

State Letter AN 11/57-22/87 Supporting Document 2 FAQ on Switching from Magnetic to True North Reference

1) *What is the driver for switching from Magnetic to True North reference in aviation?*

There are two primary issues:

One is the ongoing significant cost of maintaining the magnetic system, borne mainly by airlines and States.

- Cost to upgrade Magnetic Variation (Mag Var) tables in Flight Management System (FMS) and Inertial Reference Unit (IRU) systems every five years
 - One airline reported \$21M for 200 aircraft. Another \$1.2 million for 32 aircraft. Est. 50,000+ IRUs in the International Air Transport Association (IATA) fleet that will require updated Mag Var maps over time.
 - Aircraft costs are changing. Some will now allow the new Mag Var tables to be loaded on wing.
 - Some airlines have the table updates built into their avionics agreements, lease agreements or purchase agreements so the cost may not be specifically called out to the airline. However, someone is still paying for those embedded costs.
- Cost to continually align airports – Estimated at \$10K per hold line.
- Cost to continually align VHF Omni-directional Radio (VOR) beacons and airways.
- Cost to complete ‘busy’ work to update Instrument Flight Procedures (IFPs) for Mag Var only changes.

The second issue is the denial of procedures where the IRU/FMS Mag Var values are out of date against the Instrument Approach Procedure (IAP) – specifically CAT II/III procedures. Boeing and Airbus maintain a list of Category II/III procedures that are unavailable until the airline updates the Mag Var tables. Airworthiness Directives (ADs) on other aircraft with out-of-date tables deny procedures and increase pilot workload.

There is also an outlier as a third issue. The constant but generally irregular change in the Earth’s magnetic field is difficult to predict, and while the aviation industry is currently able to produce acceptable correction values, this cannot be guaranteed in the long term. The Earth’s magnetic field has ‘flipped’ in the past. We do know that the rate of magnetic variation change is increasing. As an example, the usual 5-year epoch period between updates of magnetic variation had to be shortened when the 2015 Epoch magnetic variation tables had to be reissued in 2018 (vs 2020) because the rate of magnetic variation change surpassed the model.

2) *Is the idea of switching to True North reference predicated on RNAV (PBN everywhere) and the removal of conventional procedures?*

No. In fact, Performance Based Navigation (PBN) procedures are more tolerant of Magnetic Variation (Mag Var) errors than conventional procedures. While a Mag Var error in a PBN procedure might make the track look ‘off’ on the Flight Management System (FMS), using RF and TF legs ensures that the aircraft will still follow the correct track over the ground.

All Instrument Flight Procedures (Instrument Approach Procedures (IAPs), Standard Instrument Departures (SIDs), Standard instrument Arrival (STARs) and enroute) are designed in TRUE. Mag Var is incorporated as the last part of the design process. Since the Instrument Landing System (ILS) Localiser (LOC) broadcasts a signal off the ground, only the track value in the database would need to be changed. Non-Directional

Beacons (NDBs) are heading based; again, publish the TRUE value and the procedure is fine. VHF Omni-directional Radio (VORs) would need to be rotated to align to true. Depending on the age of the VOR and how much rotation is required, that could be done electrically or may need to be done physically. Canada has a very good process to rotate VORs that addresses rotations between publication cycles; that could be shared.

3) *Would both MAG and TRUE need to be maintained going into the future?*

No. The entire system would operate in TRUE. Inertial Reference Unit (IRU) aircraft would bypass current Magnetic Variation (Mag Var) tables as they currently do when operating in the 'keyhole' or Canadian Northern Domestic Airspace. Attitude and Heading Reference System (AHRS) aircraft with flux valves (magnetic sense) would need to update with Micro Electro-Mechanical System (MEMS), Fibre Optic Gyro (FOG) technology or low-cost DO178 heading converters. Small General Aviation (GA) aircraft would read the magnetic compass, adjust for Mag Var and set the adjusted heading on the directional gyro. Air Traffic Control (ATC) vectors and surveillance would all be in True as Mag Var tables in Surveillance Systems would be eliminated by zeroing out the Mag Var values or removing the Mag Var tables.

