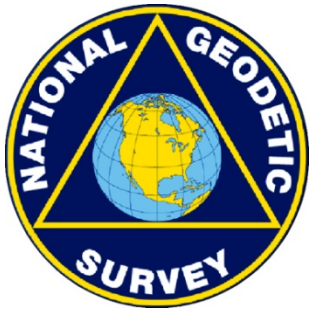
Modernization of the National Spatial Reference System



Maryland State Geographic Information Committee
Catonsville
January 26, 2011

Dave Doyle
NGS Chief Geodetic Surveyor
dave.doyle@noaa.gov
301-713-3178
ftp://ftp.ngs.noaa.gov/dist/DaveD/MSGIC

Mission and Vision of NGS

- To define, maintain and provide access to the National Spatial Reference System to meet our nation's economic, social, and environmental needs

- "Maintain the NSRS" means "NGS must *track all of the temporal changes* to the defining points of the NSRS in such a way as to always maintain the accuracy in the NSRS definition."

- Vision - Modernize the Geopotential ("Vertical") and Geometric ("Horizontal") datums

Problems with NAD 83 and NAVD 88

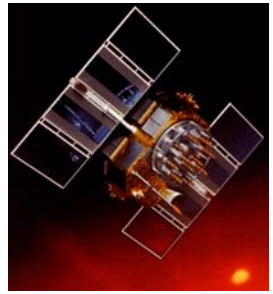
- **NAD 83** is not as geocentric as it could be (approx. 2 m)
  - Surveyors don't see this - **Yet**
- **NAD 83** is not well defined with positional velocities
- **NAVD 88** is realized by passive control (bench marks) most of which have not been releveled in at least 40 years
- **NAVD 88** does not account for local vertical velocities (subsidence and uplift)
  - Post glacial isostatic readjustment
  - Subsurface fluid withdrawal
  - Sediment loading
  - Sea level rise
    - **Annapolis – 3.4 mm/yr (0.01 ft/yr)**
    - **Baltimore – 3.1 mm/yr (.01 ft/yr)**
    - **Cambridge - 3.5 mm/yr (.01 ft/yr)**
    - **Chesapeake City – 3.8 mm/yr (.01 ft/yr)**
    - **Ocean City – 5.5 mm/yr (.02 ft/yr)**
    - **Solomons Island – 3.4 mm/yr (0.01 ft/yr)**

GLOBAL POSITIONING SYSTEM

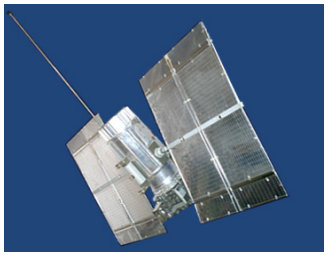
- 1978 1st NAVSTAR Satellite Launched (October 22, 1978)
- 1995 Fully Operational
- 2000 Selective Availability turned off (May 1, 2000)
- 2005 Additional Band L2C
- 2010 Additional Frequency L5 added (May 28, 2010)
- 2020? 10-50 cm real-time accuracy?

The Global Navigation Satellite Systems (GNSS) Constellations

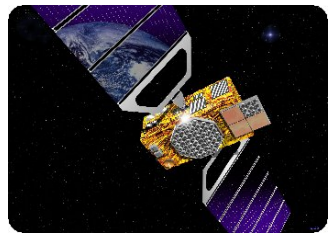
- Three positioning and navigation systems
  - Navstar/GPS – US (Currently 31)
  - Glonass – Russia (Currently 24)
  - Galileo – EU (Currently 2)
  - Beidou/Compass – China (Complete by 2020?)



US - GPS



Russia - GLONASS

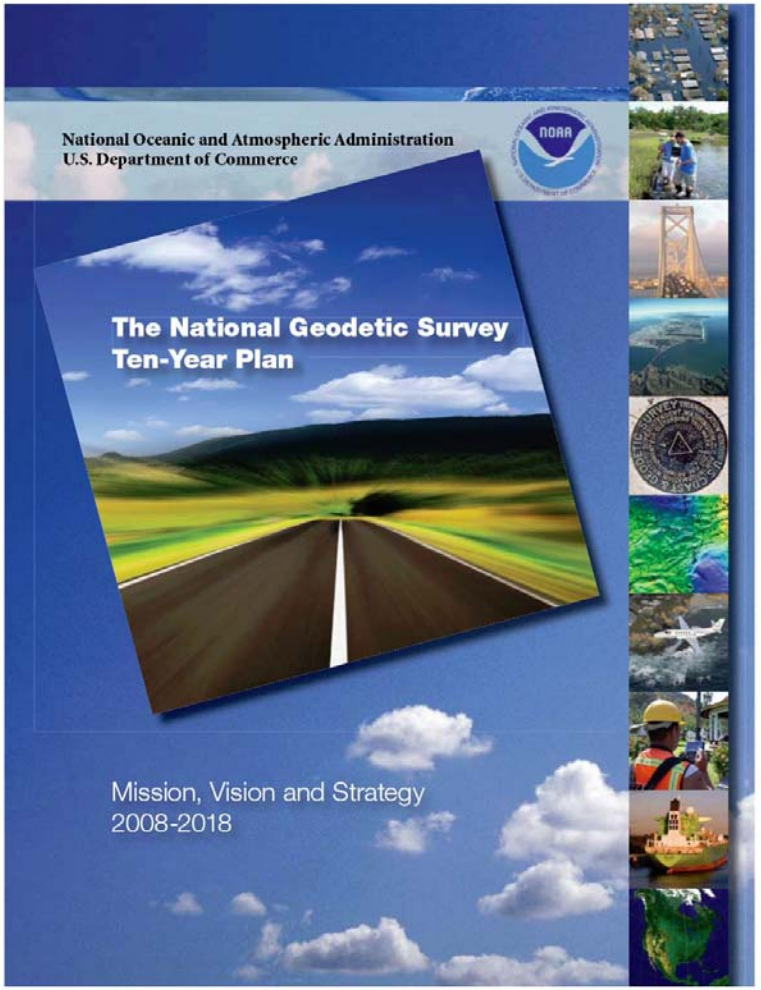


EU - Galileo

The National Geodetic Survey 10 year plan
Mission, Vision and Strategy
2008 – 2018

http://www.ngs.noaa.gov/INFO/NGS10yearplan.pdf

- *Official NGS policy as of Jan 9, 2008*
  - *Modernized agency*
  - *Attention to accuracy*
  - *Attention to time-changes*
  - *Improved products and services*
  - *Integration with other fed missions*
- *2018 (2022?) Targets:*
  - *NAD 83 and NAVD 88 re-defined*
  - *Cm-accuracy access to all coordinates*
  - *Customer-focused agency*
  - *Global scientific leadership*



File Edit View Go Bookmarks Tools Help

http://www.ngs.noaa.gov/TOOLS/ Go

NGS Geodetic Tool Kit

on-line interactive computation of geodetic values

See the text version of an article about the NGS Geodetic Toolkit that appeared in the *Professional Surveyor* magazine, May 2003 Volume 23, Number 4

(**See all the Professional Surveyor Articles about the NGS Geodetic Toolkit**)

To learn more about a particular online program, click on its link for a description:

DEFLEC99
DYNAMIC_HT
G99SSS
GEOID99
GEOID03
USGG2003
HTDP
IGLD85
Inverse/Forward/Invers3D/Forwrd3D
LVL_DH
Magnetic Declination
NADCON
NAVD 88 Modelled Gravity
Online Adjustment User Services
Online Adjustment Utilities User Services
OPUS
State Plane Coordinates
Surface Gravity Prediction
Tidal and Orthometric Elevations
U.S. National Grid
Universal Transverse Mercator Coordinates
VERTCON
XYZ Coordinate Conversion

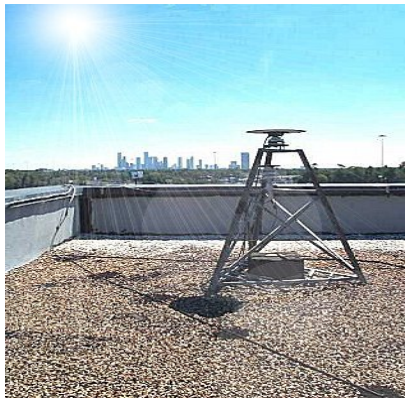
OR... Know what you want to do?
Select a function from this list:

