featured articles

The Impact of the Implementation of The North American Datum of 1983 (NAD 83) on Aeronautical Navigation in the United States*

Ronald M. Bolton

Chief, Aeronautical Chart Branch, National Oceanic and Atmospheric Administration, Rockville, Maryland 20852 U.S.A.

On October 15, 1992, the horizontal geodetic reference system used for all aeronautical charts and chart-related products published by National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) changed from the North American Datum of 1927 (NAD 27) to the North American Datum of 1983 (NAD 83). The Global Positioning System (GPS) now allows satellites to define much more accurately geographic locations in terms of latitude and longitude, utilizing an earth centered reference system; the NAD 83 is based on this new technology. As a result, the latitude and longitude of almost all points in the National Airspace System (NAS) were revised. The greatest coordinate shifts were in Hawaii and Alaska where latitude moved by as much as 1200 feet and longitude by up to 950 feet. In the conterminous U.S., the largest changes were approximately 165 feet in latitude and 345 feet in longitude. The impact to aeronautical navigation in the U.S. of the datum shift from NAD 27 to NAD 83 was not limited to aeronautical charts and related publications. All Flight Management Systems (FMSs) and Air Traffic Control Systems (ATCs) had to be modified to accept and utilize the NAD 83 coordinates. The impact of the implementation of NAD 83 on aeronautical navigation in the United States was significant.

INTRODUCTION

On October 15, 1992, the horizontal geodetic reference system used for all aeronautical charts and chart related products published by National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) changed from the North American Datum of 1927 (NAD 27) to the North American Datum of 1983 (NAD 83). This change was mandated by the Congress of the United States. The latitude and longitude of almost all points in the National Airspace System (NAS) were revised (see Figure 1). The greatest coordinate shifts were in Hawaii and Alaska where latitude moved by as much as 1200 feet and longitude by up

Differences Between NAD 83 and NAD 27

	CONTERMINOUS UNITED STATES				ALASKA				HAWAII				PUERTO RICO & VIRGIN ISLANDS			
	Range Min.	Range Max.	Avg.	Std. Dev.	Range Min.	Range Max.	Avg.	Std. Dev.	Range Min.	Range Max.	Avg.	Std. Dev.	Range Min.	Range Max.	Avg.	Std. Dev.
Latitude	-0.814	1.658	0.317	0.509	-6.014	0.595	-2.600	1.489	-20.251	3.523	-11.617	2.899	-7.279	-6.990	-7.128	0.079
Longitude (arc seconds)	-3.733	5.149	0.873	1.977	5.368	12.700	9.033	1.775	-10.261	-9.725	-9.993	0.114	-1.547	-1.305	-1.417	0.066
Latitude	-25.152	51.023	9.746	15.691	-185.828	18.432	-80.473	46.043	-622.975	-108.310	-357.282	89.223	-223.801	-214.887	-219.158	2.428
Longitude (meters)	-106.632	105.417	20.690	48.372	77.597	206.190	126.416	23.871	-294.455	-284.085	-289.432	2.622	-45.477	-38.181	-41.694	1.951

Figure 1: Latitude and longitude shifts as a result of the change to NAD 83 from NAD 27.

* Mention of a commercial company or product does not constitute an endorsement by the National Oceanic and Atmospheric Administration. Use for publicity or advertising purposes of information from this publication concerning propriety products or the tests of such products is not authorized.

to 950 feet. In the conterminous United States, the largest changes were approximately 165 feet in latitude and 345 feet in longitude (See Figure 2 & Figure 3).

BACKGROUND

Why is NAD 83 going to be the official datum? What were the problems with NAD 27? What makes this new datum, NAD 83, preferable to use? These are good questions that were often asked because NAD 27 had been utilized for many years.

