True North ICCAIA Ad-hoc group
White Paper v1.1

Preamble

This document has been developed by the True North ICCAIA ad-hoc group which is composed of the following people:

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The impacts have been assessed for each type of flying platform by the following actors:

Air Transport:	Airbus/Boeing
Business Jet:	Bombardier/Collins Aerospace
Regional Turboprop/Jet:	Collins Aerospace/Thales AVS France
Helicopter:	Bell
General Aviation:	Ad-hoc group member of GAMA
Data Provider:	Jeppesen

Executive Summary

Air Navigation is currently organized and dependent on magnetic heading while there are parts of the world where aviation safely operates in True heading reference today thanks to the introduction of GPS and Inertial systems. Therefore, to fly the magnetic tailored routes, aircraft must convert their true heading into magnetic heading using a magvar. Depending upon the instrument procedure and the aircraft/avionics design/integration, MagVars can be sourced by different methods (e.g. database, World Magnetic Model (WMM), etc.).

The local magnetic variations vary of a few degrees over a period between 5 and 10 years, sometimes accelerating locally with a shorter time scale. The consequence is the need to maintain the survey of the local magnetic variations and the regular update of on-board database, WMM and Aeronautical Information Publications which has a significant cost for Airspace users. Nav Canada initiated a discussion on the possibility of removing references to magnetic heading and using true north navigation. Following the completion of a survey, ICAO has created a group to further consider the feasibility and impacts of such a change.

Aerospace industries must understand the implications, assess the impacts including from a safety and an operational point of view and advise on the consequences, the risks, the costs and the feasibility of this transformation including the transition phase.

This transformation raises several challenges and significant costs for the aviation community to be balanced by the expected savings. Most modern civil aircraft modifications affect multiple systems in a limited manner but with large fleets and multiple configurations to address, while costs for business, regional and general aviation aircraft will be significant. The biggest challenges will be the transition phase, its duration, the acceptance by all ICAO states, the operational impacts for Crews & ATC, the coexistence of equipped/non-equipped aircraft and the cost of evolutions.

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1. SCOPE & OBJECTIVES

Air Navigation is currently organized and dependent on magnetic heading for historical reasons that go back to Maritime navigation. There are parts of the world where aviation safely operates in True heading reference today. In most aviation today, magnetic headings are utilized to orientate runways, and airways routes. Aircraft operating only using magnetic headings has become rare thanks to the introduction of GPS and Inertial systems. Therefore, to fly the magnetic designed routes, aircraft must convert their true heading into magnetic heading using a magvar database, that map the globe with local magnetic variations.

The local magnetic variations vary a few degrees over a period between 5 and 10 years, sometimes accelerating locally with a shorter time scale. The consequence is the need to maintain the survey of the local magnetic variations and the regular update of on-board database, WMM and Aeronautical Information Publications which has a significant cost for Airspace users (ANSPs, Aerodromes, Aircraft manufacturers, Air Operators). Since the technology appears to be available and equipping modern aircraft, Nav Canada initiated a discussion on the possibility to eliminate any reference to magnetic heading and to use a true north referenced navigation. Following a survey of members States and Industry, an advisory group (TRUE-AG) will be created in ICAO to further the development of ConOps, assess feasibility, identify benefits, risks, and costs and propose how a transition phase could be managed.

Aerospace industries through their ICCAIA membership such as aircraft manufacturers of any size and of any kind (Air Transport, Business & Regional, General Aviation, Helicopters, UAV), Avionics manufacturers and Ground Systems manufacturers are directly concerned by this change targeted for 2030. Therefore, they must understand the implications, assess the impacts including from a safety and an operational point of view and voice towards ICAO on the consequences, the risks, the costs and the feasibility of this transformation including looking at the transition phase.

To address these challenges, an ad-hoc group of ICCAIA CNS/ATM committee was created. The aim of this ad-hoc group is to study and assess all repercussions of true north navigation implementation from the Industry (ground and air) point of view, on technical, safety, certification, operational and economical aspects.

While the main focus is on the technical aspects, the development and certification/qualification of equipment involve safety, certification and operational aspects that will also be addressed in complement of other groups involving airworthiness experts, Air Navigation experts, regulators and Ops groups. This includes considering the transition phase.

This ad-hoc group of ICCAIA CNS/ATM Committee members is intended to contribute to ICAO effort to bring stakeholder analysis on potential True North Navigation. At the date of this White Paper, it includes representatives from two Civil Aircraft manufacturers, one Helicopter manufacturer, one Business Jet Aircraft manufacturer, two Avionics manufacturers and one Data Provider, all being regular participants of NSP, IFPP, ATMOPS, FLTOPSP and Aerodrome Panel. It is desirable that people from General Aviation manufacturers and from UAS/UAM Industry join the effort or instead that their point of view is being considered and heard, assuming they might not be able to participate to ICAO panels.

2. OPEN POINTS

The following points are kept open and will be addressed in a future version of this document and upon additional participation or inputs from ICAO are provided.

