Why the Greenwich Meridian Moved

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3 November, 2015

Sir George Airy (1801-1892)
7th Astronomer Royal

https://en.wikipedia.org/wiki/George_Biddell_Airy
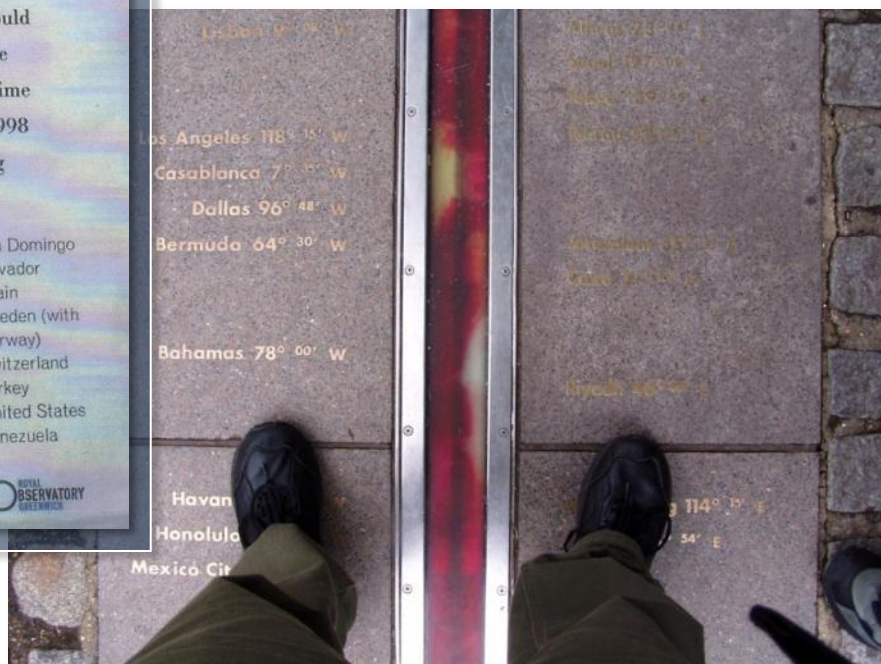
Prime Meridian (0⁰ Longitude…Greenwich Meridian)

