MAGNETIC VARIATION: A PRIMITIVE CONCEPT AND ITS HOLD ON CONTEMPORARY NAVIGATION

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ABSTRACT

When the magnetic compass was a primary—if not sole—means of navigation, the application of magnetic variation was a fairly simple process. True North and Magnetic North are not collocated; the old rhyme "East is Least and West is Best" reminded navigators to apply the correction in the proper direction. Armed with map and compass, a navigator of land, sea, or air could plot a course as a true heading, apply the local magnetic variation, and find a magnetic course to follow. The magnetic compass backed up the idea that the route he was following was the one he really wanted.

The advent of radionavigation stations has done nothing to diminish the magnetic compass' hold on navigation. Navigation stations, aligned with Magnetic North, ensure that their plotted radials coincide with those of the magnetic compass. The Magnetic North Pole is not fixed; variations for a given location constantly change. Navigators took this in stride until the recent advent of sophisticated navigation systems—many with their own magnetic variation models—produced a new problem: systems' indications of a magnetic course often disagree with published flight data.

This paper addresses the application of magnetic variation to components of the National Airspace System (NAS). It examines the determination and application of magnetic variation, discusses rates of change and differences in variation, and recommends rules for making this ancient mariners' computation more relevant for modern navigators.

HISTORY

The discovery of the lodestone, and the subsequent development of the magnetic compass, ranks with the discovery of fire and the wheel among man's great achievements. Though the Chinese knew its properties before 1000 A.D., the earliest evidence that the lodestone was used to locate Magnetic North dates to 12th century Europe. Early navigators determined the location of True North by observing that compass magnets did not agree with the position of Polaris (The North Star). The difference between True and Magnetic North (magnetic variation) allowed them to use the compass to plot and navigate a true course. Christopher Columbus pioneered the charting of magnetic variations in the Western Hemisphere during his famous first voyage across the Atlantic Ocean. His logbooks aboard the Santa Maria frequently note the position of Polaris versus Magnetic North. The magnetic compass is still used today as a navigation tool; though courses and tracks are determined by True North, magnetic variations are estimated and applied to determine a magnetic course.

DETERMINING MAGNETIC VARIATIONS

These magnetic variations are determined by documented observations—taken at thousands of locations worldwide—which establish a model that allows the calculation of local variations. The National Oceanic and Atmosphere
ric Administration (NOAA)--compiler of magnetic variation values and publisher of navigation charts for the U. S. Government--uses measurements made every five (or "epoch") years, i.e., 1980, 1985, etc. These magnetic variations are commonly published in a format which includes value, direction (East or West), and epoch year.

If the Magnetic North Pole could be located at any given time, and if the magnetic lines of flux traveled straight between the Magnetic North and South Poles, figuring variations would be a simple problem in spherical geometry. Yet magnetic lines wander an erratic path, and the poles are not separated by a neat 180 degrees. These vagaries tend to thwart arriving at any simple solution for magnetic variations.

The Magnetic North Pole is currently located North of Hudson Bay and West of Greenland. Constantly following an erratic path at an erratic speed, it has foiled attempts to accurately predict its position beyond 25 years. Forecasters have predicted with reasonable accuracy no more than five years into the future. That is, in fact, the process used to predict magnetic variations. Achieved values for two consecutive epoch years (1980 and 1985) were evaluated and an internationally agreed upon model was established which forecast the value for 1990. Once values for 1990 are compiled, the 1985 and 1990 values will be used to develop a model for the 1995 values. Therefore, the most current or future values are those forecast based upon the previous two achieved epoch year values.

Figure 1.
RATE OF CHANGE

Changes in magnetic variation are a direct result of the movement of the Magnetic North Pole. The rate of change is not constant throughout the continental United States and Alaska, but varies according to the distance from (and proximity to) the Magnetic and True North Poles (see Figure 1). Achieved values for epoch years 1980 and 1985 are used to determine the approximate rate of change throughout this area. Miami, Florida shows the fastest rate of change: one degree every six years. At the other end of the spectrum, Bangor, Maine experiences only a one degree change each century. The rate of change throughout the CONUS is therefore less than one degree between epoch years. (Though one may interpolate an estimated value between two epoch years, considering the miniscule rate of change, this serves no useful purpose.)