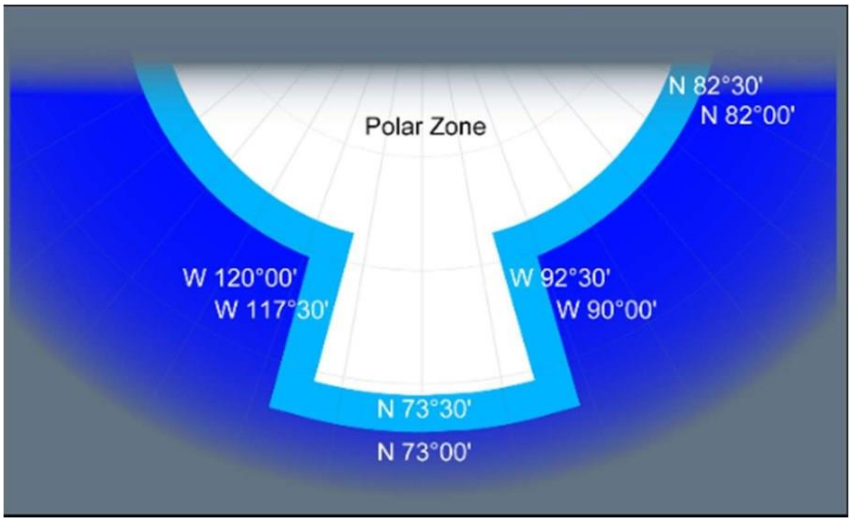
- UAS/UAM and Ground Navaids are not addressed because there were no participants from these industries.
- While several of the contributors have also military aircraft and derivatives, the impact on these platforms has not been assessed. Besides, some restrictions linked to the classification of information prevent from covering these aspects. It is expected that stakeholders involved in this effort for ICCAIA will cover this problematic within their organizations.
- Some aspects with regard to helicopters could not be covered and will be addressed in a future revision of this document.
- The costs aspects for many industry partners are not mature enough to be shared and need further investigation while some qualitative aspects have been shared in this first version.

3. BACKGROUND

The difference between Magnetic North and True North is the Magnetic Variation. The True North is the point of Convergence of Longitude lines whereas the Magnetic North is the location where the Magnetic Field lines converge. Indeed, the Earth can be modelled as a dipole with field lines leaving from the South Pole and converging to the North Pole close to True North Pole.

In order to navigate, itis necessary to indicate whether it is using True North Heading/Track or Magnetic North Heading/Track. The deviation between these quantities is called the Magnetic Variation. This Magnetic Variation is a function of the localization due to the earth crust movement and the iron density beneath. As a consequence, the Magnetic North Pole is always moving; at this point in time, it is shifting towards Russian territories.

Nav Canada has recently proposed to transition towards True Navigation. Canada has two airspaces with a Southern Domestic Airspace using a navigation based on Magnetic North and a Northern Domestic Airspace with the well-known key hole where True North Navigation is in force.



Key hole zone where True North Navigation is in force

Canada would like to explore the conversion of the Southern Domestic Airspace to operate in True North, using available technologies such as GNSS and Inertial Navigation. It is expected to bring significant benefits like a reduction in updating AIP, no need to survey zones where ground navaids (e.g. VOR) are located, a more precise navigation and a reduction of calibration flight tests. The cost reduction for Canada alone could reach millions of USD.

4. CONOPS ASSUMPTIONS

In the frame of this initiative, Nav Canada has established a ConOps, focusing on the Canadian airspace specificities and will form a good basis for a future global ConOps that should be developed in the forthcoming ICAO Study Group about True North Navigation.

The ad-hoc group reviewed the Nav Canada ConOps and raised the following observations:

- The case of cross-borders or cross-FIRs or large States navigation in case the two airspaces are organized differently, one in True and one in Mag, is not addressed. This is one of the key point that this ad-hoc group is concerned about. Indeed, it is expected that the transition to True Navigation will not be instantaneous and thus will be done by incremental steps. Besides, there could be some States that refuse to switch to True North Navigation. In any case, during a flight, several airspaces with different settings could be crossed whereas today the situation is non ambiguous with only the key hole area and appears only once for long haul missions.
- There is a lack of description of inter ANSPs coordination. Indeed, the Canadian situation looks at the northern and southern domestic airspace of Canada with only one ANSP. The ConOps shall address how ANSPs of different States will work and coordinate together.
- The transition phases over large States must also be questioned since it is expected that large States will not transition the whole airspace in one step.

The ad-hoc group has suggested ICAO to develop a global ConOps addressing both transition & end-state phases and this was described in an IFPP paper.

5. HOW DO WE NAVIGATE IN TRUE NORTH VS MAGNETIC NORTH

5.1 CASE OF AIR TRANSPORT

Many air transport aircraft are able to operate with both true north and magnetic heading references. Many, but the exact number is not known, flight decks are equipped with a heading reference switch that allows the pilot to change the heading reference from magnetic to true, and vice versa. Furthermore, the avionics equipment such as the flight management computers, inertial reference systems and ground proximity systems are equipped with magnetic variation (magvar) databases and navigation databases that contain magnetic declination field that support the conversion between magnetic and true headings. For many aircraft they are able to fly seamlessly with either true north or magnetic heading reference if properly equipped, either through automatic transition at the polar regions and/or activating a heading reference switch.

Aircraft that are not equipped with the necessary hardware and software would need to be upgraded and certified to enable true north navigation.

There is a cost in the updating and certification for each of the magvar databases which are also levied to the airline operators. Some airline operators choose not to update the databases if they do not see a cost benefit if

the aircraft have minimal impact flying in regions where magnetic declination do not vary greatly or if the estimated cost of operating the aircraft during the "life" remaining may not outweigh the cost to upgrade the databases. These aircraft may see discrepancies between the heading references calculated by the onboard avionics systems, if out of sync. A number of aircraft were designed decades ago when the navigation database standard did not support the magnetic variation field. Furthermore, not all flight decks may be equipped with the heading reference switch mentioned above as most aircraft flying continental operations outside the polar regions do not need to change intermittently between True and Magnetic heading references.

