and landing can be supported, the aerodrome can be the departure, destination, or an alternate aerodrome (Scenario C in Figure 3). Meteorological minima for the GBNA procedure will be considered in addition to meteorological alternate requirements.

Alternate navigation for recovery will be provided by VOR/DME. Aircraft approved for PBN will carry certified conventional navigation system(s) suitable for safe IFR recovery of the aircraft. The equipment combination will depend on the route/procedure being flown i.e. VOR or VOR/DME.

A network of VOR/DME stations will be provided at aerodromes for recovery of aircraft. This network is known as the Minimum Operating Network (MON), see the proposed network in Figure 4. The proposed MON provides GBNA at New Zealand's 17 controlled aerodromes and two uncontrolled aerodromes.

The MON will provide a basic conventional enroute infrastructure, providing connectivity to conventional arrivals and approaches at suitable[33] IFR Recovery aerodromes. The number and type of approaches to recovery aerodromes (both runway ends, VOR versus VOR/DME) will be considered from a safety perspective, noting that when an aerodrome is being used for IFR recovery, the approach will be the pilot's final means of landing safely[34]. Approaches can be based upon existing Instrument Landing System (ILS) where applicable[35].

If loss of PBN capability is based upon aircraft system failure this will restrict future PBN operations until the on-board system is repaired or replaced (unless relief can be provided under Minimum Equipment List (MEL). CAA approval of the MEL will be based upon safety and with consideration to the operational context.

If loss of PBN capability is due to GPS signal in space, then further IFR flights will be subject to a safety evaluation by the ATS provider and the CAA, noting IFR contingency operations may be put in place (refer to section 4).

Pilots and air traffic controllers will remain current and competent in procedures associated with IFR Recovery of aircraft using conventional GBNA. Mixed mode (PBN and conventional) operations will continue (albeit reduced) to maintain competency in these operations. Mixed mode operations will require safety management oversight by the ATS provider within an operational philosophy of best equipped best served.

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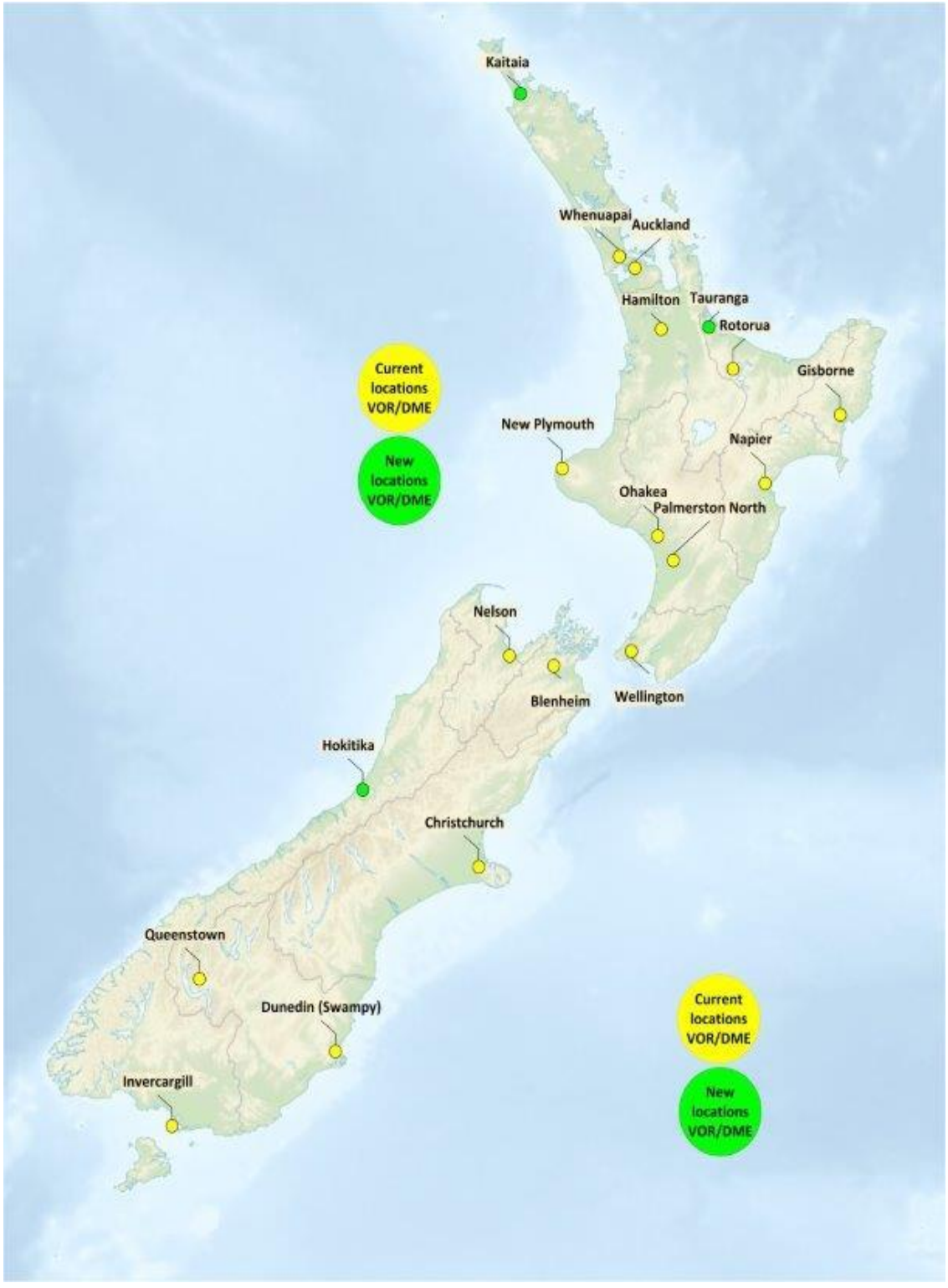
[33] Suitable means appropriate to the operation, aircraft type and category