AVIATION

The Office of Aviation System Standards (AVS) exercises sole authority to determine and assign magnetic variation values to elements of the NAS, per FAA Order 8260.25B. AVS policy assigns values referenced to an epoch year, and that value is rounded to the nearest whole degree. The rationale of this is that all flight data is published in whole degrees; therefore, the rounding off process takes place at the point during the development and/or the publication of the item. Since the rate of change, moreover, is less than one degree between epoch years, all references will be to those years. Although the updating of assigned magnetic variations is an on-going process, specific facilities are not considered a priority until the update results in a change of three degrees or more.

Just as numerous values can be associated with specific locations and epoch years, there are also the most current and/or next, forecasted values. The Magnetic Variation of Record is the value referenced to an epoch year, used in the development and publication of all procedural elements predicated on, or associated with, a specific facility. "Old" epoch year values may be acceptable when the rate of change is minimal. Many facilities in New England carrying a 1965 epoch year are still within three degrees of current value. Variation of record on a given facility is published along with other facility data, e.g., restrictions, frequencies, location.

Magnetic variation is applied to all components and airports within the aviation arena. Runway numbers are determined by applying the magnetic variation to each runway's true bearing and rounding it off to the nearest ten degrees. This results in runway designations that correspond to magnetic bearings. Assigned airport values normally apply to all the airport's navigational facilities. TACANs, VORs, and radials published for use--whether en route or as part of a terminal procedure--are referenced to Magnetic North.

Loran-C nonprecision approach procedures will require the application of a magnetic variation. It is impractical to consider assigning a magnetic variation to each runway's true bearing and rounding it off to the nearest ten degrees. This results in runway designations that correspond to magnetic bearings. Assigned airport values normally apply to all the airport's navigational facilities. TACANs, VORs, and radials published for use--whether en route or as part of a terminal procedure--are referenced to Magnetic North.

Since Loran-C is oriented to neither Magnetic nor True North, the assignment of a magnetic variation will be restricted to published approach procedures. The variation applied will be the variation of record for the airport being served. Where the majority of Loran-C approaches serve airports with no other instrument approaches, such airports will be assigned the most current value. In the case of procedures to airports with existing instrument approaches, the magnetic variation of record will be applied to the Loran-C approach. Loran-C approaches are scheduled to be evaluated annually, along with all other instrument procedures, to ensure that all criteria (including magnetic variation) are current and within standards. GPS (and/or other earth-referenced navigation systems, including multi-sensor systems) are likely to be handled in the same manner.

In the publication of aeronautical charts, specific criteria are used to show VORTAC facilities and the resulting compass rose. Sectional chart legends specify the epoch year used in their preparation; VORTAC compass roses depicted on those charts are oriented toward Magnetic North based upon these epoch year values. On the other hand, en route charts have the compass roses aligned to indicate the magnetic variation to which the facility is aligned. (This explains why a course between two VORs may not have reciprocal radials defining it.) Both en route and sec-
tional charts use quoted epoch year values to depict their isogonic lines.

Note that, regardless of the magnetic variation applied, the ground track never changes. To illustrate, take a runway with a true bearing of 093 degrees and a magnetic variation of 1 degree West/1965; the magnetic bearing of the runway becomes 094 degrees, and the designation is "Runway 09." When the runway is updated to the 1990 value, the new magnetic variation is 4 degrees West/1990. This now equates to a magnetic bearing of 097 degrees, and the runway is redesignated as "Runway 10." The designation changes; the runway stays put. The only real difference between 1965 and 1990 is the reference of the runway bearing to a point on a magnetic compass.

**CURRENT DILEMMA**

This concept of applying a magnetic variation to a facility and publishing procedural elements predicated on that facility has proved satisfactory with station-referenced systems. Courses are referenced to facilities aligned to Magnetic North, and these electronic courses will now approximate the indication on a magnetic compass.