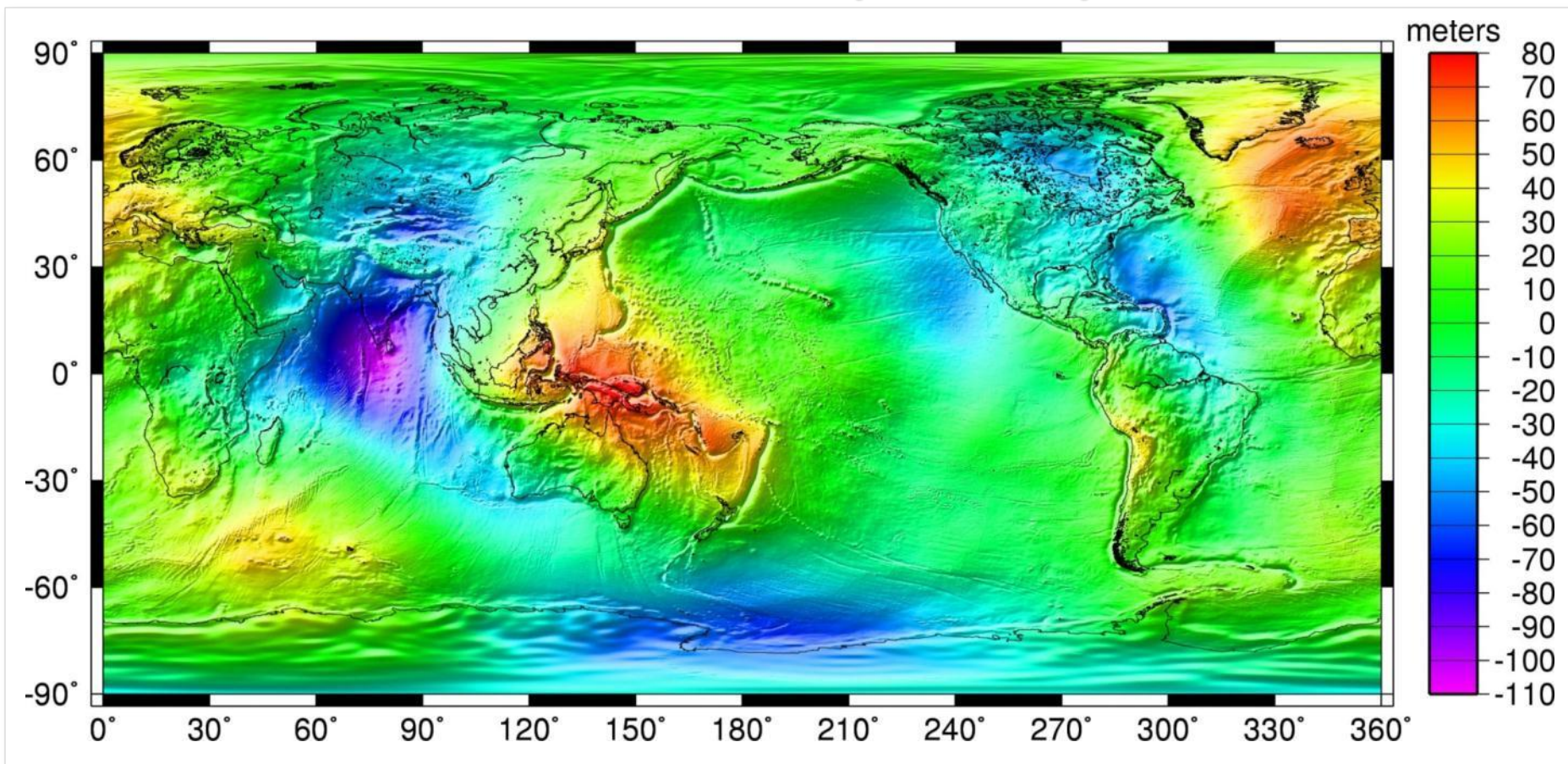**International Meridian Conference of 1884**

The Airy meridian (dotted line) and the ITRF and WGS 84 Zero Meridian (solid line)

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Geoid Undulations from the Earth Gravitational Model 2008 (EGM08)

A Global Potential Field and its Representation

The gravitational field generated by a mass distribution can be described *completely* using a scalar function of position called potential.

Gravitational Potential

Potential Coefficients

$$V(r,\theta,\lambda) = \frac{GM}{R}\left[1 + \sum_{n=2}^{\infty}\left(\frac{R}{r}\right)^{n+1}\sum_{m=-n}^{n}C_{nm}\cdot Y_{nm}(\theta,\lambda)\right]$$

Introduced by Gauss (1839) , Clairaut and Stokes (~1840) then by Helmert (1884)

For practical application, truncate "∞" to some maximum degree "Nmax".

1839, C.F. Gauss	Nmax =	4 *('WMM 39')* ⇒	**14**	**Magnetic Pot. Coeff.**
1960, I. Fisher	Nmax =	13 (Mod Mercury) ⇒	**192**	**Gravitational Pot. Coeff.**
1998, F. Lemoine et.al.	Nmax =	360 (EGM96) ⇒	**130,317**	**Gravitational Pot. Coeff.**
2012, N. Pavlis et.al.	Nmax =	2160 (EGM08) ⇒	**4,669,917**	**Gravitational Pot. Coeff.**

Deflection of the Vertical (η,ξ)