5.2 CASE OF BUSINESS JET

Business Jets can be considered to fall into four groups:

- AHRS only: A significant percentage are equipped only with AHRS and have no capability to select and operate in True Heading.
- IRS certified for Magnetic Heading Only: Of the aircraft equipped with IRS, most have a limitation against selecting True Heading. One, two or three IRS are installed to support oceanic operations, not True Heading.
- IRS Certified for True Heading En route Only: Some aircraft are certified to use True Heading only when en route and have a limitation against using True Heading for Departure, Arrival and approach.
- Certified for True Heading for All Flight Phase: Only a small percentage of aircraft have been certified for True Heading for all flight phases, including departure, arrival and approach. For aircraft of this type, when operating in airspace and on terminal and approach procedures defined by TRUE tracks, the flight crew are to ensure that the Primary heading reference is selected to TRUE. When operating in airspace defined by MAGNETIC tracks, flight crew are to ensure that the primary heading reference is selected to MAG. The Primary Heading Source automatically transitions from MAG to TRUE where the IRS automatically transitions from MAG to TRUE, and the crew cannot manually override the MAG/TRUE selection where the IRS equipment only supports TRUE heading. However, the IRS does not automatically transition from TRUE to MAG, and to resume using magnetic heading always requires a crew action. For some, but not all, conditions that the primary heading reference selection (true or magnetic) is incorrect for the current flight operation, the equipment provides a message, such as "CHECK HEADING REF", to the flight crew.

5.3 CASE OF REGIONAL TURBOPROP/JET

The case for Regional jet aircraft is the same as for Business aircraft.

Today, regional turboprops such as ATR can switch from a Magnetic heading to a True Heading through a selection on the MCDU, the conversion using the magnetic variation retrieved from the MagVar Database.
However, a capability to fly in HLN (High Latitude Navigation) is quite difficult as, with no IRS available, it requires to use existing AHRS in a Directional Gyro mode with the necessity for the crew to periodically re-align using NDB reference along the route. The performance is therefore not the best.

5.4 CASE OF HELICOPTER

For smaller aircrafts and operators which not only includes Rotorcrafts, there are many avionics configuration that still rely on the earth's magnetic field sensing through the use of magnetometer for the heading reference system. For these aircraft, there is no conversion needed today to operate. With the increased presence of electronic flight decks and flight management systems, most operators are also able operate in a True heading reference given they are equipped with these latest electronic flight decks. This is accomplished by using the MagVar

database to compute a magnetic based heading to a true based heading which is the opposite of what larger carriers using Inertial reference systems do. For older aircrafts using analog instruments, they simply lack the ability to convert the magnetic heading to true heading without relying on manual computation. For aircrafts occasionally operating in the Northern Domestic Airspace regions, when not equipped with an Inertial reference system an unslaved Directional Gyro mode not relying on magnetic sensing is used.

To be able to navigate using a true referenced heading, the access to a surveyed up to date MagVar database is crucial. Since today the majority of operators navigate in a magnetic referenced heading territory, they are not very concerned about maintaining an up to data database more specifically if their aircraft does not have the capability to operate using a True North reference. Moving to a global True North reference system would not alleviate the industry from the need to maintain surveyed MagVar databases as long as Magnetometer Slaved AHRS are flying.

5.5 CASE OF GENERAL AVIATION

The majority of recreational General Aviation aircraft lack EFIS (and thus a HDG REF switch) to portray true north headings. Those airplanes are equipped with magnetic compasses and directional gyros set with reference to the magnetic compass. Implementation of True North only would eliminate this basic method of navigation and drive expensive updates or withdrawal from use.

RNAV procedures frequently include “fly runway heading” legs as the initial legs of a departure procedure or a missed approach portion of an instrument approach procedure. Additionally, there are also many times these procedures include “course to altitude” or “course to fix” legs where the course is magnetic and thus is not truly a fixed track over the ground.

5.6 CASE OF DATA PROVIDER

When looked at from a data providers perspective, the coding and use of the data is consistent with what is published by State source. ARINC 424 allows the use of either true or mag bearings for a given data element. As of this time, either mag or true bearings can be coded, but they are mutually exclusive. Both are not possible to code on a single data element.

ARINC 424 provides provisions to code a procedure design mag variation on a given procedure, transition, or segment. This then can be used by downstream users of the data where they can then apply the mag variation as indicated by the procedure designer.

In some limited cases, primarily in far northern or southern latitudes, State source provides all bearings as true only. These are coded and can be provided to users downstream accordingly.

6. BENEFITS OF SWITCHING TO TRUE NORTH FOR INDUSTRY

6.1 CASE OF AIR TRANSPORT

In order to follow magvar evolution, it is necessary to update magvar databases every 5 to 10 years. Air Transport aircraft are usually equipped with two to three Inertial Navigation Systems. The update of magvar database it contains requires to certify a new equipment for each version/programme. For the airframer, it means a non-recurring (i.e. one-off) cost of validation and certification and for the airline, a recurring cost with an upgrade

through a Service Bulletin and a maintenance activity that also has a significant cost, according to the number of aircraft concerned, since the aircraft must be grounded and requires specific maintenance operations.

According to Nav Canada, for a large airline, the savings brought by the transition to True North Navigation include a simplified configuration management, a reduction of maintenance operations and the removal of limitations due to a non-updated magvar database. For 200 aircraft, it could reach 21 millions of dollars of cost savings every 5 to 10 years.