SELECT A TOOLKIT SHORTCUT

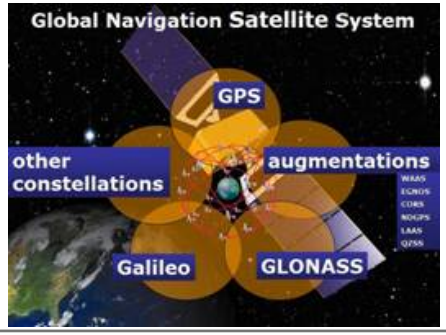
The NSRS has evolved

1 Million Monuments (Separate Horizontal and Vertical Systems) → 70,000 Passive Marks (3-Dimensional)

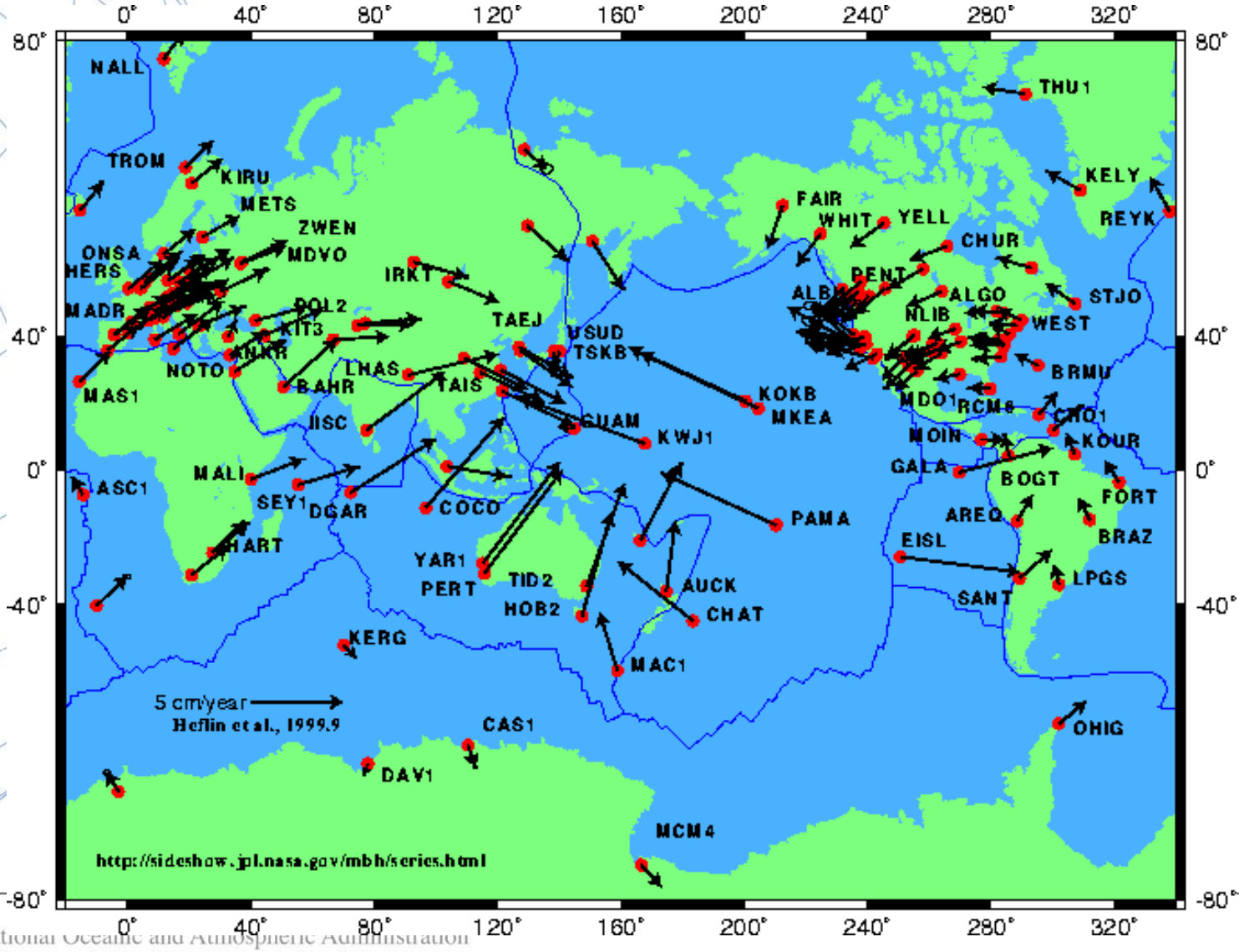
Passive Marks (Limited Knowledge of Stability) → 1,500+ GPS CORS (Time Dependent System Possible; 4-Dimensional)