$$\Lambda - \lambda = \frac{\eta}{\cos\varphi}$$

North Pole

Zenith

Plumb Line

Ellipsoidal Normal

λ

Λ

Geodetic Meridian

Astronomical Meridian

ξ

P

Geoid

φ

Φ

Equatorial Plane
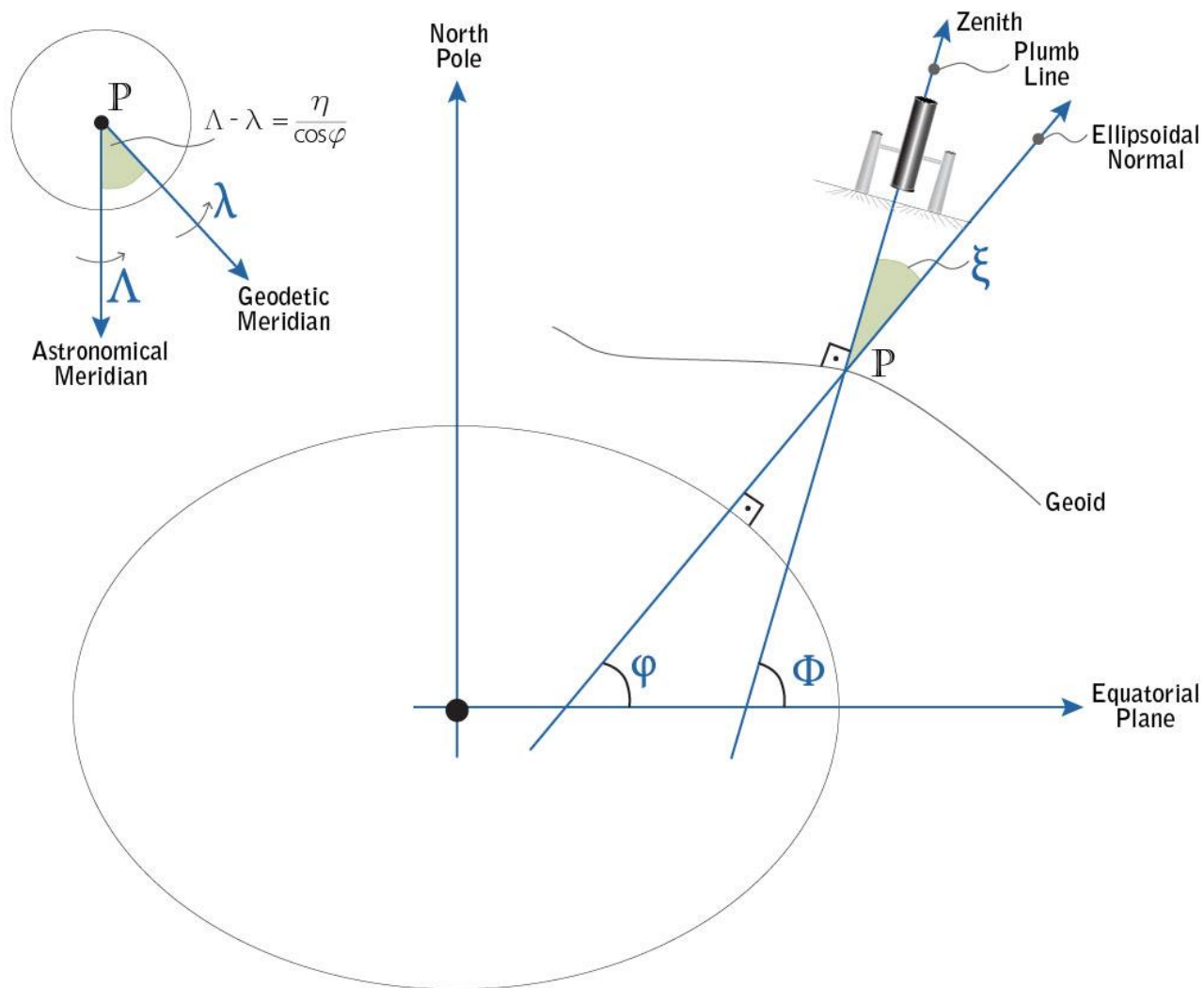
Schematic of a Typical Transit Circle