Large airliners like Boeing and Airbus are able to perform automatic landings use either ILS (Instrument Landing system) or GLS (GBAS Landing System) as a Navigation source and other sensors on-board the aircraft. In order to ensure correct tracking of the runway centerline during automatic roll-out, the use of runway heading can be one solution. This heading is referenced to magnetic North except at very high Latitudes. The magnetic heading is indicated through two figures painted at each runway end. Therefore, the magnetic heading of the runway and of the aircraft are both dependent of the magnetic variation quality and coherence. As such, Air Navigation Service Providers must maintain within 1° the magnetic variation for Cat II/III runways. Similarly, the aircraft must maintain the magnetic variation tolerance coherent of the ground and up to date in order to avoid any guidance issue. The tolerance is checked and maintained on a regular basis and airlines are informed when a magvar database version is not anymore within an acceptable tolerance compared to the one applicable on the ground. The operators can either upgrade their ADIRS at their expense with an updated MagVar database or leave it while accepting an operational limitation which is to not perform automatic landing on a number of affected runways. In principle, automatic landing using true course of the runway is feasible but may not be certified as there is a very limited number of runways above 70° of Latitude

Other aspects where magvar apply include the airways referenced to magnetic North, the need to apply the magvar to the True heading computed by the inertial system and the need to update the database in the FMS which is a normal process using the AIRAC cycle. For this latter, this could result in a small misalignment (a few degrees) displayed on the Navigation Display. The same applies on the HUD (Head Up Display) where the displayed runway could be slightly different compared to the real runway as seen by the crew.

Finally, this evolution could be a mean to harmonize the way the wind direction is utilized and displayed since the wind direction linked to an airport is in magnetic the one computed by the aircraft is in true.

Button TRUE/MAG and TRUE HDG indication

Display of TRUE mode on PFD/ND

6.2 CASE OF BUSINESS JET

There are no benefits unique to business jets. The technical benefit to switch to TRUE navigation is numeric courses and FMS lateral paths should agree with the charts because there are no discrepancies between actual, current local mag var and the aircraft mag var model and ground-based navaid declination. After True North operations are fully implemented everywhere in all aspects, it would prevent issues with incorrect lateral paths where it is ambiguous how to apply magnetic variation to the paths for local mag var and for ground-based navaid declination. Aircraft with IRS would no longer require using Mag Var tables that could be outdated very quickly.

The following explains the drawbacks of not having capability for True North heading for some or all flight operations. Business aircraft may have different suppliers of Avionics equipment. For example, the IRS and FMS can have separate suppliers and separate Mag Var Tables, either of which may be out of date. As discussed above, the MAG VAR tables may induce significant errors in heading/track referenced to Magnetic North, if the data are based on an old WMM Epoch year and/or differ between each Avionics system.

AHRS aircraft currently have no Mag Var tables and therefore have no errors due to out-of-date Mag Var tables and incur not costs to update Mag Var Tables. However, where procedures remain based on ground-based navaids, there can still be numeric and path discrepancies due to navaid station declination. FMSs in AHRS aircraft can still have numeric and path discrepancies with the charts because of discrepancies and ambiguities in how mag var should be applied.

Non exhaustive list of potential flight deck effects of magnetic operations that would be addressed by changing all operations to True North Reference:

- FMS with out-of-date Mag Var table: For en route operations on airways and point-to-point navigation, the display of the numeric track may differ from charted and actual track, but the ground track will be correct. For the special case that the crew manually selects course to intercept a fix, the lateral ground track may differ from the desired track. (Terminal operations on SIDs, STARs and approach procedures are not impacted, and en route operations to a fix that is a VOR are not impacted.)

- IRS with out-of-date Mag Var table: Unstable CAT II and CAT III Instrument Landing System (ILS) approaches
- Navaids not maintained/re-aligned to magnetic north: Where ILS/LOC, VOR and TACAN have not been maintained to remain aligned with magnetic north, this can have an indirect effect when using the FMS to overlay conventional procedures there can be numeric and sometimes lateral ground track discrepancies by the amount of the navaid misalignment.
- True operations
    - AHRS with out-of-date Mag Var table: Heading is in error by the amount of the AHRS mag var error.

6.3 CASE OF REGIONAL TURBOPROP/JET

The case for Regional jet aircraft is the same as for Business aircraft.

As for Air Transport Aircraft, concerning turboprop aircraft, benefits are expected on both operational workload, safety aspects and cost of operation.

On safety aspects, having true reference only will avoid some discrepancy observed today between different navigation components (FMS, IRS, TAWS, ILS) due to potentially different MagVar models (WMM, IGRF, USGS) or unsynchronized magvar model update between the components. Common source as well as update synchronization seems to be difficult.

Concerning the procedures, lack of repeatability and seamless navigation performance may arise on flight path segments lacking a common and consistent source of magnetic variation information. Errors in the magnetic variation increase the procedure construction errors at both the Flight Management System and Flight Guidance levels, leading sometimes to misleading legs orientation along a procedure. True Reference navigation will fix this issue and will improve significantly the level of safety of navigation with such magnetic sensitive legs in the flight plan, thanks to consistency between the different avionics' software and reference in True North.

On the cost aspect, savings are expected due to termination of magvar databases update, currently on a 5 years basis. Another source of savings is expected from an easier aircraft installation (no attached MSU) as well as the simplification of the initial and recurrent magnetic reference calibration on Magnetic Sensors Units (MSU), which requires dedicated calibration function. Also, some savings are expected when magvar database development, qualification, loading and verification activities will be terminated as they are of significant effort supported by the operator today.

When the Avionics equipage will allow true north navigation only (which is not currently the case for some aircraft (such as ATR, Dash8-Q400), and when the transitory period where two references will coexist will be completed, it means operational simplification, less update of procedures in the AIRAC cycles. Therefore, few savings are expected as navigation database loading and verification still represent some cost for the operator.