GPS CORS → GNSS CORS

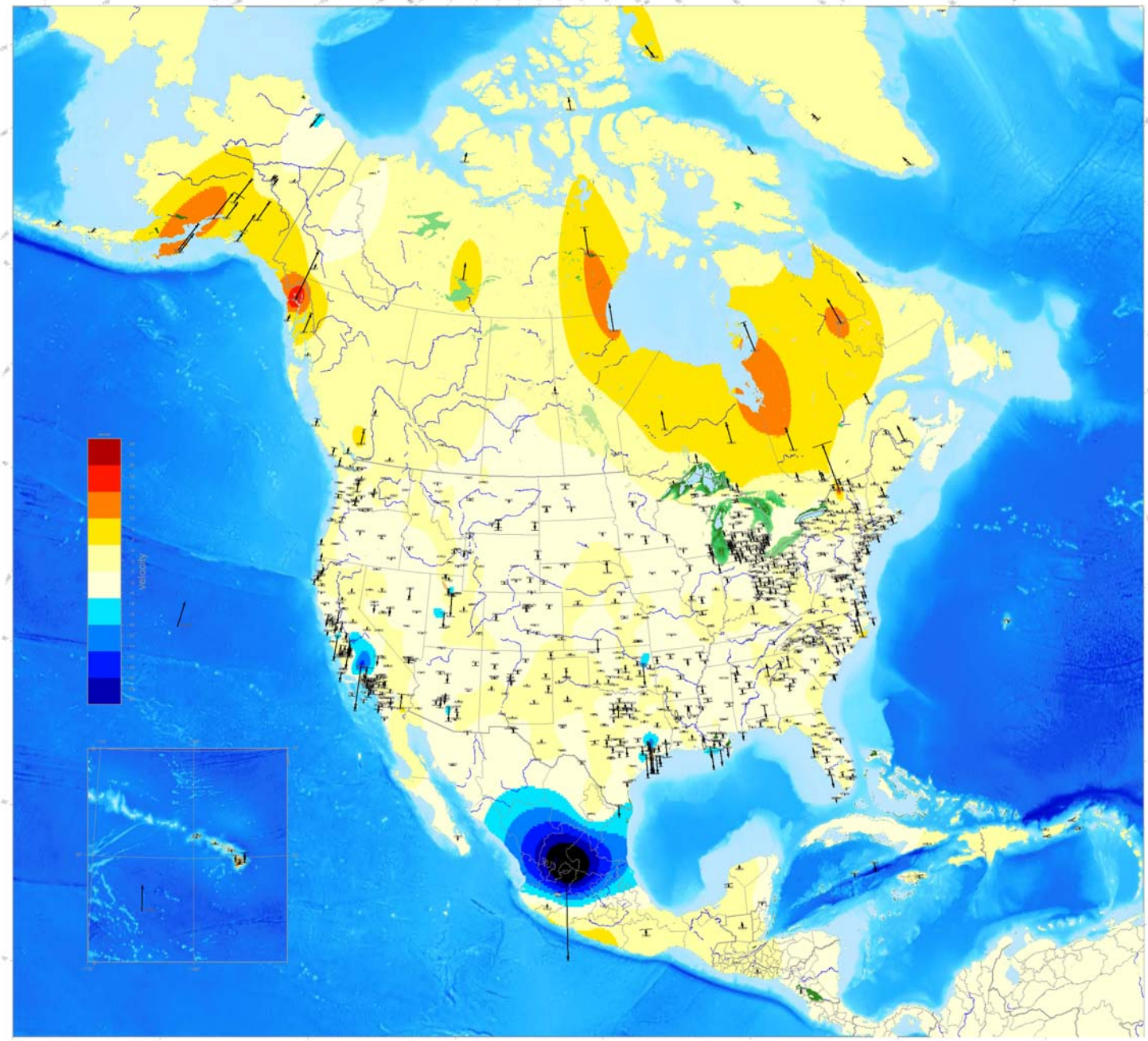


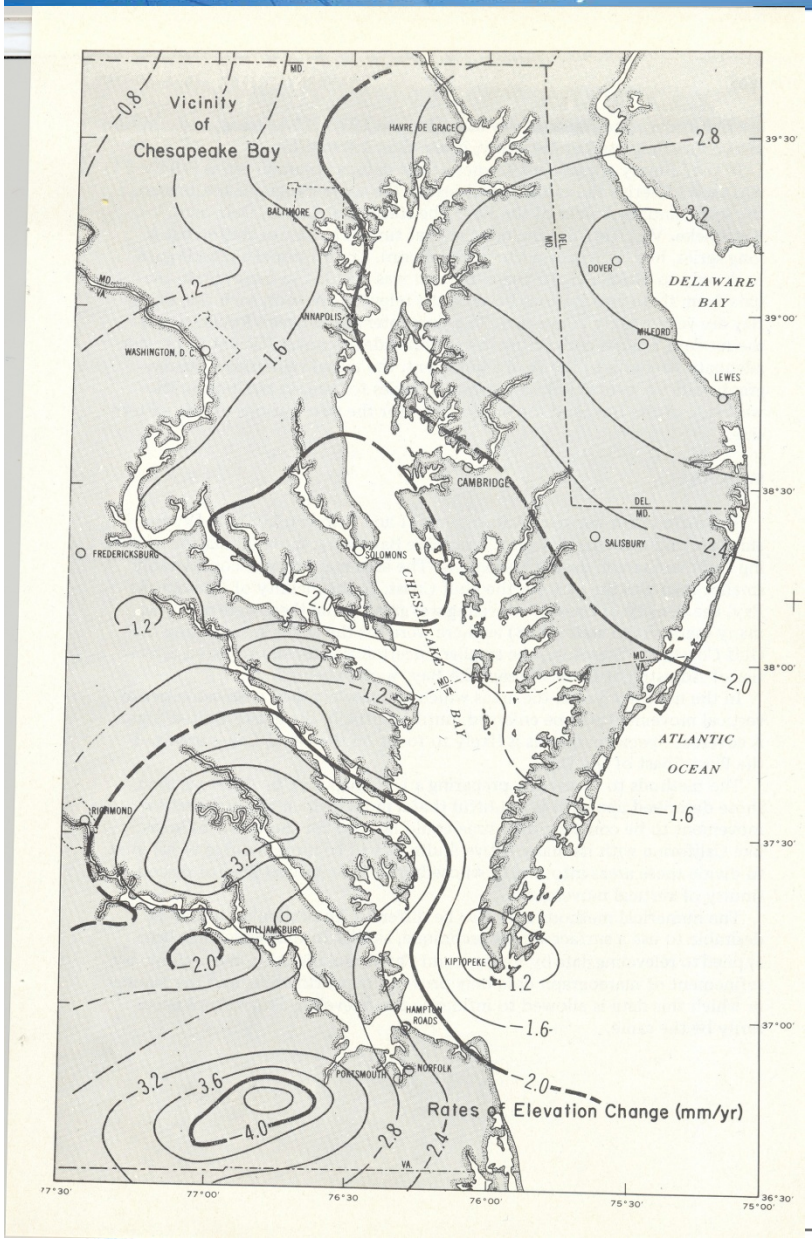
Tectonic Motions



HORIZONTAL VELOCITIES

VERTICAL VELOCITIES





Subsidence in Eastern Maryland and Delaware

"Regional Investigations of Vertical Crustal Movements in the U.S., Using Precise Releveling and Mareograph Data"
S. Holdal and N. Morrison
(1974)

International Earth Rotation and Reference System Service (IERS)

(http://www.iers.org)

The International Terrestrial Reference System **(ITRS)** constitutes a set of prescriptions and conventions together with the modeling required to define origin, scale, orientation and time evolution

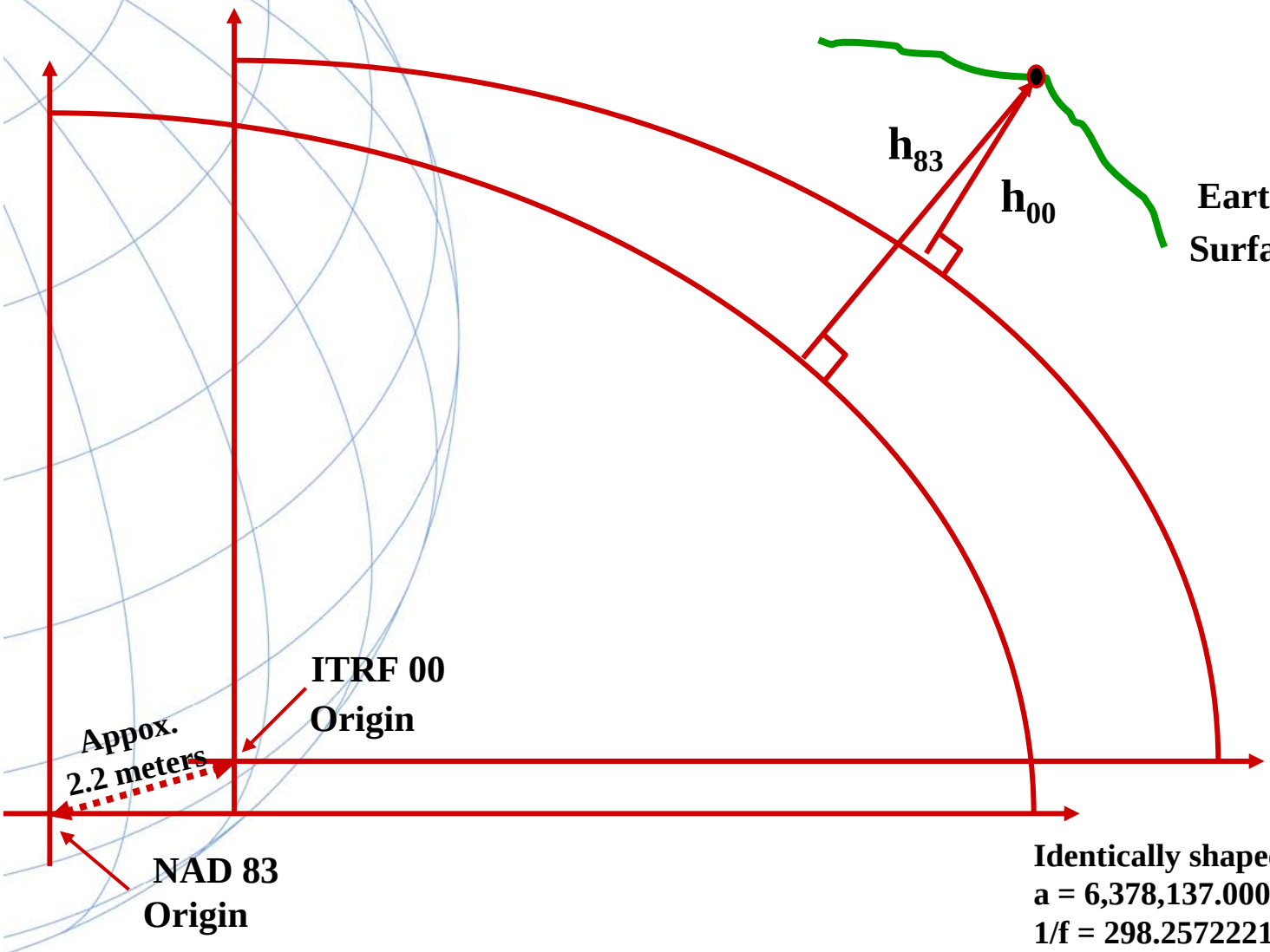
ITRS is realized by the International Terrestrial Reference Frame (**ITRF**) based upon estimated coordinates and velocities of a set of stations observed by Very Long Baseline Interferometry (**VLBI**), Satellite Laser Ranging (**SLR**), Global Positioning System and GLONASS (**GNSS**), and Doppler Orbitography and Radio- positioning Integrated by Satellite (**DORIS**).