[34] Upon arrival at the safe recovery aerodrome some aircraft will have limited fuel remaining.

[35] New Zealand intends to retain all existing ILS

Figure 4: Recommended[36] Ground Based Navigation Aids - VOR/DME[37]



[36] Note that the MON is a recommendation and has not been agreed at the time this document has been published.

[37] Locations shown yellow have existing VOR/DME. Green locations will have VOR/DME as a new station or replacement of an NDB.

Contingency Operations
Long term loss of GNSS

4 Contingency Operations - Long Term Loss of GPS

Contingency operations are intended to support continued **IFR Air Transport operations** in the event of long-term regional loss of GPS that prevents primary means PBN navigation.

Although contingency is primarily for air transport operators, other operators may be able to conduct IFR under contingency conditions. However, this will be dependent on aircraft equipage and acceptance by the ATS provider (from a risk and safety perspective).

Regional loss of GPS will affect PBN and ADS-B surveillance capability. Infrastructure[38] will be in place to support main trunk IFR contingency operations through the following ground infrastructure:

- GBNA – VOR/DME (GBNA Contingency System)[39]
- Mode S surveillance solution[40] (limited surveillance service supporting the main trunk)
- VHF communications

Aircraft will be suitably equipped with systems to operate within the contingency system. The CARs will define the function, equipment and contingency requirement. The operators and ATS provider will develop and manage safe operations.

The GBNA Contingency system is made up of VOR/DME stations. Conventional navigation procedures will be in place for departure, enroute, arrival, and approach providing connectivity between Auckland, Wellington, and Christchurch airports.

Noting that all controlled aerodromes[41] have a GBNA (refer to Figure 4), connectivity of the main trunk may be extended to key regional aerodromes. This is beyond the original intent of contingency operations and will be discussed between the ATS provider, aerodromes, and operators.

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[38] Ground based navigation aids and non GNSS dependent secondary surveillance radar.

[39] The GBNA contingency system uses the GBNA of the MON.

[40] Incudes mode A and C

[41] All controlled aerodromes have a GBNA at the time this document was published.

As contingency operations will default to conventional IFR navigation means, pilots and ATC personnel will be current and competent in these operations. The ATS provider will have plans to facilitate contingency operations when required.

Air transport aircraft will be equipped with dual independent ground-based navigation systems appropriate to the route being flown. They will have Mode A/C/S transponder capability. It may be possible for transport aircraft with advanced navigation capability to continue operations based upon PBN. This will be discussed with the regulator and ATS provider. The ATS provider may also be able to support IFR operations through the procedure and ATM/ATC capability.

Conventional Ground Based Nav Aids IFR Navigation 2023

5 Conventional GBNA IFR Navigation 2023

As mentioned in section 1, conventional GBNA navigation will not be the primary means of navigation in 2023. However, a conventional GBNA navigation system and infrastructure will be in place alongside PBN for the safe recovery of aircraft when loss of PBN capability occurs as well as for IFR Air Transport contingency operations when PBN is not available[42]. This provides New Zealand with a limited conventional GBNA network and associated procedures.

Aircraft equipped only with conventional IFR equipment[43] will be able to use the GBNA infrastructure for normal navigation operations as described in the CARs. Operators that choose to conduct IFR navigation based upon conventional GBNA will understand operations will be limited due to:

- The MON GBNA network and associated procedures[44], refer to section 3.2.2
- The Contingency GBNA network and associated procedures, refer to section 4.

Normal operations continuing to use conventional GBNA results in:

- Continued mixed mode (conventional and PBN) operations. The ATS provider will manage the system to ensure safe operations, PBN capable aircraft will be managed more efficiently than aircraft operating conventional GBNA means.
- ATS provider and operators maintain currency and competency of conventional GBNA navigation. Ensuring retention of skills for recovery of PBN aircraft upon loss of PBN or IFR Air Transport contingency operations, when required.

[42] Due to a long term GPS outage.

[43] Not PBN capable

[44] The procedures supporting the MON do not include conventional departures, the procedures are for recovery of aircraft upon loss of PBN capability.


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