There are some fundamental reasons why the geodetic reference system for the United States required reconsideration. Increased accuracy requirements by the surveying community, the introduction of improved and highly accurate electronic measuring systems, and the advent of satellite systems such as Doppler and the Global Positioning System (GPS) were all factors which contributed to the identification of weakness in NAD 27. Discrepancies between existing control systems and newly executed surveys utilizing improved technology dictated the establishment of an entirely new datum rather than a revision or repair of NAD 27. The NAD 27 control network was never completely adjusted and, as it grew, unpredictable errors and distortions were created (Schwarz et al. 1989). In summary, the use of NAD 27 became unacceptable (Dewhurst 1990) because of 1) an outmoded and obsolete mathematical representation of the Earth, i.e. the a and b axis were in error, 2) inconsistencies arising from partial adjustments of data on a regional basis, 3) limitations due to outdated survey instrumentation (Vogel 1986), and 4) use of a surface reference point in Kansas, Meades Ranch (MR), for the lower 48 states, Canada, and Alaska in the development of NAD 27 led to small errors in the vicinity of Meades Ranch but very large errors at greater distances away from the MR station. These factors led to inconsistencies that needed to be removed in order to provide an accurate and consistent datum reference system from coast to coast and between the nations within the North American Continent.

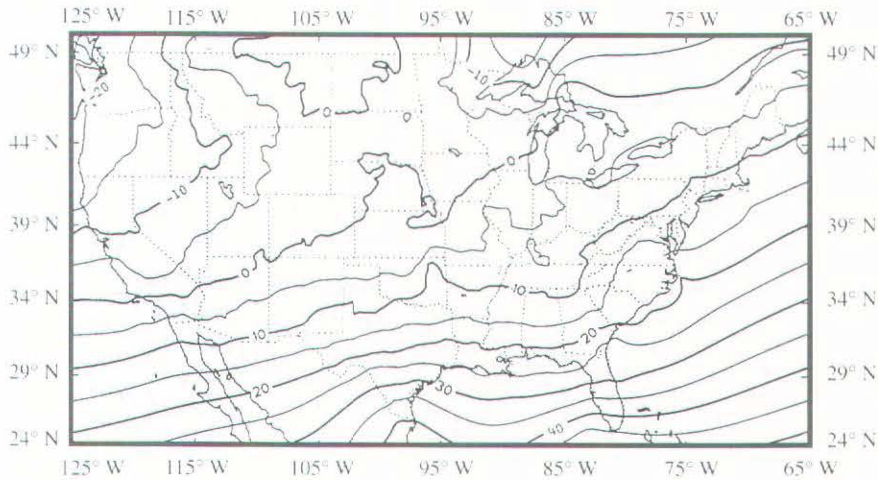

Figure 2: Latitude datum shift in the conterminous United States in meters (NAD 83 minus NAD 27) (from: Schwarz 1989).

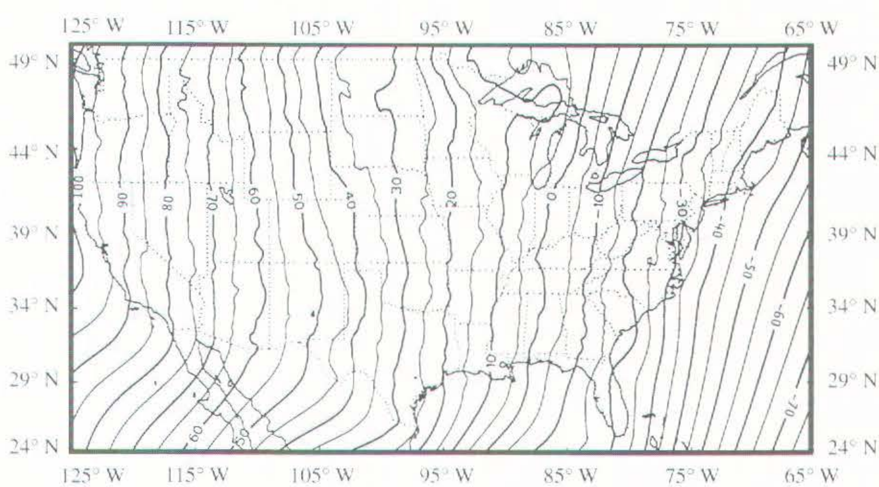

Figure 3: Longitude datum shift in the conterminous United States in meters (NAD 83 minus NAD 27) (from: Schwarz 1989).