ITRF89, ITRF90, ITRF91, ITRF92, ITRF93, ITRF94, ITRF95, ITRF96, ITRF97, ITRF2000, ITRF2005, ITRF2008

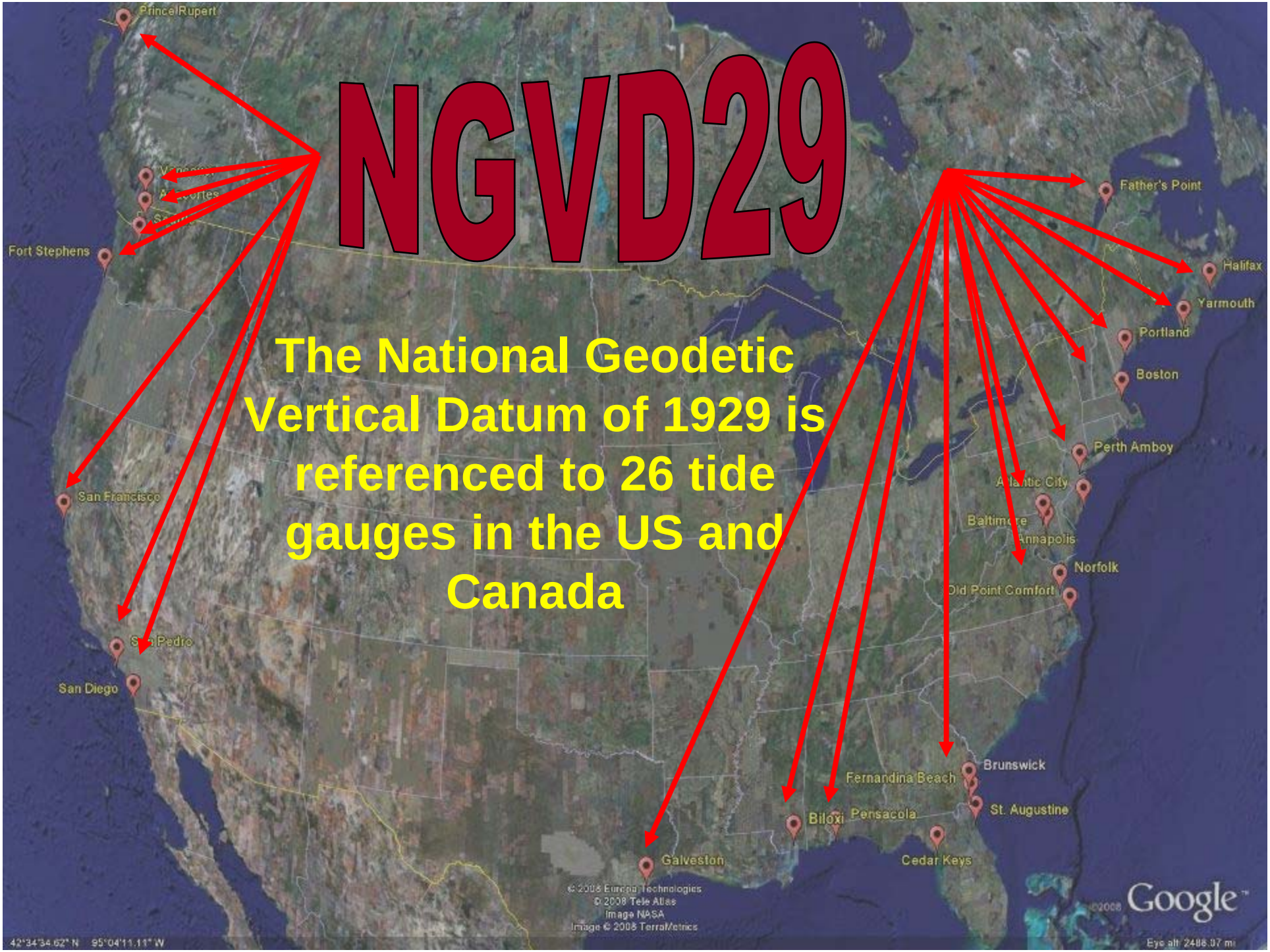
International Terrestrial Reference Frame

4 Global Independent Positioning Technologies

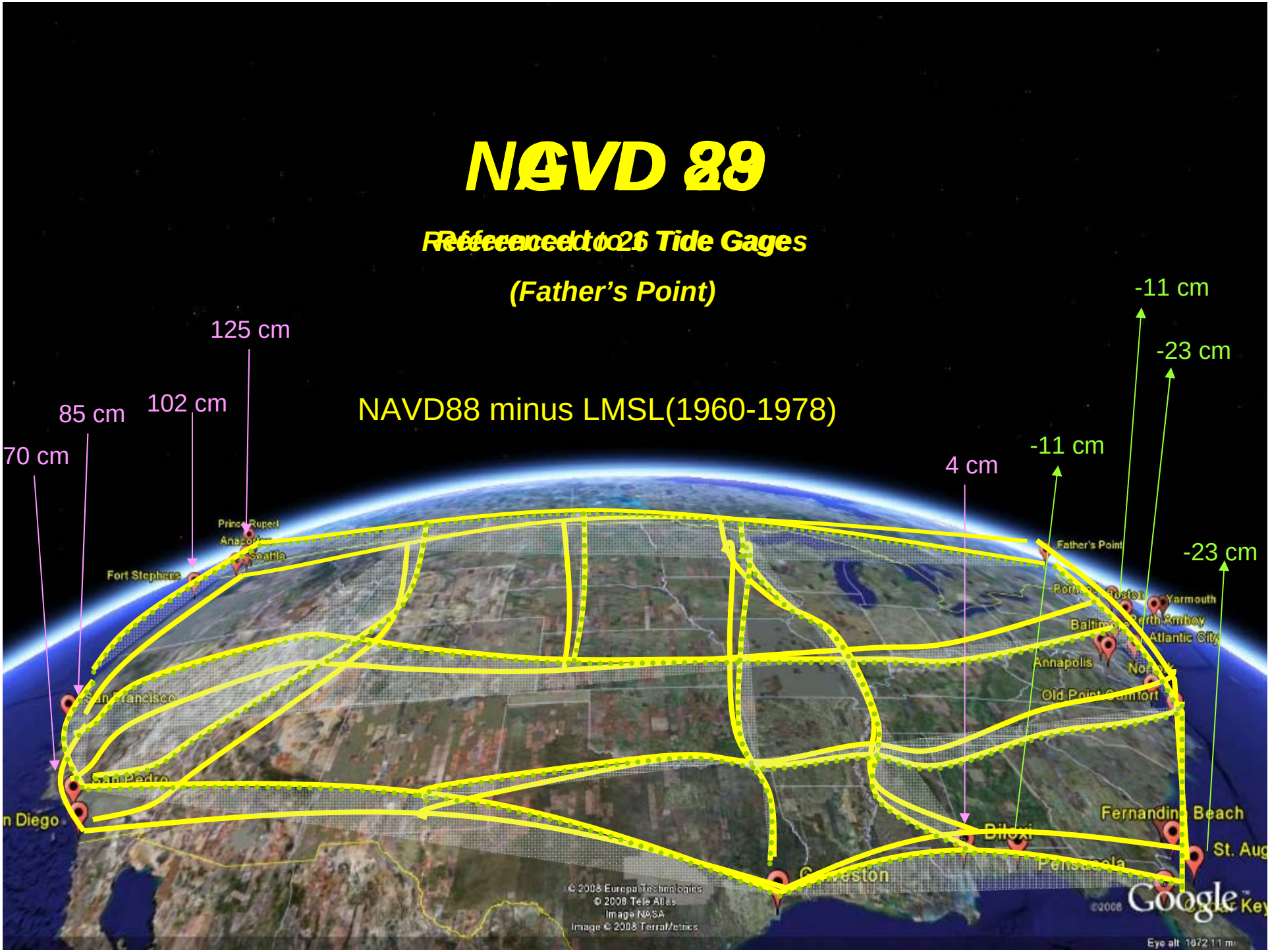
Simplified Concept of NAD 83 vs. ITRF00



Identically shaped ellipsoids (GRS-80)
a = 6,378,137.000 meters (semi-major axis)
1/f = 298.25722210088 (flattening)