Concerning the weather data, roughly all wind data are expressed in magnetic reference when related to the runway (such as ATIS and ATCO reports) or from ATCO information over the radio whereas most wind data are in True reference for weather data/model reports such as TAF/METARs/Winds aloft, surface analysis charts. It implies a conversion to the Runway course expressed in magnetic reference to determine if the wind is within the airplane performance for max cross, head and tail intensity per airplanes limitation. Error with the application of the conversion to the magnetic wind orientation leads to erroneous calculation of the wind versus the limitations, a major safety concern with the take-off and landing preparation.

6.4 CASE OF HELICOPTER

For aircrafts equipped with Inertial reference systems, there is a benefit in which the need to maintain MagVar database is alleviated but for aircrafts that are equipped with AHRS relying on magnetometer sensing the earth's magnetic field to produce a magnetic reference heading, there is not much benefit.

Aircrafts equipped with electronic Flight Decks using magnetometer will still be required to maintain a valid MagVar database to convert the Magnetic heading to true heading. The change is going to drive additional requirement to maintain a valid MagVar database.

For smaller aircrafts and operators still using analog instruments, investments would be required to upgrade their avionics equipment or accept the increased pilot workload for a manual heading conversion during flight planning.

6.5 CASE OF GENERAL AVIATION

There are several areas where True North would be beneficial. First, PBN procedures are published with reference to ground track, a transition to true north navigation would harmonize all methods of air navigation along a common heading reference. In recent years, GA aircraft have started to deliver with EFIS capabilities, enabling native true north measurements. Second, the precision that will be necessary for the operation of advanced air mobility aircraft in urban environments will likely require true north heading reference.

6.6 CASE OF DATA PROVIDER

Bearings provided in mag require adjusting by States as time elapses and the magnetic variation shifts. States may need to update bearings on tracks only due to this in cases where the procedure does not require any additional changes. When this occurs, data providers will need to amend the coded information with the new mag bearings.

By eliminating the need to update magnetic variation, bearings, tracks and bearings do not need to be updated until an actual track or bearing change is needed by the procedure designer due to new obstacles, procedure track optimization, etc. This may mean less updates to track information as the true track remains consistent. Data providers may benefit from this as there will be less need to update tracks only for a mag bearing change due to variation shift.

7. OPERATIONAL & TRAINING IMPACTS OF SWITCHING TO TRUE NORTH PARTIALLY (TRANSITION PHASE)/GLOBALLY (END-STATE PHASE)

7.1 CASE OF AIR TRANSPORT

Upon the transition to True North Navigation, we need to assess and revise all operational procedures that would have a dependency with Magnetic/True North and identify what level of training could be needed. Impact on workload and capacity to manage multiple times during a flight the transition between the two worlds.

7.2 CASE OF BUSINESS JET

As discussed above, assessment and revise applicable pilot manuals and training will be required. Aircraft with newer avionics can already operate and transition between Magnetic and True airspace and there can be some leverage from this experience.

7.3 CASE OF REGIONAL TURBOPROP/JET

The case for Regional jet aircraft is the same as for Business aircraft.

Concerning Regional Air Transport, many regional jets or regional turboprop aircraft are not equipped with IRS. For instance, ATR and Dash8-Q400 aircraft are currently only equipped with AHRS. The issue is that the AHRS heading has to be corrected by the magnetic variation to be considered as a having true heading navigation capability.

So AHRS heading navigation performance is considered low due to:
- AHRS gyro drift,
- Earth rotation measured by gyros and no longer compensated by the slaving loop,
- Convergence of meridians not compensated (AHRS heading changes as a grid heading).

Therefore, a manual periodic heading re-alignment has to be performed by crew, for instance:
- Heading re-alignment on ground before take-off by using runway QFU (true reference),
- Heading re-alignment in flight by using Non-Direction Beacon (NDB) information.

The operational impact is significant and when the airborne equipment will allow true north navigation, this operational impact will be drastically reduced.

However, old airplanes, as well as some aircraft planned to be removed from service may still operate with no equipment retrofit by 2030 or 2035 when True North will be the basis. The traffic diversity is a theme that will have to be addressed on the ATC and pilots' sides to find a mitigation to maintain the level of safety with an acceptable level of workload for both. For the non-equipped aircraft there should be several ways forward such as reducing the quantity of vectors in directions, using point-to-point navigation, or applying an ATC surveillance with vectors expressed in quantified change of right/left directions rather than heading values.

Onboard, the operational improvement expected is better understanding and also less mistakes due to the MagVar reference coding with therefore improved confidence on FMS coded procedures, simplified training and airplane guidance improvement. No more complex Magnetic to True reference transition for oceanic sections. Improvement is also envisioned with low visibility operations in airports where a magnetic variation is significant and globally a better pilot confidence on the autoflight guidance for the Cat II, Cat III precision approaches where some are not possible today if the mag var is not consistent.

7.4 CASE OF HELICOPTER

For all aircraft relying on magnetic sensing to produce a magnetic heading, Training material and maintenance manual will need to be updated to account for the change to a True North heading reference. Emphasis on the importance and consequences of an outdated MagVar database is crucial.

7.5 CASE OF GENERAL AVIATION

N/A

7.6 CASE OF DATA PROVIDER

Training would be minimal, if at all, for the production teams at a Data Provider as Data Providers would only code and chart the bearings as published by the state.