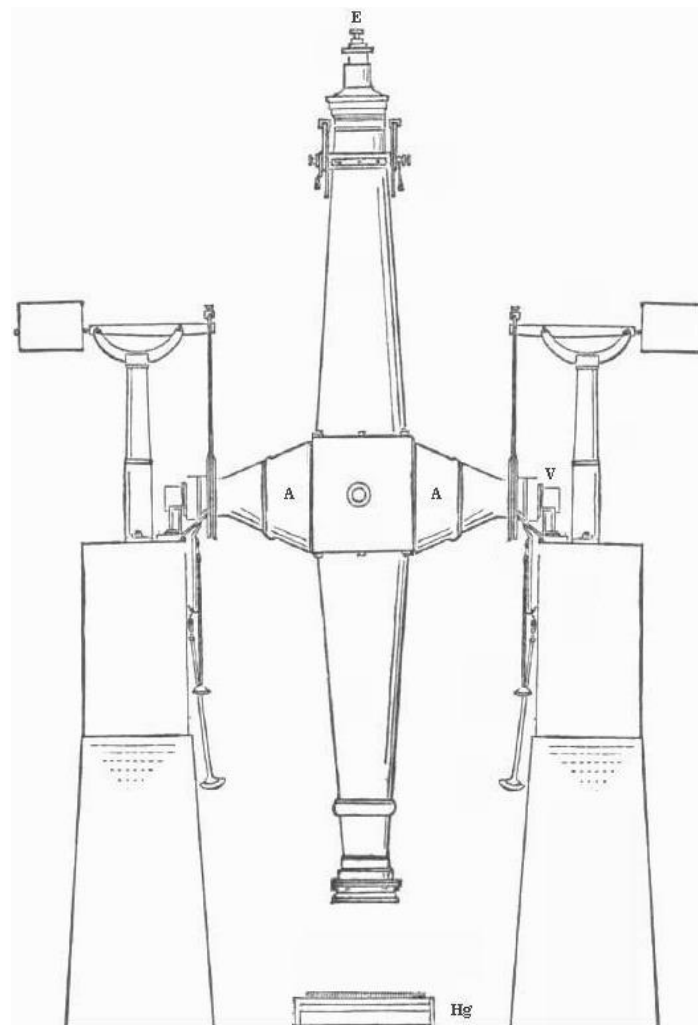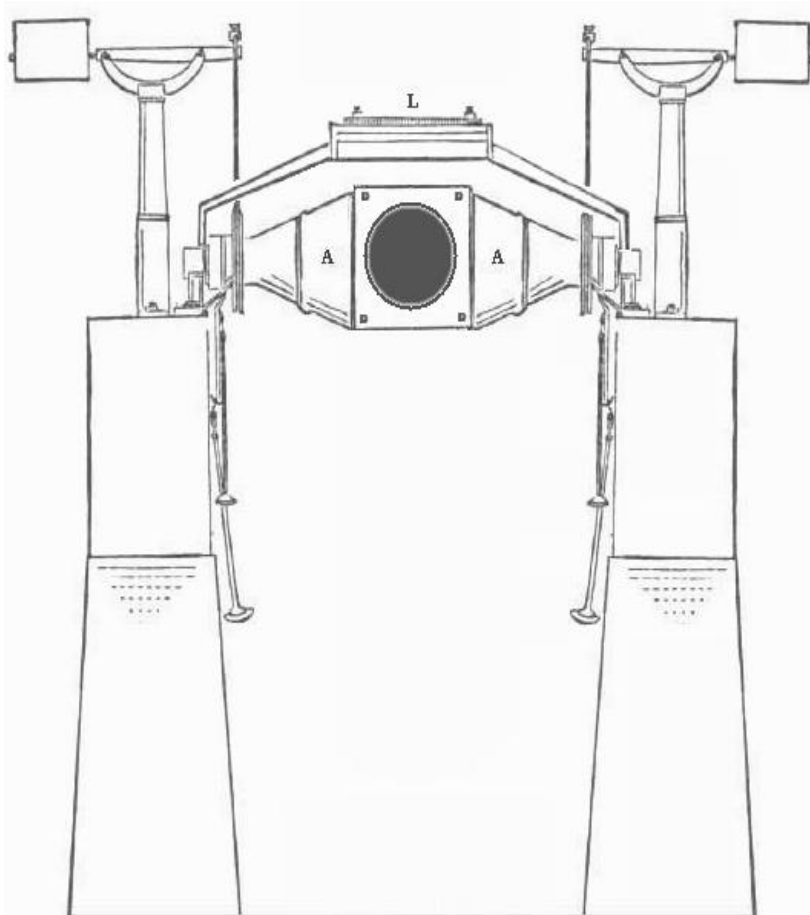Adapted from: Norton WA (1872) A Treatise on Astronomy, Spherical and Physical, 4th edn. John Wiley & Son, New York, p 31