NGVD29
The National Geodetic Vertical Datum of 1929 is referenced to 26 tide gauges in the US and Canada
Prince Rupert
Fort Stephens
San Francisco
San Diego
Galveston
Biloxi
Pensacola
Fernandina Beach
Brunswick
St. Augustine
Cedar Keys
Norfolk
Old Point Comfort
Annapolis
Perth Amboy
Boston
Portland
Yarmouth
Halifax
Father's Point
© 2008 Europa Technologies
© 2008 Tele Atlas
Image NASA
Image © 2008 TerraMetrics
Google


NAVD88
The North American Vertical Datum of 1988 is referenced to a single tide gauge in Canada
Prince Rupert
Vancover
Anacortes
Seattle
Fort Stephens
San Francisco
San Pedro
San Diego
Galveston
Biloxi
Pensacola
Fernandina Beach
Brunswick
St. Augustine
Cedar Keys
Father's Point
Halifax
Yarmouth
Portland
Boston
Perth Amboy
Atlantic City
Baltimore
Annapolis
Norfolk
Old Point Comfort
© 2008 Europa Technologies
© 2008 Tele Atlas
Image NASA
Image © 2008 TerraMetrics
Google
Eye alt 2486.97 mi


NAVD 88
Referenced to 26 Tide Gages
(Father's Point)
NAVD88 minus LMSL(1960-1978)
125 cm
102 cm
85 cm
70 cm
4 cm
-11 cm
-23 cm
-11 cm
-23 cm
Prince Rupert
Seattle
Fort Stephens
Father's Point
Yarmouth
Atlantic City
Annapolis
San Francisco
San Diego
Fernandina Beach
St. Aug
Galveston
© 2008 Europa Technologies
© 2008 Tele Atlas
Image NASA
Image © 2008 TerraMetrics
Google
Eye alt 1672.11 mi

Problems using traditional leveling (to define a National Vertical Datum)

- Leveling the country can not be done again
  - Too costly in time and money (Estimated ~ $1B)
- Leveling yields cross-country error build-up; problems in the mountains
- Leveling requires leaving behind passive marks
  - Bulldozers and crustal motion do their worst

Height Modernization Bottom line

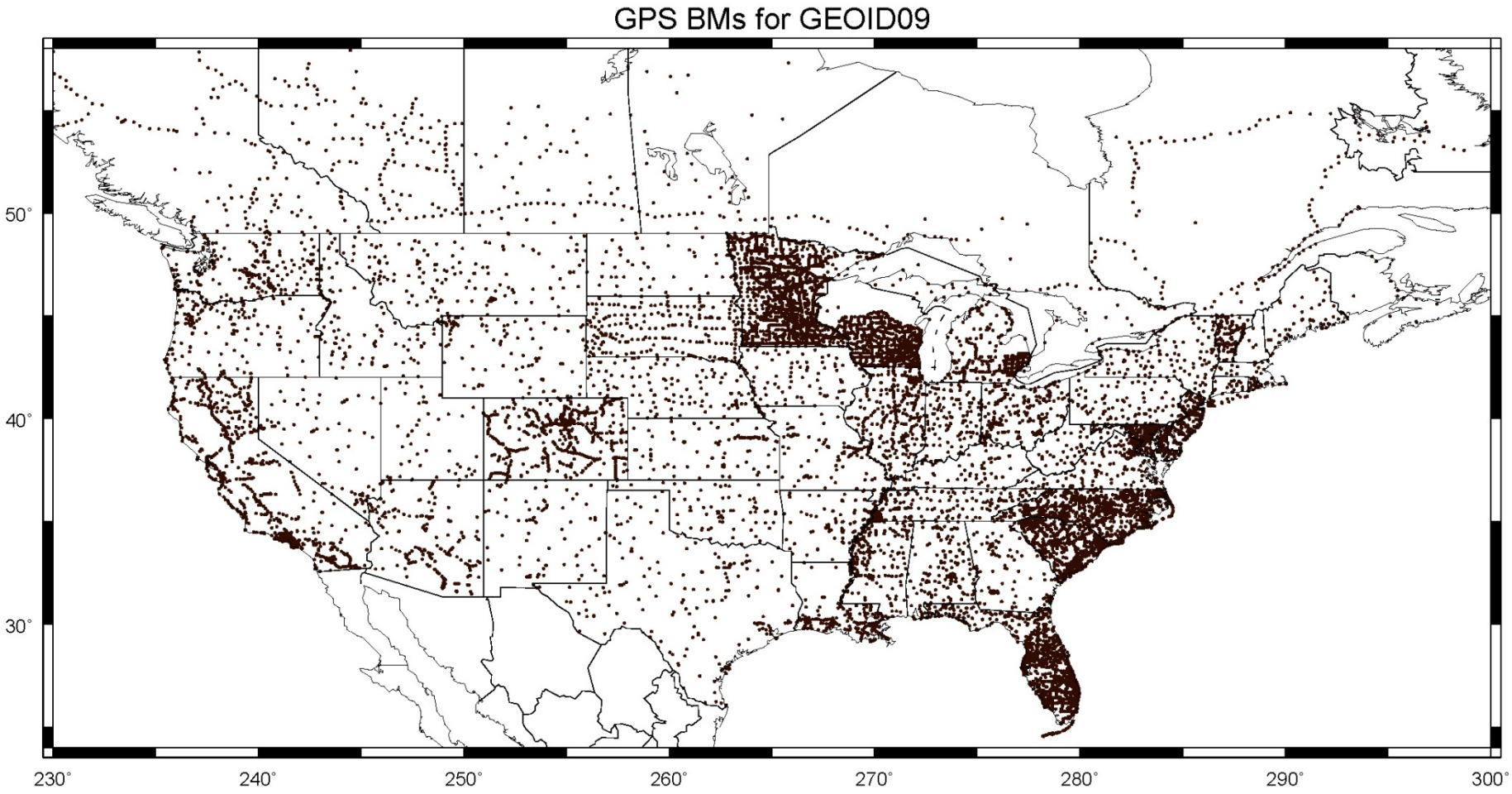
1. Using GNSS is cheaper, easier than leveling

2. To use GNSS we need a good geoid model

Types of Geoid Height Models

- **Gravimetric (or Gravity) Geoid Height Models**
  - Defined by gravity data crossing the geoid
  - Refined by terrain models (DEM's)
  - Scientific and engineering applications

- **Composite (or Hybrid) Geoid Height Models**
  - Gravimetric geoid defines all regions
  - Warped to fit available GPSBM control data
  - Defined by legislated ellipsoid (NAD 83) and local vertical datum (NAVD 88, 6 State/Territorial island Datums)
  - May be statutory for some surveying & mapping applications