Operational impacts are significant, however. As each data element that has a bearing needs to be changed in the coding and on charts, a large change during a given AIRAC cycle may create workload issues for Data Providers. A transitional plan similar to the RNP name change as outlined in ICAO CIR 353 would be preferred. This way it can be ensured that Data Providers are able to handle the changes when they are planned and scheduled.

8. TECHNICAL IMPACTS OF SWITCHING TO TRUE NORTH PARTIALLY (TRANSITION PHASE)/GLOBALLY (END-STATE PHASE)

8.1 CASE OF AIR TRANSPORT

Concurrently, ground navaids must be calibrated referenced to True North. Considering the limitations that can exist when magvar is not up to date, an analysis must be performed on this matter to assess the feasibility and the cost of modifications if deemed necessary.

As a preliminary summary, the following systems are concerned and may be impacted by the transition to True North.

Modern civil aircraft are already capable of flying True North
Two options are available, either to completely switch to True North or to maintain the duality True/Mag North

The systems concerned by the modifications:

- FMS (Flight Management System)
    - Update of databases with qualifier « true/mag »
- PFD/ND/VD (Primary Flight Display/Navigation Display/Vertical Display)
- ADIRS (Air Data Inertial Reference System)
    - Update of MagVar database with some zeros or removal of this database
    - Wind calculation in proper reference
    - Stand-By System
    - FGS (Flight Guidance System): Interpret True/Mag Heading for runway course
    - Switch « True/Mag » becomes basic if the dual system remains

8.2 CASE OF BUSINESS JET

A significant percentage of aircraft would need significant avionics updates. The existing equipment would need to be replaced with new and/or updated equipment, development flight tested, certification flight tested and the aircraft (S)TC updated. The aircraft fleet that is still using magnetic flux valves to feed AHRS compass data could be updated for non-magnetic based systems given enough lead time; however, such an update adds further costs

and may involve supply chain schedule delays because of the large number of aircraft needing the same equipment.

The Business Jets is similar to Air Transport in that the following systems may require updates for an STC for the transition to True North.

- FMS (Flight Management System):
- Display system, EFIS, PFD/ND/VD (Electronic Flight Information System, Primary Flight Display/Navigation Display/Vertical Display)
- IRS or AHRS
- Standby magnetic reference system:
- New format and certification for databases used by IRS, FMS and Surveillance systems

8.3 CASE OF REGIONAL TURBOPROP/JET

The case for Regional jet aircraft is the same as for Business aircraft.

The technical impacts depend upon the availability of IRS for which there is no issue to operate in True North.
For aircraft not equipped with IRS but equipped with AHRS only such as ATR, navigation in High Latitude Navigation area requires to switch AHRS from MAG mode to Directional Gyro (DG) mode, in which the heading is no longer slaved to the flux valve magnetic reference, and which requires periodic manual re-alignment which does not really fit to True North navigation
A possible work around could be to use new technology such as gyro-compassing S-AHRS (using the MEMS – Micro-Electro-Mechanical-Systems – technology) with promising performance (0.05°/hour drift) and no more magnetic measurement required.
Despite a much higher cost than AHRS (but still less than IRS), and the necessity to use and update the MagVar database during the transition phase where Mag referenced procedures are used, the advantages are:

- No more MSU (Magnetic Sensing Unit) calibration
- Simplified installation
- Less sensitivity to EM fields

8.4 CASE OF HELICOPTER

The change would require assessing the impact on all avionics equipment making use of heading information (i.e. Transponders, weather radar, TCAS, mission equipment) along with Flight Manuals and maintenance manual revisions, also evaluation of the impact against some AC guidance material which was used for the initial certification could drive extensive efforts to ensure compliance is maintained.

The change is also going the affect almost if not all the electronic flight Decks and Flight Management Systems. As an example, when it comes to NAVAIDS, they are assumed to be referenced to a magnetic north. The change is not just limited to switching the NAVAIDS heading reference but also upgrading all the equipment that are processing the NAVAIDS information. In all of today's cockpit, regardless of the native AHRS heading reference (IRS vs Salved AHRS), when selecting True north reference for navigation, the system uses the NAVAIDS referenced in magnetic and applies the MagVar Correction to convert it to True North. Switching the NAVAIDS reference is going to affect every system that assumes a magnetic reference from the NAVAIDS. The heading reference switch will drive upgrades to all existing equipment that is currently using a MagVar database for computation. The simple idea of removing the database for computation will drive a change for these systems.

8.5 CASE OF GENERAL AVIATION

Many manufacturers engaged in the design and production of general aviation (GA) aircraft and avionics hereinafter hold serious reservations about the wisdom and feasibility of the proposed implementation of true north navigation as the primary means of heading reference in air navigation. However, some allow that the true north proposal is technically feasible and within reach of the aviation community given a reasonable timeframe.

Those manufacturers that are concerned highlight the following points:

1. The majority of the GA fleet is equipped with the simplest, most tried-and-true instrumentation to measure heading: mechanical gyroscopic direction indicators. Pilots update their directional gyros—as well as non-slaved horizontal situation indicators (HSIs) in aircraft so equipped— before and during flight, nulling out heading inaccuracy that results from gyroscopic precession and drift, with sole reference to the magnetic compass. Aircraft with slaved HSIs likewise depict magnetic rather than true headings based on gyro-stabilized input from the flux valve magnetic sensor. In the absence of expensive equipment upgrades, the flight instruments in these aircraft lack any true north measurement capability, and their pilots would be wholly reliant on procedural methods to operate in a true-north-based air navigation system.