BIH Terrestrial System 1984 (BTS 84)

Original WGS 84 reference frame was created by Transforming NSWC 9Z2 into BTS 84

Table 1 – BIH TERRESTRIAL

CONTRIBUTING NETWORKS

Name	Set of station Coordinates	Time span	Nb of coloc. sites	Status of the transformation parameters		
				Centre	Scale	Orient.
RN	SSC(NGS) 83 R 01	1980-1984	11	free	free	free
RJ	SSC(JPL) 83 R 05	1971-1983	5	free	free	free
MJ	SSC(JPL) 84 M 01	1970-1984	2	fixed	free	free
LC	SSC(CSR) 84 L 01	1976-1984	27	fixed	fixed	free
DM	SSC(DMA) 77 D 01	1975-1984	34	free	free	free

A : optical astrometry
D : satellite Doppler tracking
L : satellite laser ranging
M : Lunar Laser Ranging
R : Radio Interferometry (CERI, VLBI)

TABLE 3 – TRANSFORMATION BETWEEN THE INDIVIDUAL TERRESTRIAL SYSTEMS AND THE BTS

NETWORK	SSC	T1	T2	T3	D	R1	R2	R3
		cm	cm	cm	10^{-8}	0.001"	0.001"	0.001"
RN	SSC(NGS) 83 R 01	165.2	-94.9	47.1	-4.4	-5.2	8.0	-5.7
RJ	SSC(JPL) 83 R 05	10.1	-36.8	-15.1	2.8	-8.5	-5.0	-7.8
MJ	SSC(JPL) 84 M 01	0.0	0.0	0.0	-4.8	2.1	3.3	-8.8
LC	SSC(CSR) 84 L 01	0.0	0.0	0.0	0.0	-5.9	-2.6	-3.8
DM	SSC(DMA) 77 D 01	10.6	-69.7	-490.1	60.4	1.2	4.7	-813.7

The above parameters are to be used with equation (1), p. A-3.

This figure illustrates the key entries in the BIH 84 report

Selected offsets among prime meridians from the "Space Age" and the Airy Transit Circle.

The yellow circle provides a reference for each documented offset
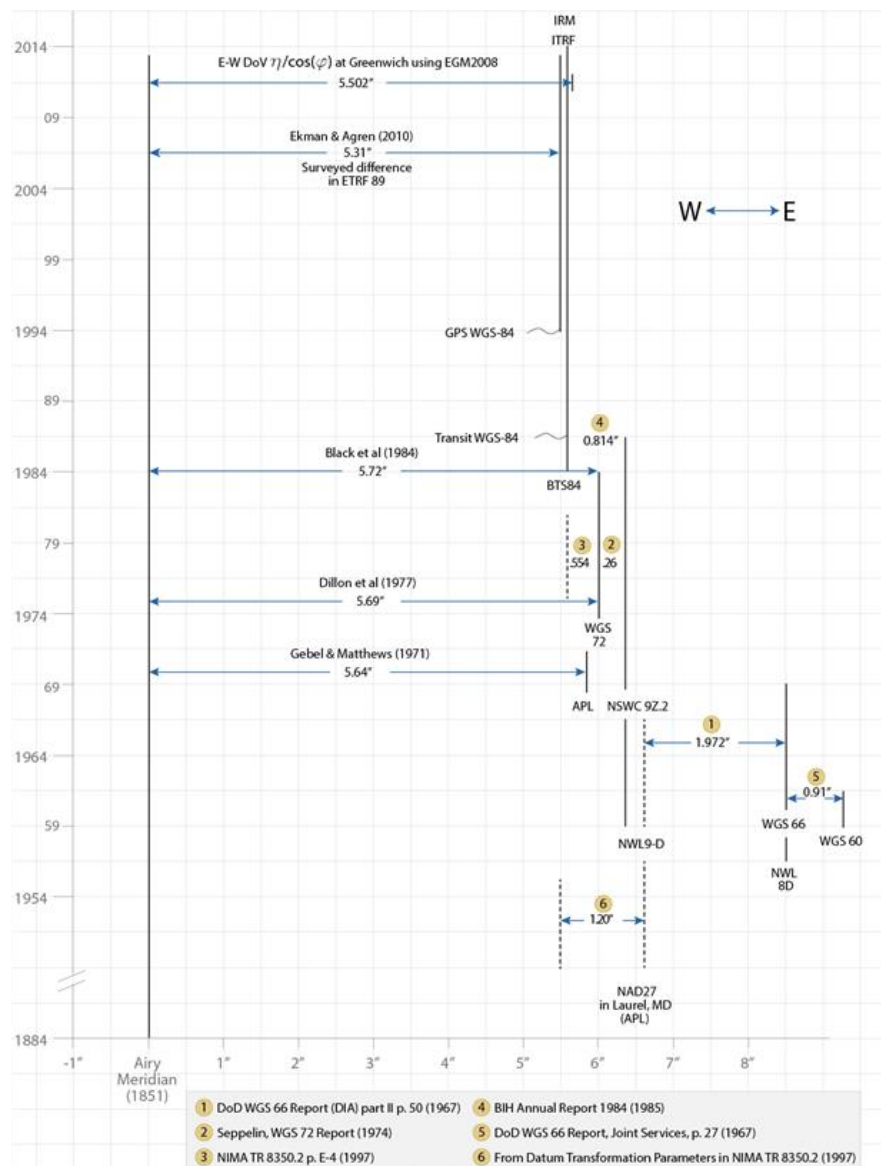
Why the Greenwich Meridian Moved