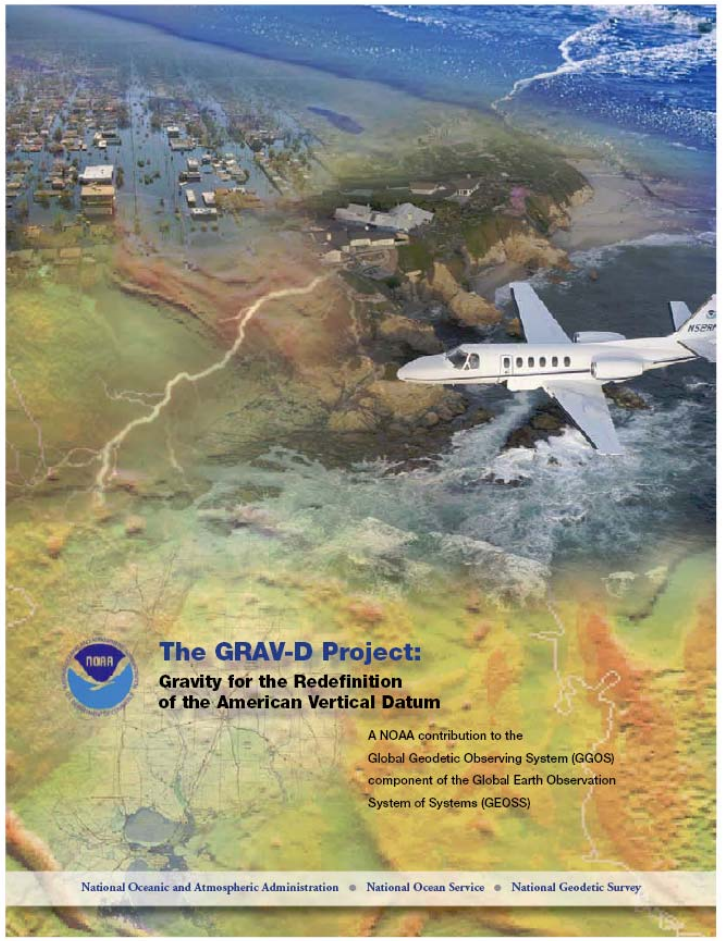

GPS BMs for GEOID09
50˚
40˚
30˚
230˚
240˚
250˚
260˚
270˚
280˚
290˚
300˚

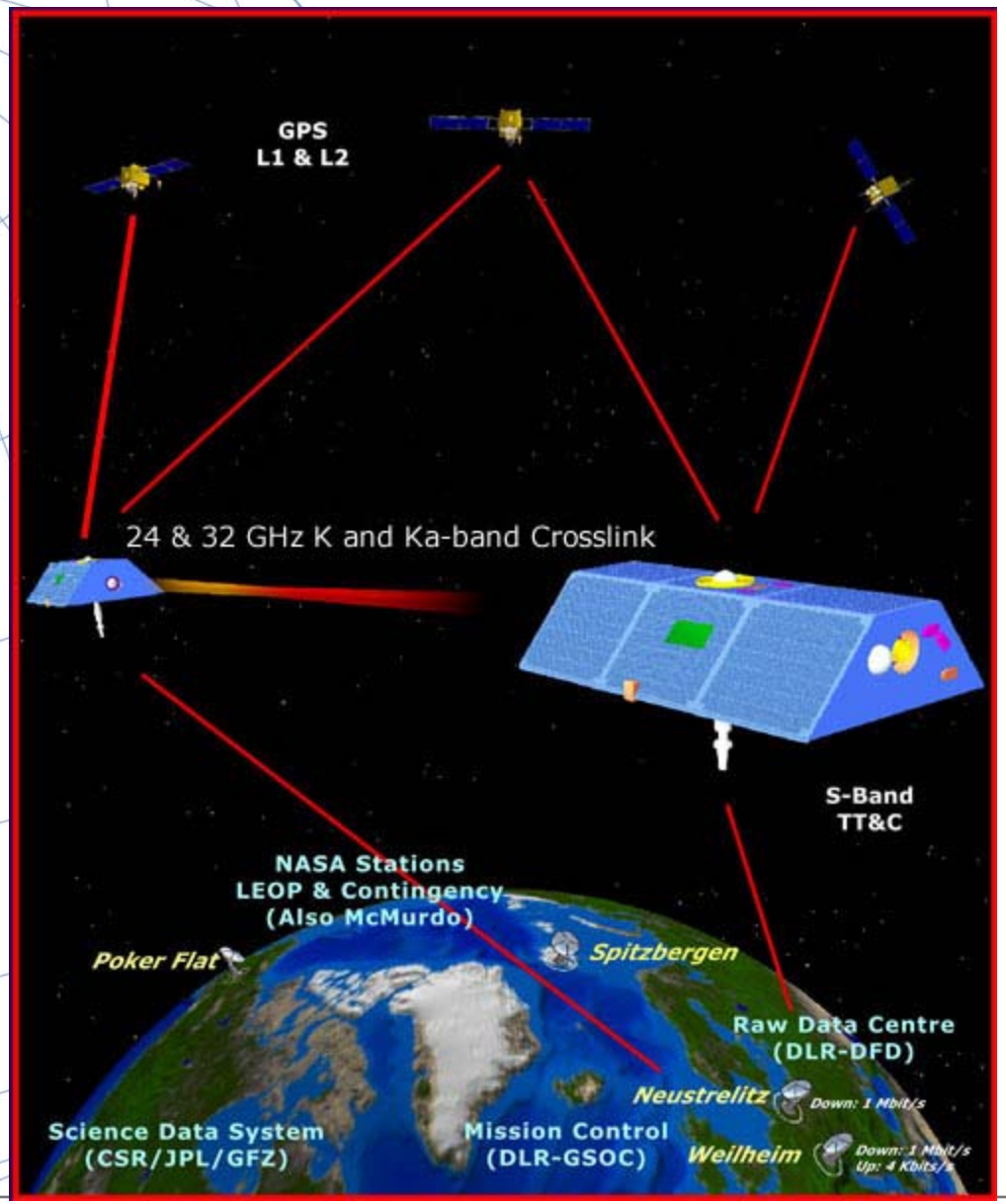
Transition to the Future – GRAV-D

Gravity for the Redefinition of the American Vertical Datum

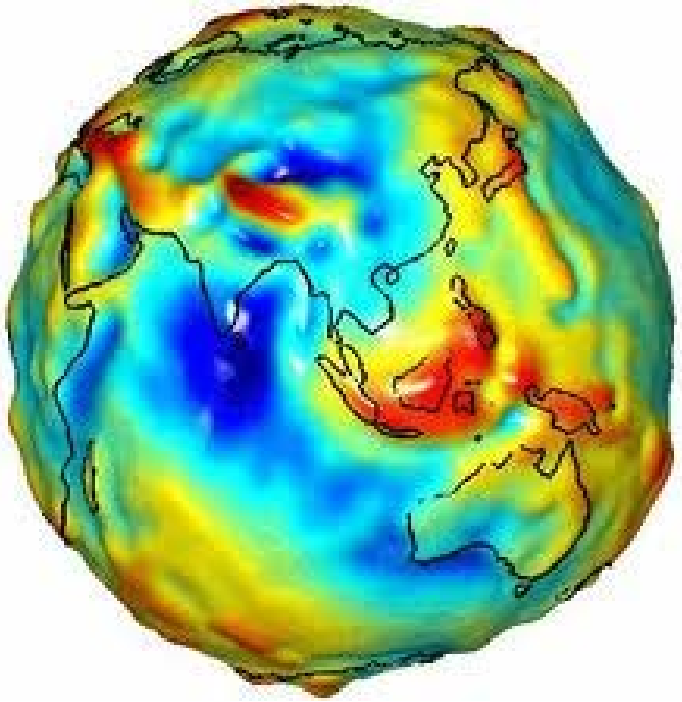
- Official NGS policy as of Nov 14, 2007
  - – $38.5M over 10 years
- Airborne Gravity Snapshot
- Absolute Gravity Tracking
- Re-define the Vertical Datum of the USA by 2018

  (2022 more likely due to funding issues)