DATUM IMPROVEMENTS

NAD 83 was a significant improvement over NAD 27 (Wade 1985) for several reasons. The Geodetic Reference System of 1980 (GRS 80) was accepted as the reference system for NAD 83 and the ellipsoid of GRS 80 was adopted for use in defining NAD 83 (see Figure 4). Various observations using Doppler satellite systems had shown that this ellipsoid better defined the correct reference ellipsoid than did the Clarke Spheroid of 1866 which NAD 27 utilized. The GRS 80 earth model was recommended by the International Association of Geodesy (IAG) and accepted by the National Geodetic Survey (NGS) of the United States (Schwarz et al. 1989). Because NAD 83 utilizes a geocentric origin, it is compatible with satellite systems such as the Global Positioning System (Burgess 1991) and the military World Geodetic System (WGS 84).

NAD 83 does away with the problems caused by geodetic observations made by outdated survey instrumentation. Astronomic observations at more than 5,000 stations, Doppler positions at over 600 stations, and 100 Very Long Line Interferometry Baseline measurements[1] using advanced technology led to very high level accuracies in the NAD 27 to NAD 83 adjustments. Doppler tests show NAD 83 to be in agreement with Doppler observations; North-South residuals have an RMS value of .591 meters and East-West residual components have an RMS value of .744 meters (Schwarz et al. 1989).

GEODETIC REFERENCE SYSTEM OF 1980
(GRS 80)

- Geocentric (Center of geoid Mass)
- Ellipsoid Parameters (GRS 80)

a = 6,378,137 meters (exactly)
b = 6,356,752.3141 meters
1/f = 298.257222101 (12 digits)

Note: Once NAD-83 is implemented, all software routines using the NAD-27 reference spheroid, Clarke Ellipsoid of 1866 (where a = 6,378,206.4 meters and b = 6,356,538.8 meters) will have to be altered to use GRS 80 parameters.

Figure 4: Characteristics of GRS 80.

Furthermore, the inconsistencies caused by partial adjustments on a regional basis were eliminated by utilizing a Helmert blocking strategy to adjust the whole NAD 83 geodetic network as a single system rather than a series of regional network solutions having no interconnection or interrelation. Thus, NAD 83 is a vast improvement over NAD 27 in terms of accuracy and compatibility with modern satellite technology for navigation (Skorupa 1990) and geodetic position determination.

IMPLEMENTATION IMPACT OF NAD 83 IN UNITED STATES AIRSPACE

The implementation impact of NAD 83 for aeronautical navigation was greater than expected due to the users it affects. Users of geodetic data can be grouped into three categories: primary users– geodesists and land surveyors who utilize and develop coordinate information directly; secondary users– those who employ the data produced by primary users in some manner such as mapping, charting and digital representations of the earth's surface; and tertiary users– those who use the work of secondary users in order to gain knowledge and insights. A pilot or navigator would be an example of a tertiary user. Typically, knowledge of surveying and geodetic datums decreases with each category of user. In fact, a tertiary user may have absolutely no concept of geodesy. However, it is critical for such a tertiary user, i.e. a pilot-navigator, to recognize a datum

[1] A major goal of the Very Long Line Interferometry Baseline measurements is to reduce the uncertainty in intercontinental baselines to the centimeter level. The measurements are based on vector separations between the antennas of two widely separated radio telescopes to produce an "interference" pattern.

inconsistency and be able to obtain and use coordinates in either datum with confidence and little problem. The tertiary users of coordinate data far outnumber primary and secondary users. Since the NAS of the United States is utilized, controlled, and described by such tertiary users of geodetic data– pilots, air traffic controllers, navigators, and aeronautical data specialists, the implementation of NAD 83 in the NAS has had a great impact and required careful planning.