Orientation used to measure Universal Time (UT) remains the same

ITRF and WGS 84 zero meridian

Airy's zero meridian

DoV in East-West Direction at Greenwich

102 m

Location of Airy's Transit Circle (telescope)

Modern (geodetic) zero meridian

E/W Direction of Local Gravity through Airy's Telescope

Parallel of latitude at Greenwich

The dashed grey meridian and the solid grey meridians are parallel, therefore the Deflection of the Vertical (DoV) in the East-West direction can be seen at three places in the diagram

Mean rotation axis of the Earth, looking down from North Pole

Other 'Conjectured' reasons

X TRANSIT did it

X Errors crept into the BIH process

X Greenwich functions moved to Herstmonceux in 1957

X Polar Motion

X Crustal motion (Plate Tectonics)

X Improvements in the fundamental celestial reference frame

X GPS did it

For an in-depth, peer-reviewed explanation see:

Why the Greenwich meridian moved by: Stephen Malys[1], John H. Seago[2], Nikolaos K. Pavlis[1], P. Kenneth Seidelmann[3] & George H. Kaplan[4]. Journal of Geodesy

http://link.springer.com/article/10.1007/s00190-015-0844-y

[1] National Geospatial-Intelligence Agency, Springfield, VA
[2] Analytical Graphics, Inc., Exton, PA,
[3] University of Virginia, Charlottesville, VA
[4] United States Naval Observatory, Washington DC