Difficulties arise as we lean more strongly towards earth referenced systems. With Loran-C's integration into the NAS as both en route and approach aid, problems have surfaced. The advent of sophisticated navigation--such as GPS and multi-sensor systems--only adds to the confusion. Earth referenced systems fix receiver position by latitude and longitude. Straightforward geodetic calculations using derived aircraft position and the next waypoint provide true courses between sets of coordinates. The system modifies that true course by applying a magnetic variation from its own imbedded model and displaying a magnetic course to follow. Whether systems use a 1980 epoch year or allow manually entered values, the determined magnetic course is unlikely to agree with the published course for the same route.

In all cases, the application of magnetic variation to navigation facilities and charts serves only to provide a reference for use with a magnetic compass. A magnetic course, whether used with an NDB or with a multi-sensor system, permits use of the magnetic compass as an independent, stand-alone, back-up navigation aid. The compass as a sole navigation system is notoriously inaccurate: magnetic storms and environmental conditions, such as flying over an iron-rich coast, tend to dilute compass accuracy. Even if one were to hold a magnetic course with great precision, one would not arrive at the intended destination. Since a magnetic course is a straight-line course and will not overlay a great circle course, the use of the magnetic compass as a sole means of navigation is not practical. A secondary input, be it celestial, station referenced, or earth referenced, must be used to continuously correct the magnetic course.

**CONCLUSIONS**

The magnetic compass--as an aid to or in place of celestial navigation--has given man a means of navigating the earth's surface to this very day. When man defied gravity and took to the skies, he carried the magnetic compass along with him. The magnetic compass became the primary means of navigating the skies and remained so for many years. Today's radionavigation systems have pushed the magnetic compass to the background. Yet alignment of (and references to) radionavigation systems are still expressed in terms which permit approximating indications on a magnetic compass.

We are entering an age where determining aircraft position and true course between waypoints can be refined with pinpoint accuracy. Inaccuracies fog the picture when we insist on relating these courses to points on a magnetic compass. A pilot who depends on the magnetic compass as a sole means of navigation can only expect to stay on course within +/- 5 degrees (given smooth air and good weather conditions). Sophisticated navigation systems are capable of accuracies at many times this level. Remember that the magnetic course is but a wobbly approximation of the as-the-crow-flies true course. Determining the true course with a modern navigation system and then applying a magnetic variation is like measuring with a micrometer and cutting with a chain saw.

Unless an aircraft travels a route overlaying (or parallel to) an isogonic line, the pilot will see wide changes in magnetic variation during the flight. An aircraft flying from Kennebunkport to Seattle shows a 40 degree change; 1990 variation for Maine averages 20 degrees West, for Washington 20 degrees East. Even a relatively short flight (York, ME to New York, NY) shows a 7 degree change.
RECOMMENDATIONS

Though often misleading and confusing, magnetic variation applications can be made easier by following these ground rules:

1. Keep matters in perspective when you apply magnetic variation. Remember that the magnetic course you get only approximates the true course on your magnetic compass.

2. Expect the published magnetic course to differ from the system-derived course. The simple fact that the same epoch year models are not used implies a disparity.

3. To minimize disparities between system-derived courses and those predicated on VORs, you should apply the magnetic variation of record for each VOR. These published values are readily available.

4. To minimize disparities between approach procedures, you should apply the airport's (also published and available) magnetic variation of record.

A final, unpopular recommendation--one which may seem extreme--is to publish flight data referenced to True North. All courses and routes could be published as true bearings and the isogonic lines, or chart notation, would provide the current magnetic variation for the aviation public to apply on their own recognizance. Applications of magnetic variation would thus become the user's responsibility. This would eliminate disparities between published and system-derived routes, since both would be considered true values. This apparently simple solution would force users to read flight data referenced to True North. Until then, the compass and magnetic variation will retain their age-old tight grip on navigation.