2. For aircraft with more advanced equipage, attitude and heading reference systems (AHRS) based on micro-electromechanical systems (MEMS) compute heading data but lack the capability of measuring true north. Rather, MEMS-based AHRS—which are common amongst more advanced business and GA aircraft—measure heading with a magnetometer and use AHRS for stabilization. In aircraft equipped with electronic flight instrument systems (EFIS), MEMS based AHRS feed raw magnetic heading data into the EFIS, which may convert a magnetic heading measurement to a true heading for purposes of display to the flight crew by adding or subtracting declination from magnetic variation models. One major avionics manufacturer advises that, at the current and near- to medium-term levels of technology, MEMS-based AHRS will not be capable of independently measuring true north for the foreseeable future.

3. Transition to true north operations carries with it unintended risks to aviation safety, largely related to human factors.

   First, in aircraft without EFIS or other instrumentation that can display true headings to flight crews, a requirement for pilots to manually convert their magnetic headings to true headings would significantly increase workload, unnecessarily increasing pilot workload and thence risk to the safety of flight.

   Second, safety risks would still accrue in aircraft with true-north heading reference capability, especially when true north, instead of magnetic, reference is the default heading mode. In States or regions whose ANSPs have not implemented true north navigation as well as in certain non-normal exigent situations in flight, for example, safe operation may require that pilots select “magnetic” instead of “true” as their heading reference source. This extra procedure introduces the bundle of safety risks associated with inconsistent operational procedures, especially when pilots are accustomed to flying in States that have adopted true north navigation.

   Third, there are safety risks associated with the logistics of coordinating a worldwide change from magnetic to true that includes updating every procedure, every navaid, every runway marking, every aircraft, training for every pilot, and the like. Expecting such a change to occur “overnight” and without incident is unrealistic.

Fourth, there will be safety risks associated with equipage. As mentioned above, in EFIS equipped aircraft, display modes and associated selectors and legends will become more complicated with multiple modes required for magnetic and true north navigation. Risks also would arise in cases of equipment failure, even in aircraft equipped to provide true north reference either natively (e.g., true-north-seeking inertial) or by conversion (i.e., magnetic conversion to true north), because the backup heading instrument installed in nearly all aircraft (including large transport aeroplanes) is an unpowered magnetic compass.

8.6 CASE OF DATA PROVIDER

Systems exist today where both Mag and True bearings can be captured when provided by the state. Therefore, there should be little to no technical impacts. This would be limited to small system adjustments depending on what may be present in the Transition Phase.

For charting, a method to ensure users have access to both values in case their FMS/Avionics may not be updated or able to handle true would be to chart both magnetic and true bearings for all tracks as part of the transition.

9. ROUGH ESTIMATE OF COSTS AND EXPECTED READINESS TO TRANSITION TO TRUE NORTH FOR INDUSTRY

9.1 CASE OF AIR TRANSPORT

All avionics systems users of magnetic heading/track will need to be adapted, certified and deployed simultaneously. The modifications are probably small to medium complexity and will affect, as a minimum, the systems listed in §8.1. However, the number of systems concerned and the number of configurations existing per aircraft type and for each aircraft type will make the evolutions, the cost of certification and the cost of upgrade potentially quite significant for the airframe manufacturers and the airlines.

9.2 CASE OF BUSINESS JET

The business case to update an STC for the sole purpose to add capability for True Heading for all operations is not obvious. STC costs are non-trivial, and the savings benefits are realized only long term for inertial-based installations, accruing in five-year increments with each Mag Var Table update.

The costs and effort for an STC are according to the magnitude of the equipment changes:

- AHRS only: A significant percentage are equipped only with AHRS and have no capability to select and operate in True Heading. These aircraft would involve the most equipment updates and would involve the most costs and effort. It would be expensive.
- IRS certified for Magnetic Heading Only: Of the aircraft equipped with IRS, most have an AFM limitation against selecting True Heading. There would be reasons for the AFM limitation. Hence, these aircraft would need equipment updates, but the costs and effort are expected to be less than for AHRS only aircraft. It would still be expensive, but less expensive than for an AHRS-only aircraft.
- IRS Certified for True Heading En route Only: Some aircraft are certified to use True Heading only when en route and have a limitation against using True Heading for Departure, Arrival and approach. There would be reasons for the AFM limitation, and the costs and effort could be as much as for updating the Magnetic Heading Only aircraft. The expense would be approximately the same as to update an aircraft in IRS certified only for Magnetic Heading

9.3 CASE OF REGIONAL TURBOPROP/JET

The case for Regional jet aircraft is the same as for Business aircraft.

Although it might be possible today for regional Turboprops such as ATR aircraft to perform some “degraded” True North Navigation provided a manual periodic heading re-alignment is performed by the crew invoking a subsequent training, it is not envisioned to have those aircraft ready before a capable technology such as S-ARHS is installed onboard which means readiness might not be before at least 2027 provided customers estimate it is worth the return on investment.

Costs are difficult to estimate but it should be significantly more expensive for these aircrafts to be equipped with True reference navigation capable IRS or even with S-AHRS than with AHRS.

9.4 CASE OF HELICOPTER

This will be covered in a future version of this document.

9.5 CASE OF GENERAL AVIATION

The cost associated with this transition, from a manufacturer’s perspective, would vary widely from one manufacturer to the next. However, it would be extensive as most manufacturers would be required to hire new engineers and maintenance personnel to efficiently staff the design and implementation of these changes across a vast fleet of aircraft. From a General Aviation aircraft owner perspective, in some cases, the cost to upgrade capabilities would exceed the value of the aircraft.