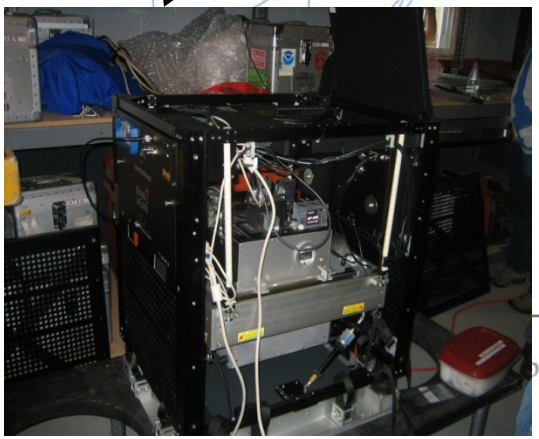


GRACE – Gravity Recovery and Climate Experiment

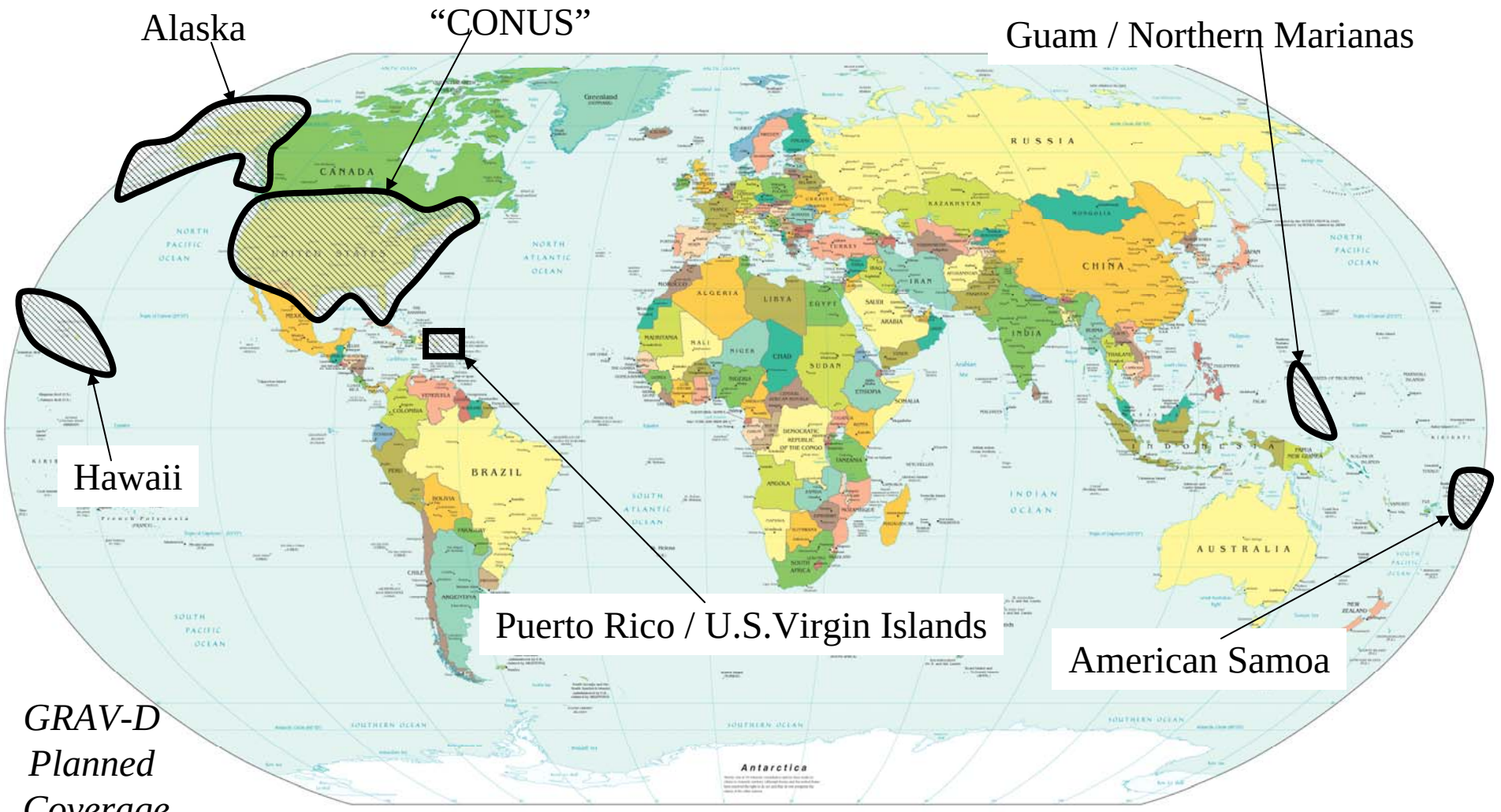


Gravity Survey Plan

- National Scale Part 1
  - Predominantly through airborne gravity
  - With Absolute Gravity for ties and checks
  - Relative Gravity for expanding local regions where airborne shows significant mismatch with existing terrestrial



What is GRAV-D?



GRAV-D Planned Coverage

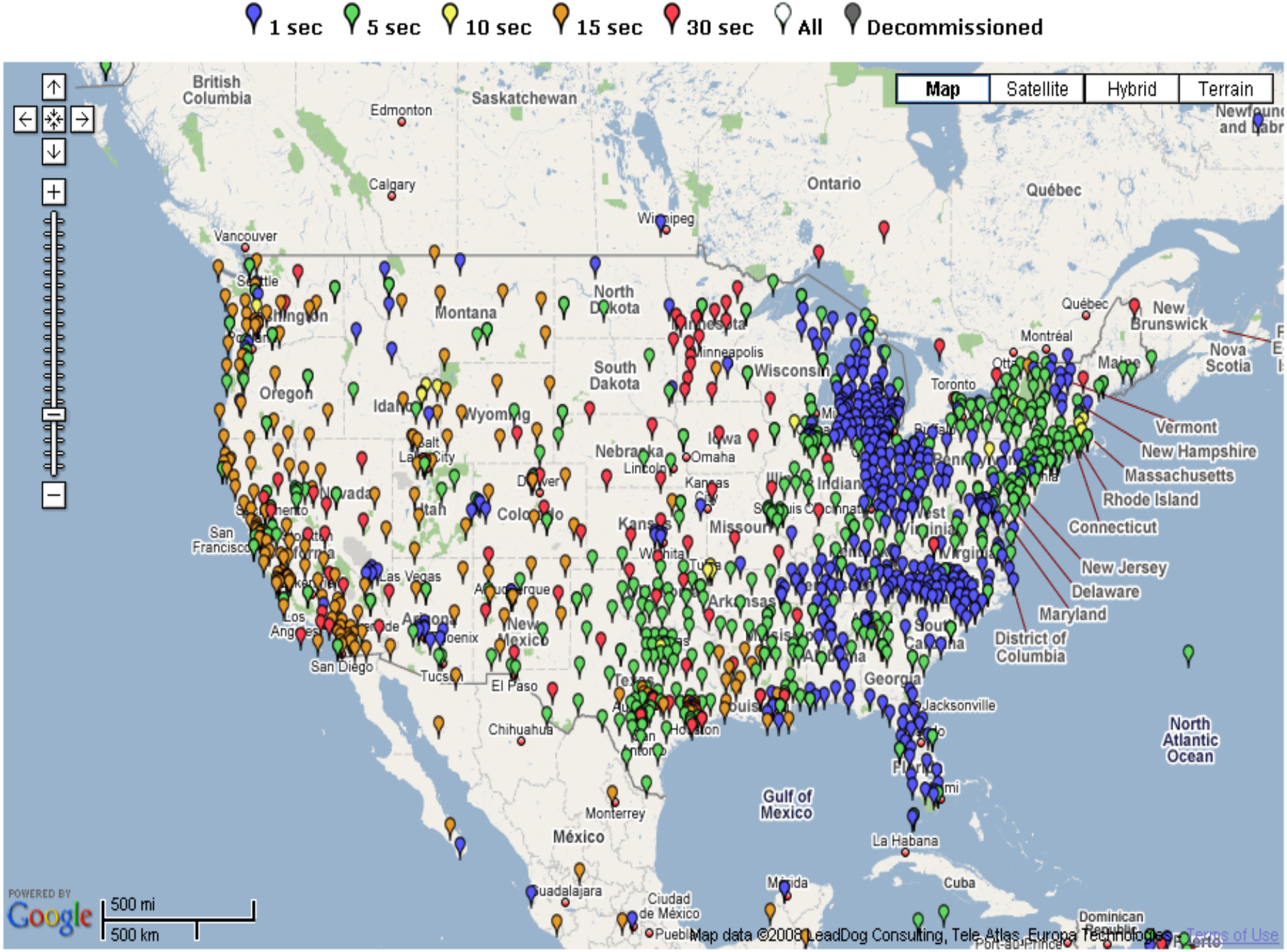
What is GRAV-D?