4) *How would you do the change? How do you switch everyone to TRUE at one time? Could you do the change regionally?*

States with regions experiencing Magnetic Variation (Mag Var) differences within $\pm 4^\circ$ and $\pm 10^\circ$ of True North Values could plan and pace their change. The great majority of States fall within this range. In the transition period, $\pm 10^\circ$ for runway alignment would be fine and $\pm 4^\circ$ for airway alignment would also be acceptable. Canada, USA, Brazil and Russia would have to deal with the largest impacts due to variation values greater than $\pm 10^\circ$ over much of their domestic airspace. Much of the rest of the world could phase in a soft change where runway renumbering, as an example, could be completed during planned runway maintenance between now and 2030-2035. The current Aeronautical Radio Inc. (ARINC) 424 navigation database data records and data fields can be maintained with 0° entered as the Mag Var value in columns 52 to 56 inclusive *and* column 86 set to TRUE Indication. In this manner, navigation data will be reflected as TRUE regardless of the Flight Management System (FMS) method to determine and operate in True. While this ensures the navigation database records will reflect TRUE values only, the FMS/Inertial Reference Unit (IRU) would still need to be operated in TRUE to provide TRUE heading from the IRU or Attitude and Heading Reference System (AHRS) heading source and to allow the FMS to not use the main embedded Mag Var map in the FMS. Some Air Navigation Service Providers (ANSPs) are publishing True and Magnetic on charts now and that could be an interim step leading to up to the day of change globally, or regionally, as determined by the TRUE North implementation plan (yet to be determined).

5) *Could the entire planet achieve such a massive change to aeronautical navigation?*

We have three positive examples to date in other disciplines. The 'Year 2000' computer requirement; the change from SAE to Metric (with the exception of the US, Myanmar and Liberia); and marine navigation switching from Magnetic to True. Also, the adoption of Reduced Vertical Separation Minimum would be another ICAO led programme that could be a model for this global change.

However, given the conservative nature of aviation change, it is suggested that the transition occur on a regional or hemispheric basis. It could look something like this:

1. Remote and Oceanic
2. Canada
3. Europe and Africa
4. US and Mexico
5. South America
6. Asia

6) *Would airspace need to be redesigned?*

Classes of airspace? No – but the bearings and tracks of the procedures within would be published as designed, that is TRUE.

7) *Would it require a major avionics upgrade on aircraft?*

Inertial Reference Units (IRUs), Flight Management Systems (FMSs), Synthetic Vision Systems (SVS) and Multi-function displays are designed to complete the ‘maths’ in TRUE and then add Magnetic Variation (Mag Var) prior to displaying it to the pilot. In Canadian Northern Domestic Airspace aircraft operate, and NAV CANADA has proven operation of, all conventional and PBN procedures, in TRUE.

General Aviation (GA) aircraft without coupled directional gyros could add Magnetic Variation mathematically (as is done with compass correction card values) when manually setting the DG. Light GA aircraft could manually add or subtract the local Magnetic Variation (Mag Var) after compass observation prior to manually setting the Directional Gyro (DG). GA aviators are used to doing this today with the current compass correction card. Drawing track lines on a Visual Flight Rules (VFR) chart produces a True Track. Upper winds to set heading are supplied in True. Then the GA pilot adds the Mag Var for the magnetic heading to make good the True Track. If GA pilots make the adjustment from the magnetic compass heading to a True heading to set the DG, then no additional equipment would be required.

GA aircraft with slaved gyros, and using a Garmin system, operate well in True today. Cost effective heading converters are also available which automatically convert system heading from Mag to True automatically.

Older regional or air taxi type aircraft (generally less than 50 seats) would require either a heading converter to work in conjunction with the flux valves and an Attitude and Heading Reference System (AHRS) or change to one of the new north-seeking (Inertial Reference Unit (IRU)-like) AHRS units on the market, by 2028.