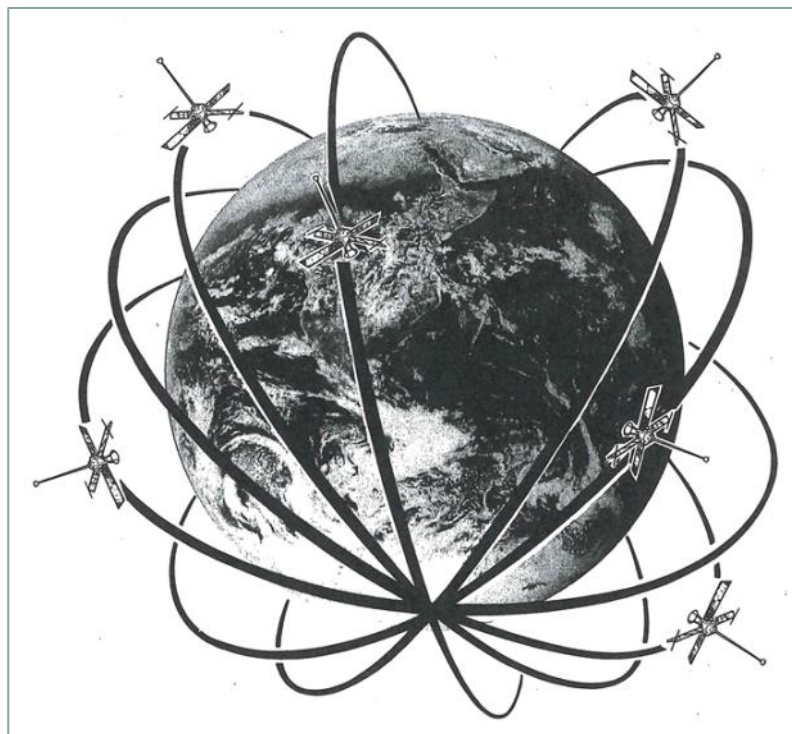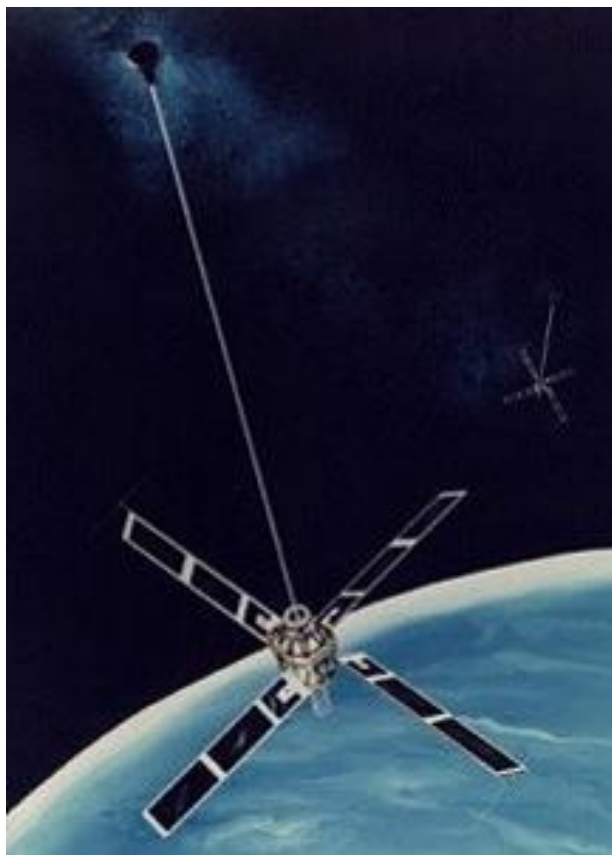
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Navy Navigation Satellite System
a.k.a. TRANSIT

Transit Satellites Form a "Birdcage" of Circular, Polar Orbits About 1075 km Above the Earth

Ref: The TRANSIT Navigation Satellite System, Thomas A. Stansell, Status, Theory, Performance, Applications, The Magnavox Government and Industrial Electronics Company, June, 1983

Early US Global *Geocentric* Earth Models

Need for these was driven by 'Long Range Missiles' & Defense-Related Satellites
Most of these were 'Classified' at the time and only declassified in1993

Name	Acronym	Methods	a (meters)	f
US Air Force 1958	USAF1958*	Gravimetric	6378270	1/297
US Air Force 1959	USAF1959	Gravimetric + f from Satellite Vangaurd1958β	6378185 +/- 50	1/298.3 +/- 0.1
US Army 1959	USA1959	Gravimetric + f from Satellite Vangaurd1958β	6378147 +/- 8	1/298.25
World Geodetic System 1960	WGS 60	Combination of earlier results	6378165	1/293
World Geodetic System 1966	WGS 66**	Gravimetric + TRANSIT, BE-B, BE-C, ANNA 1B, GEOS-A	6378145 +/- 20	1/298.25 +/- 2.2×10^{-7}
World Geodetic System 1972	WGS 72	'Unified'	6378135 +/- 5	1/298.26 +/- 0.6×10^{-7}

*a.k.a. USAF WGS 58,   ** a.k.a. DoD WGS 66 and builds upon NWL-5, 5K, NWL-8, 8B, 8D, APL