In order to plan and implement the conversion from NAD 27 to NAD 83 in the National Airspace System, a committee was formed. The NOS, "The Nation's Aeronautical Chartmaker," the FAA and the National Geodetic Survey (NGS) had representatives on the committee. After a review of the conversion problem, the committee, chaired by Ronald M. Bolton (NOS), identified the following impacts (Bolton and Hoover 1986) to the regulators, FAA, and users of the NAS:

• Charts and Publications– all hard copy (both charts and publications) had to be revised in all areas that list or depict latitude and longitude.

• Digital Data– all digital data files with latitude and longitude fields had to be converted to NAD 83. This included air traffic control files, Flight Management Systems (airborne/ground based), and charting databases.

• Hard copy files– all documents containing latitude and longitude entries had to be marked to indicate that they were referenced to NAD 27 or NAD 83 (FAA and NOS identified over 1,000,000 such files or documents that must be properly labeled).

• Chart Graticule Shifts– most chart graticules were not affected because of the slight position change (usually less than .005 inches). However, 150 of 300 airport diagrams had their graticules shifted due to their large scales.

COORDINATE CONVERSION

To accomplish the coordinate conversion, a program, North American Data CONversion (NADCON), was developed by Warren Dewhurst of the NGS. The author recognized that a majority of users of coordinate data would not be geodesists and, therefore, developed a user friendly system that was very accurate (.15 to .5 meters) (Dewhurst 1990). The NGS and FAA distributed NADCON to all FAA activities and NAS users upon request. The conversion committee helped expedite the distribution and utilization of NADCON.

ANNOUNCEMENTS OF IMPLEMENTATION OF NAD 83 IN UNITED STATES NATIONAL AIRSPACE SYSTEM

The October 15, 1992 implementation of NAD 83 in the NAS was announced in several ways so as to reach the maximum number of interested parties.

• The Federal Register carried a notice.

• The Aircraft Owners and Pilots Association's Magazine carried a notice.

• FAA sent flyers to all regions and centers that announced the change, solicited questions, and requested recipients to return their "NADCON" software requirements to FAA HQ.

• NOAA/National Ocean Service sent out a notice to all chart sales agents and all subscribers to aeronautical charts and publications.

NAD 83 IMPLEMENTATION TASKS

The NAD 83 implementation work of the FAA and the NOAA/NOS Aeronautical Chart Branch (ACB) began in the summer of 1991 and continued until October 15, 1992. The FAA and NOS Aeronautical Chart Branch published revised coordinates for every coordinate position used in the NAS. This effort involved the processing of billions of characters in the NOS/ACB and FAA data bases. Datum notes have been added to all paper files, charts and chart related products; this effort required the review of millions of computer and paper file records.

The conversion from NAD 27 to NAD 83 went smoothly considering the scope and complexity of the task. All FAA facilities were ready for the change over. All revisions to charts, chart related products, and aeronautical publications produced to support safe flight in the NAS were completed.

BENEFITS FROM THE IMPLEMENTATION OF NAD 83

The NAD 83 implementation in the NAS allowed navigators and pilots to use the capabilities of the Global Positioning System (Wilkins 1992) and Loran-C[2] to their full potential. Puerto Rico, Hawaii, & Alaska were properly tied geodetically to the "Lower 48" (Conterminous U.S.) and Canada. The use of NAD 83 as the NAS reference datum also allowed international air carriers to use WGS 84 as they entered the US NAS without changing datum references systems, for the expected difference between the datums is small– less than a meter.