8) *How will the many legacy General Aviation (GA) aircraft be accommodated in the new system?*

Few General Aviation (GA) aircraft carry inertial systems. Light GA are required, under current International Civil Aviation Organisation (ICAO) standards, to include a system for displaying magnetic heading. However, that requirement was written when there was no means of displaying aircraft track, and nowadays the vast and increasing majority of GA pilots carry either panel mount or hand-held Global Navigation Satellite Systems (GNSS) receivers (and often both). These systems calculate the aircraft’s True track which is usually

then adjusted to display Magnetic track to the pilot. The pilot can then adjust the aircraft heading to maintain the desired track, without having to make mental calculations to compensate for wind. Although GNSS requires a suitable power source, its output is much more accurate than a magnetic compass with its errors and retains its accuracy in most flight attitudes. This is a way forward for the 200,000 GA aircraft in the US alone, most of which do not have navigation-grade inertial sensors.

Operators of light GA aircraft could manually add or subtract the local Magnetic Variation (Mag Var) after compass observation prior to manually setting the Directional Gyro (DG). GA Aviators are used to doing this today with the current compass correction card. Drawing track lines on a Visual Flight Rules (VFR) chart produces a True Track. Upper winds to set heading are supplied in True. Then the GA pilot adds the Mag Var for the magnetic heading to make good the True Track. If GA pilots make the adjustment from the magnetic compass heading to a True heading to set the DG, then no additional equipment would be required. GA aircraft with slaved gyros and using a Garmin system operate well in True today. Cost effective heading converters are also available which automatically convert system heading from Magnetic to True automatically.

9) *How can GA aircraft manage in the event of an emergency?*

As stated in the response above, the manual application of Magnetic Variation (Mag Var) from compass heading to DG setting is a simple mathematical task. Also, for any aircraft that has a Master Minimum Equipment List and certified Airplane Flight Manual (AFM) procedures, those procedures would have had the aircraft diverting to land as soon as possible after the loss of the critical power generation system. Heading and attitude are wired to the essential bus in compliance with aircraft certification with typically 30 minutes of battery remaining with which to land as soon as possible.

The pilot would be required to apply Mag Var to the compass heading to know the aircraft's True heading, and then adjust that heading for wind to maintain a given true track. Private pilots are required by the International Civil Aviation Organisation (ICAO) to understand the principles and operation of instruments and carry out pre-flight planning. These both require an understanding and application of Mag Var, since charts are oriented to True North, and there is no intention to change that requirement.

The whole system will be operated in True during normal and emergency operations.

10) *How will the conversion of all directional information contained in the Aeronautical Information Publications (AIP) be managed?*

States already follow the International Civil Aviation Organisation (ICAO) standards and recommended practices to adjust Magnetic Variation (Mag Var); the only difference here would be the size and scope. Planning is key to implementing a world-wide change. Planning and coordinating the change on a regional or hemispheric basis has been demonstrated to be a workable approach. One method to complete this by region would be to cease the creation of new procedures for a period of 6 months prior to the change with the exception of emergency procedures. During this period, Air Navigation Service Providers (ANSPs) and States would only change data in their State Aeronautical Information Publications (AIPs) linked to the change, or, put another way, $MAG\ VAR = 0$. As that work is released to the public, data

warehouses/integrators would apply this information to the Aeronautical Information Regulation And Control (AIRAC) file for the date of change.

Finally, some States are already publishing both True and Magnetic within their AIPs. If more States wished to do this from today until the date of change in the future, that is allowed for in ICAO documentation-

11) *How will the implementation of the Aeronautical Information Regulation And Control (AIRAC) changeover be affected?*

In the Aeronautical Radio Inc. (ARINC) 424 data records, fixes are all of the following: Navaid, Waypoint, Intersection, Turning Point and Runway Threshold. All fixes are stored as Lat/Long with related declination and other relevant data. Where fixes are defined as Rho Theta from a Navaid, the Rho element is currently the magnetic radial to the nearest tenth of a degree (which is suppressed) and if required replaced with "T" where the procedure is coded in °T.

To properly use Rho Theta navigation, the VHF Omni-Directional radio (VOR)/ Tactical Air Navigation (TACAN) beacon would need to be rotated to True North, the radials published in degrees True and a fix redefined with the new True Radial and the Aeronautical Radio Inc. (ARINC) 424 data record changed to show declination as 0°, or use the "T" to conduct operations in True.

