Which Way is North?

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Note: This article is part of a recurring feature called Pilot's Corner by NAV CANADA's Manager of Flight Operations Anthony MacKay.

When I learned how to fly and did my first cross country, simple math was required to convert true bearings on maps to a final magnetic heading:

- draw the true track on the VNC,
- assess the true wind to determine true heading to make good the true track, and
- add or subtract the magnetic variation to convert the true heading to a magnetic heading to set course in the aircraft.

It was very simple in an analogue aircraft using a magnetic compass.

As I progressed into larger aircraft over the course of my career, I was no longer concerned with drawing lines on VNCs as the lines were drawn for me on my IFR charts. The aircraft had magnetic stabilized Attitude Heading Reference Systems (ARHS) and, as a result, the amount of math decreased.

As I progressed onto even larger aircraft with inertial reference units (IRU) and flight management systems (FMS), I became even less concerned with the true to magnetic conversions as it was all done within the 'magic' of the navigation boxes on the aircraft.

In the RNAV era however, magnetic variation on even the most complex aircraft has revived discussions in the flight deck about why displayed tracks on the flight management system are not the same as what NAV CANADA has published on the maps. This has become even more of a problem with the increased use of digital data, as there are numerous sources of magnetic variation and for any given location and point in space, they may not all match.

Why this happens

All IRU/FMS complete their internal calculations with reference to TRUE North. After the track calculations are complete, the navigation systems reference their internal magnetic variation table to provide a magnetic track. These tables are imported into the IRU or FMS by the unit manufacturer and each could be slightly different from the other.

Older systems may not have the latest magnetic variation tables in them. Magnetic variation tables are generated as EPOCHs based on five year intervals (1995, 2000, 2005, 2010, 2015 etc.).
If your IRU was installed in 1999, it may have had the 2000 EPOCH magnetic variation table installed. If that was the case, your magnetic variation would be 13 years out of date.

As for AHRS units, they generally use a magnetic sense input from flux valves located somewhere on the aircraft so they are subject to changes in the earth's magnetic field which are more pronounced at high latitudes.

Sources of magnetic variation

Magnetic variation on the aircraft comes from either the IRU (if used instead of AHRS) or the FMS.

While the EPOCH in the IRU is generally set, the Magnetic Variation Tables in the FMS database are further divided into two sources:

1. The EPOCH loaded into the core FMS for general use.

2. The magnetic variation supplied in the Navigation Database for each procedure.

The magnetic variation in the Navigation Database is further broken down into individual elements dependant on the procedure to be flown and the magnetic variation source specified to be used by the FMS manufacturer and the ARINC 424 record for the procedure. These values are modified when changes are loaded into your FMS on the standard 28 day AIRAC cycle. These elements are:

1. airport magnetic variation

2. VOR declination

3. procedure design magnetic variation as designated by the procedure designer.

Each of the 23 ARINC 424 legs then pulls the magnetic variation value assigned to it based on the ARINC 424 standard as adopted by the specific FMS manufacturer.

When the FMS uses a different source of magnetic variation than the procedure designer used, or, the FMS is using an outdated magnetic variation table, the FMS or GPS will show a discrepancy between the published track on the IFR chart and the track displayed on the FMS or GPS.

Because of these multiple sources, leg disconnects can occur and the displayed value may be different. Most issues are seen with CF and FA leg types associated with the VOR station declination and HM, HF and HA legs used in holds which typically use the airport magnetic variation value.

However, the true tracks underlying the procedures are the same for all the leg types other than those mentioned above. The FMS/GPS is navigating by waypoints based on latitude and longitude and for that reason when a FMS/GPS is navigating on an airway, the true track over the ground is always the same, even if the displayed magnetic value on the FMS/GPS is different than published.

Examples of FMS MAG VAR Functions:

1) Departing CYQH to CYXY with the following flight plan:

CYQH YQH V326 YXY CYXY

- ››CYQH has a Magnetic Variation of 22° E assigned
- ››YQH VOR has a declination of 21° E assigned
- ››Waypoint CANYO has a magnetic variation assigned from the FMS internal table
- ››YXY VOR has a declination of 23° E assigned
- ››CYXY has a Magnetic Variation of 25° E assigned

As the LO Chart above shows, V 326 has an outbound radial of 261 from YQH and this is displayed on the initial leg of the FMS from YQH.

After leaving CYQH, 24 miles into the flight, the track on the FMS changes to the 260R and this will continue to be updated as the FMS Magnetic Variation table assess the aircraft position all the way to CANYO. CANYO is only 82 DME from YXY yet its track is displayed as 258 which is 4 degrees different than the published 074 radial from YXY. This is because CANYO is assigned a Magnetic Variation value from the FMS Magnetic Variation Table – not the declination of the closest VOR.

41 miles from CANYO the track is now displayed as 259 degrees and this indicated track change will continue after CANYO all the way to Whitehorse where the track will eventually indicate 254 to match up with the 074R to Whitehorse. Throughout the flight the aircraft maintained the correct track (great circle route) over the ground between YQH and YXY.

Magnetic variation differences can cause havoc in modern aircraft with varied sources and uses within the system. When we flight check the procedures with reference to TRUE North, we never see alignment issues, however, when working in magnetic, it can be a little more challenging. While the above example relates to the en route portion of the flight, the same issues also occur with approach procedures.

Each aircraft heading source and FMS/ GPS installation is a little different. If you see discrepancies in tracks, you need to first understand how your system is processing magnetic variation. If you have IRUs, which EPOCH is your IRU using? Was it updated with the latest 2010 or 2015 data? These are all issues that need to be understood for each AHRS, IRU, FMS, GPS aircraft installation when operating in airspace with reference to magnetic tracks.