9.6 CASE OF DATA PROVIDER

Rough one-time, up-front costs would reach into the eight-figure range for Data Providers. Annual costs would reach into the six-figure range until the transition to true is completed globally.

10. RISKS & CHALLENGES IDENTIFIED BY INDUSTRY TO BE ADDRESSED BY ALL STAKEHOLDERS (E.G. ICAO, ANSPS, AIRWORTHINESS AUTHORITIES, OPERATORS)

10.1 AIR TRANSPORT

The transition phase seems to be the most challenging part. Indeed, to have all States or to consider transition in a very large state would be done at once is improbable. For instance, the organization of ATC, the changes in documentations, the modifications of markings and the VOR calibration are some of the examples identified. Therefore, we must envisage how to manage the transition phase. The cost implications would need to be determined as we would need to maintain both systems on-board the aircraft.

Besides, we need to assess the operational implications in particular for a crew navigating between two FIRs or States, one being referenced to True and the other to Mag as it could happen multiple times during a long-haul flight. The operational impacts as well as the training impacts must be determined.

The Cost Benefit analysis will be different per stakeholder and we need to see how no one would be left behind and bear important costs.

Finally, UAS and UAM will enter the airspace and we need to manage their navigation coexisting with legacy platforms if the systems of navigation are different.

10.2 CASE OF BUSINESS JET

There are thousands of aircraft operating worldwide, of which only a small percentage are certified to operate in True Heading. The aircraft are from a variety of aircraft OEMs, and each OEM has a variety of equipment sets. For many aircraft, it may not be cost effective to update. Even in the case it might be cost effective, it may not be feasible to staff to the levels needed to develop and certify new avionics for so many aircraft in such a short time frame (less than 15 years). Although this would not stop the initiative, if these aircraft are to be accommodated, the practicality and timeline to continue to accommodate them needs to be considered in any transition plan.

In the case of a solution for AHRS to use GNSS position for the conversion to True heading, to make the primary heading source dependent on GNSS makes the aircraft operation significantly more vulnerable to GNSS interference, and the vulnerably increases as GNSS interference increasingly becomes more widespread worldwide. Loss of GNSS would result in misleading heading because presumably the heading would revert to magnetic. Spoofing and jamming the GNSS receiver could result in misleading heading, either steady state or erratic. Although might stop the initiative, this widely discussed implementation might have unacceptable safety risks long term.

10.3 CASE OF REGIONAL TURBOPROP/JET

The case for Regional jet aircraft is the same as for Business aircraft.

The main risk is definitely the transition period where some aircraft navigating in True Ref will share a common airspace with aircraft still navigating in Magnetic reference where the update of Mag Var reference tables will need to be performed periodically and synchronized as much as possible between the different systems (FMS, IRS) requiring it.

10.4 CASE OF HELICOPTER

This will be covered in a future version of this document.

10.5 CASE OF GENERAL AVIATION

The primary inhibitor for this proposed transition is the timeframe necessary to incorporate changes in every ANSP, every procedure, every manufacturer, every aircraft and every pilot. Another significant inhibitor is the various risks associated with this transition, especially during the failure of true north capable avionics and the likely transition back to basic navigation using magnetic compasses.

10.6 CASE OF DATA PROVIDER

Due to the potential workload of many changes within one AIRAC cycle, the lack of a transition plan is a blocker. A transition plan needs to be created, adopted, and implemented globally in order to manage the change globally and not put too much workload on Data Providers over a short time frame.

11. CONCLUSION & WAY FORWARD

A transformation of Air Navigation is envisaged by adopting True North Navigation by 2030, with several challenges ahead and significant costs for the aviation community to be balanced by the expected savings. Most modern civil aircraft modifications affect multiple systems in a limited manner but with large fleets and multiple configurations to address, while costs for business, regional and general aviation aircraft will be significant. The biggest challenges will be the transition phase, its duration, the acceptance by all ICAO states, the operational impacts for Crews & ATC, the coexistence of equipped/non-equipped aircraft and the cost of evolutions. The manufacturing industry represented by ICCAIA intends to play a significant role in the work of ICAO going forward.

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13. LIST OF ACRONYMS

ADIRS	Air Data Inertial Reference System
AFM	Airplane Flight Manual
AHRS	Attitude Heading Reference System
AIP	Aeronautical Information
AIRAC	Aeronautical Information Regulation and Control
ANSP	Air Navigation Service Provider
ATCO	Air Traffic Control Organization
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
CNS	Communication Navigation Surveillance
EFIS	Electronic Flight Instrument System
FIR	Flight Information Region
FLTOPSP	ICAO Flight Ops Panel
GAMA	General Aviation Manufacturers Association
GBAS	Ground Based Landing System
GPS	Global Positioning System
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
HLN	High Latitude Navigation
HUD	Head-Up Display
ICCAIA	International Coordinating Council of Aerospace Industries Associations
IFPP	Instrument Flight Procedure Panel
IGRF	International Geomagnetic Reference Field
ILS	Instrument Landing System
IRS	Inertial Reference System
Magvar	Magnetic Variation
MEMS	Micro-Electro-Mechanical-Systems
METAR	METeorological Aerodrome Report
MSU	Magnetic Sensors Units
NDB	Non-Directional Beacon
NSP	Navigation System Panel
S-AHRS	Super-AHRS
STC	Supplemental Type Certificate
TAF	Terminal Aerodrome Forecasts
TAWS	Terrain Awareness Warning System
TCAS	Traffic Collision Avoidance System
UAS/UAM	Unmanned Aircraft System/Urban Air Mobility
USGS	United States Geological Survey
WMM	World Magnetic Model