Another solution would be to define these intersection positions as waypoints, however, this is a diminishing problem, as older navaid-based procedures are replaced by the Global Navigation Satellite System (GNSS) type using waypoint and turning points.

In the ARINC 424 data records, Routes are the lines that connect the fixes, such as Airways, Standard Instrument Departures (SIDs) and Standard instrument Arrival (STARs). Airways are carried in the ENROUTE section of the database and, again, are defined as a succession of fixes / waypoints along with other relevant data. The inbound and outbound tracks are currently defined in °M but it is inferred that these are provided for the logic of the Cruise Table and would be redefined as True.

Regarding fixes and Lat/Long, all fixes in ARINC 424 have Lat/Long. If there is no provided Lat/Long value, the Data House will calculate it based on VHF Omni-directional Radio (VOR), Non-Directional Beacon (NDB), Distance Measuring Equipment (DME), etc. Theta and Rho are used for courses and distances but not for the fixes; they are using coded declination from the navaid coded as recommended navaid for Theta and Rho. Theta and Rho are used for some path terminators, for example Course to Fix (CF) or Fix to Distance (FD), but they are not used for Track to Fix (TF) path terminators, because it is a track between two fixes. Even with adequate advance notice (say 6 months) several AIRINC cycles may be required to complete the transition.

12) *The target date for implementing a change is 2030 – is there enough time for the necessary administrative process to be followed?*

2030 is the current target date. If, through the working groups, it is determined that 2030 does not leave enough time, then the date can be slipped to between two 5-year EPOCHs to reflect a date between 2030 and 2035.

13) *Is it also the intention to move away from using magnetic headings to vector aircraft?*

The plan is to move the entire Air Traffic Management (ATM) system to True, including headings provided to vector aircraft. Air Traffic Control (ATC) displays and radars can be aligned and referenced to True. There will be ATC training required, but it consists only of making controllers aware of what revised headings will be and when the change will take place.

14) *Flying an assigned track is not an option for all aircraft. Do manufacturers have plans to address this issue?*

For Nav Canada operational testing purposes their database provider changed all the Magnetic Variation (Mag Var) Values to “0”, because the Nav Canada flight test aircraft FMC couldn’t do the True designations as those fitted to other platforms did. Whether the Flight Management System (FMS) can use a True designation to bypass the Mag Var table or an Air Navigation Service Provider (ANSP) must set all the Mag Var values to “0”, the result is the same; 0° Mag Var is applied and that equates to True.

15) *Will the transition incur significant cost to implement Air Navigation Service (ANS)/Runway changes and who will bear that cost?*

ANS procedure design changes and airport runway designation changes will be required to switch to True, although changes to runway markings need not necessarily be required immediately. States would save money switching to True as opposed to constantly updating procedures, repainting/changing runway numbers and signage, and publishing changes in order to follow a constantly changing Magnetic reference.

16) *How will the transition be implemented in aircraft types fitted with Flight Management Systems (FMS) which cannot separate flying a track and referencing a vertical rate or a Glide Slope Angle (GSA)?*

Even on aircraft that fly Track/Flight Path Angle or Heading (HDG)/Vertical Speed, the track and heading is a defined output from the Inertial Reference Unit (IRU)/Air Data IRU/Flight Management Computer (FMC). If all the avionics supplying the operation are in True or, put another way, an airport with a Magnetic Variation (Mag Var) of 0°, it is doing the same thing. These aircraft can quite easily fly an approach into EGLL (London Heathrow) today; and EGLL has a current Mag Var of 0.0° east.

17) *Does the proposed transition entail any particular risks and, if so, how would they be mitigated?*

During any period of change there is always the possibility of risk. The Magnetic to True implementation will have to be managed by the International Civil Aviation Organisation (ICAO) to ensure regions or hemispheres transition in a coordinated fashion. Great care in planning will be required to ensure that: aircraft are capable of 0° Magnetic Variation (Mag Var) or true operations; Air Traffic Service (ATS) systems are moved to 0° Mag Var/True; airports have a plan to update their documentation and runways alignment/renumbering as appropriate, and Air Navigation Service Providers (ANSPs) will have to have a mature process to deal with the volume of change for the Mag Var modifications.