The long term impact of the conversion from NAD 27 to NAD 83 will be very beneficial because 1) NAD 83 will allow GPS satellites to be properly utilized for navigation in the U.S. NAS, 2) The conterminous U.S. will be geodetically tied correctly to Alaska, Hawaii, Puerto Rico and Canada, 3) Points in the conterminous U.S. will be defined more accurately and consistently, and 4) The U.S. NAS reference datum, NAD 83, will be consistent and compatible with the WGS 84.

CONCLUSION

In summary, the implementation of NAD 83 in the NAS improved aeronautical navigation in the United States. The massive datum conversion effort which was directed by FAA and NOAA will have a significant long-term beneficial impact on the aviation community.

[2] Loran C (LOng RAnge Navigation) is a system composed of ground-based transmitters called "chains" and airborne (or waterborne) receivers that derive the exact position, distance and bearing to a destination and the ground speed.

REFERENCES

Bolton, Ronald M. and Hoover, Russell A. 1986. Implementation of the North American Datum of 1983 into the NOS Aeronautical Charting Program. Paper presented at the XII Annual Meeting of the North American Cartographic Information Society.

Burgess, Alan. 1991. Global Positioning Systems (GPS) program status. In the **Proceedings of the 47th Annual Meeting of the Institute of Navigation (ION)**:397-400.

Dewhurst, Warren T. 1990. NADCON - *The Application of Minimum Curvature - Derived Surfaces in the Transformation of Positional Data from the North American Datum of 1927 to the North American Datum of 1983.* **NOAA Technical Memorandum NOS NGS-50.** Washington, D.C., January.

Schwarz, Charles R. (Editor). 1989. *North American Datum of 1988.* **NOAA Professional Paper, NOS 2.** Washington, D.C., U.S. Department of Commerce, NOAA, December .

Skorupa, Joe. 1990. *Navigation in the GPS age.* **Popular Mechanics.** 167(3):44 & 46.

Vogel, Steven A. 1986. *The new horizontal control datum for North America: NAD 83.* **National Geodetic Survey, C&GS, National Ocean Service, NOAA,** Washington, D.C., U.S. Department of Commerce, NOAA.

Wade, Elizabeth B. 1985. Impact of the North American Datum of 1988. In the **Proceedings of ASCE Convention**:49-62.

Wilkins, R. Ryan. 1992. Low altitude navigation and approach requirements V/STOL and CTOL. In the **Institute of Navigation (ION) Proceedings of the 48th Annual Meeting**:39-46.

RESUMEN

El 15 de octubre de 1992 el sistema horizontal de referencia geodética, usado para todos los diagramas aeronáticos y publicado por la Administración Nacional Oceánica y Atmosférica (NOAA) y por el Servicio Nacional de Oceanos (NOS) fueron cambiados del Datum norteamericano de 1927 (NAD 27) al Datum norteamericano de 1983 (NAD 83). El Sistema de Posición Global (GPS) permite que los satélities definan las posiciones geográficas de manera más precisa, en términos de latitud y longitud, utilizando un sistema de referencia centralizado. El NAD 83 está basado en esta nueva tecnología. Como resultado, casi todas las latitudes y longitudes en el Sistema Nacional Aeroespacial (NAS) fueron revisadas. Los mayores cambios de coordenadas se produjeron en Hawai y Alaska donde la latitud se movió 1.200 pies y la longitud hasta 950 pies. En el resto de los Estados Unidos los cambios mayores fueron de aproximadamente 165 pies en latitud y 345 pies en longitud. El impacto para la navegación aeronáutica en los Estados Unidos del cambio de NAD 27 a NAD 83 no fue limitado a diagramas aeronáticos. Todos los sistemas de vuelo (FMSs) y Sistemas de Control de Tráfico Aéreo (ATCs) tienen que ser modificados para aceptar y utilizar las coordenadas NAD 83. La implementación del NAD 83 en la navegación aeronaútica en los Estados Unidos es de mayor significancia.