18) *What impact (additional load) will the transition have on training?*

Pilots are taught to deal with Magnetic Variation (Mag Var) from the beginning because some charting (visual navigation charts) and all weather (METAR, FT, FD, PIREP, SIGMET, VOLMET, etc.) are referenced to true.

For the private pilot, they will apply the Mag Var with the compass correction when setting the Directional Gyro (DG) from the E2C. On larger aircraft, the pilots will have a button to select (MAG/TRU).

Air Navigation Service Provider (ANSP) procedure designers will no longer complete the last part of the procedure design process – applying Mag Var. Air Traffic controllers will need to adjust the vectors around the airport to compensate for the change, but this is a one-time adjustment.

19) *How will the changes to documentation necessitated by the transition be implemented?*

Like all the International Civil Aviation Organisation (ICAO) changes to Annexes and Procedures for Air Navigation Services (PANS), the current change processes would be used but with focus to this particular Magnetic Variation (Mag Var) issue.

In addition, aviation certificate and document holders have well defined processes for document amendment.

20) *Will there need to be any changes to the certification process as a result of the transition?*

For aircraft certification, there will be no need for Airworthiness Directives (ADs) or Airplane Flight Manual (AFM) amendments limiting operations with out-of-date Magnetic Variation (Mag Var) tables.

21) *Aircraft are already permitted to fly 'True' in certain circumstances (e.g. at high latitudes and following great circle tracks) – so why the need to transition?*

While it is true that some airlines use True for Oceanic and Remote operations, the real savings are to be had by no longer needing Magnetic Variation (Mag Var) tables to support the low level magnetic operations currently used at most airports (except within Canada's Northern Domestic Airspace) and approach procedures. Air Navigation Service Providers (ANSPs) and airports will not need to manage Mag Var for technical alignment in the future.

22) *Can 'True North' operation be sustained in the event of GNSS denial?*

Yes. Inertial Reference Unit (IRUs) do not need Global Navigation Satellite System (GNSS) receivers. Manual setting of a Directional Gyro (DG) Heading does not need GNSS. Ground based navigation aids do not need GNSS. If some transition applications are predicated on GNSS they would need to ensure that emergency procedures provide a pilot intervention to manage converting Magnetic to True.

Most of the world is within $\pm 10^\circ$ of the 0° isogonal and it could be argued that, in the event of an emergency, $\pm 10^\circ$ heading is an acceptable limit given that navigating with ground-based navigation aids is all tracks except for Non-Directional Beacons (NDBs). Multi sensor Flight Management Computers (FMCs) would still operate in Track.

23) *What are the implications of a transition from Magnetic to True for runway designation?*

To comply with ICAO Annex 14 the transition to True North might necessitate some amendment of runway designator numbers. The purpose of a runway designator is to identify a runway. Annex 14 specifies that the present system of using two-digit numbers on runways is normally based on magnetic North and that the designator "shall be the whole number nearest the one-tenth of the magnetic North when viewed from the direction of approach". The Annex does not specify how quickly these numbers need to be updated after a change in local Magnetic Variation. Airport and State authorities have often allowed the change to the runway designation to occur at a time of opportunity versus remaining 100% in technical alignment.

Re-designation occurs today at a financially opportune time. Thus, any re-designation could safely be left until there is a need to repaint or resurface the entire runway or carry out significant surface alternations involving holding points. Only if there is something odd about the situation, such that confusion might result, or if such a change would need to be changed again, perhaps even reversed, when the transition to True North is implemented, would there be a need to revisit the timing of the re-designation works.

If the timing of the transition were aligned with an epoch change to the World Magnetic Model, adopting True could be a free or, at least, low-cost re-designation option for many States by either negating the requirement to revise designators or changing them to True when a Magnetic change was required anyway, which might even be in advance of the transition.