- **GRAV-D will mean:**
  - As the H=0 surface, the geoid will be tracked over time to keep the datum up to date
  - The reliance on passive marks will dwindle to:
    - Secondary access to the datum
    - Minimal NGS involvement
      - Maintenance/checking in the hands of users
    - Use at your own risk

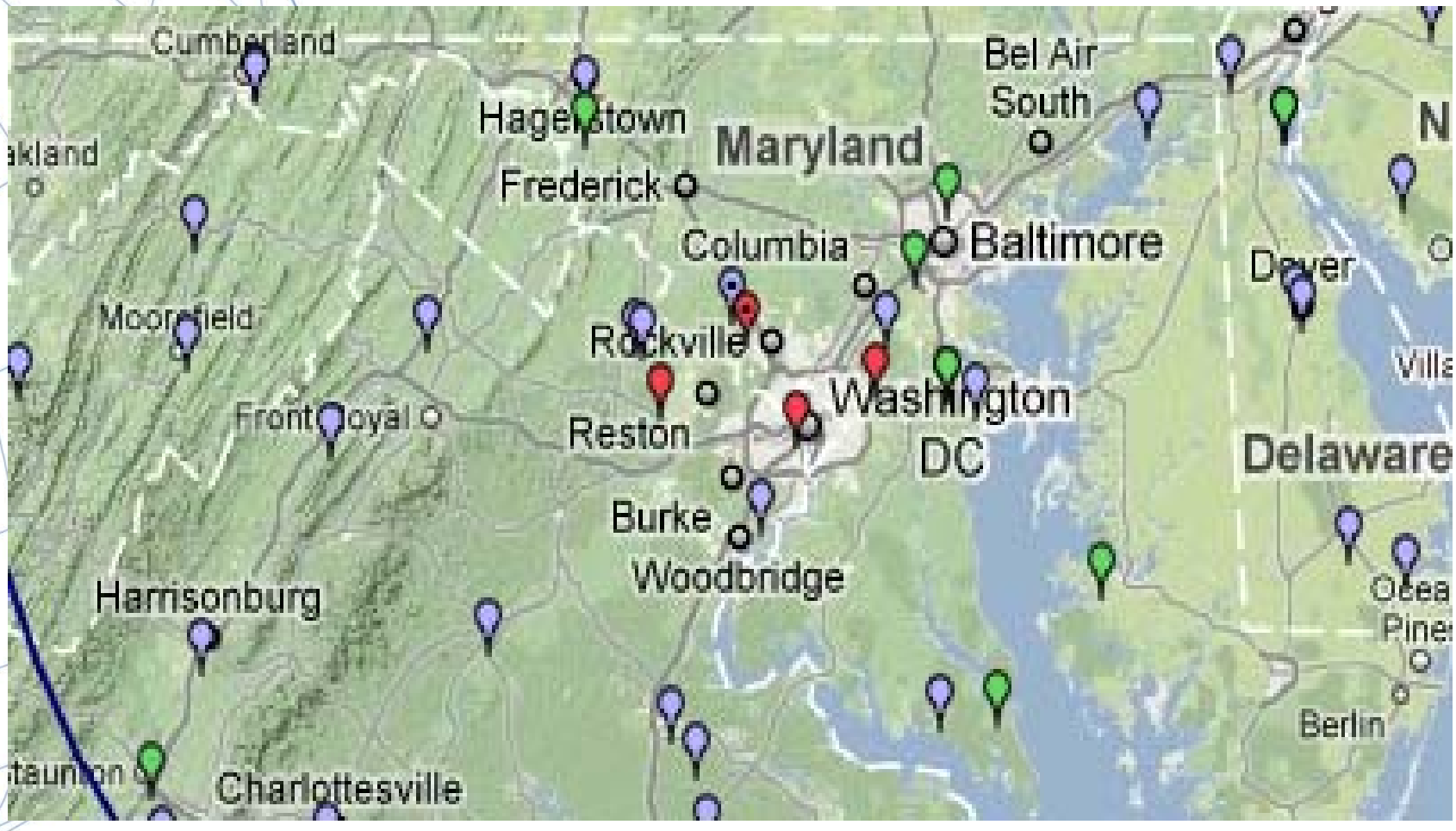
CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

1550+ Installed and operated by various public and private partners

NOAA / National Geodetic Survey
NOAA / OAR Global Systems Division
U.S. Coast Guard - DGPS / NDGPS
Corps of Engineers - DGPS
FAA - WAAS / LAAS
State DOTs
County and City
Academia
Private Companies
International Partners


1 sec
5 sec
10 sec
15 sec
30 sec
All
Decommissioned
Map
Satellite
Hybrid
Terrain
British Columbia
Saskatchewan
Edmonton
Calgary
Ontario
Québec
Winnipeg
Vancouver
Seattle
Montana
North Dakota
Minneapolis
Wisconsin
South Dakota
Oregon
Idaho
Wyoming
Toronto
Montréal
New Brunswick
Nova Scotia
Maine
Vermont
New Hampshire
Massachusetts
Rhode Island
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
Nebraska
Omaha
Iowa
Nevada
Utah
Colorado
Kansas
Missouri
San Francisco
Las Vegas
Arizona
New Mexico
Arkansas
Georgia
Jacksonville
San Diego
Tucson
El Paso
Chihuahua
Texas
Houston
Gulf of Mexico
North Atlantic Ocean
Monterrey
México
La Habana
Cuba
Guadalajara
Ciudad de México
Dominican Republic
POWERED BY Google
500 mi
500 km
Map data ©2008 LeadDog Consulting, Tele Atlas, Europa Technologies
Terms of Use

REGIONAL CORS NETWORK



U OF MD BALT COOP (UMBC), MARYLAND

Antenna Reference Point(ARP): U OF MD BALT COOP CORS ARP

PID = DF6305

ITRF00 POSITION (EPOCH 1997.0)
Computed in Feb. 2008 using 930 days of data.

X =	1136717.441 m	latitude =	39 15 24.38976 N
Y =	-4812975.828 m	longitude =	076 42 41.47606 W
Z =	4014471.484 m	ellipsoid height =	64.678 m

ITRF00 VELOCITY
Estimated in Feb. 2008 using 930 days of data.

VX =	-0.0170 m/yr	northward =	0.0010 m/yr
VY =	-0.0022 m/yr	eastward =	-0.0171 m/yr
VZ =	-0.0002 m/yr	upward =	-0.0015 m/yr

NAD_83 (CORS96) POSITION (EPOCH 2002.0)
Transformed from ITRF00 (epoch 1997.0) position in Feb. 2008.

X =	1136717.980 m	latitude =	39 15 24.36101 N
Y =	-4812977.294 m	longitude =	076 42 41.46823 W
Z =	4014471.606 m	ellipsoid height =	65.956 m

NAD_83 (CORS96) VELOCITY
Transformed from ITRF00 velocity in Feb. 2008.

VX =	-0.0006 m/yr	northward =	0.0000 m/yr
VY =	-0.0004 m/yr	eastward =	0.0000 m/yr
VZ =	-0.0031 m/yr	upward =	0.0000 m/yr

ITRF00 – NAD 83(CORS96)
ΔHoriz = 0.906 m
ΔEHt = 1.278 m

FLAVORS OF OPUS

OPUS-S
$$ Receivers
2 Hours of data
Results not shared

OPUS-RS
$$ Receivers
15 Minutes of data
Results not shared

OPUS-DB
$$ Receivers
4 Hours of data
Results shared

OPUS-Projects
$$ Receivers
2-4 Hours of data
Multiple Receivers
Network Solution
Results shared or not

LOCUS
Leveling On Line Computing Service
Integration with GPS?
Results shared or not

National Geodetic Survey

OPUS – DB

Simple
Shared Data
NGS Archived

National Oceanic and Atmospheric Ad

SURVEY DATASHEET (Version 1.0)

PID: BBBB81
Designation: PHI-MAPP 06
Stamping: CONTROL MARKER 06 2008
Stability: May hold, commonly subject to ground movement
Setting: Set in top of concrete monument
Description: Mark is located in Price Georges County, Maryland along the Potomac Electric power pathway near where it crosse Md. Rte 5 approximately 2200 feet north of intersection with Brandywine Road and is 30.9 feet east of the northbound edge of paving and is 316.5 feet from Pepco pole number 5216 in the approximate centerline of the power pathway
Observed: 2008-04-11T15:53:00Z
Source: OPUS - page5 0612.06

Close-up View

REF_FRAME: NAD_83(CORS96) | EPOCH: 2002.0000 | SOURCE: [Geoid03 NAVD88] | UNITS: m | SET PROFILE | DETAILS

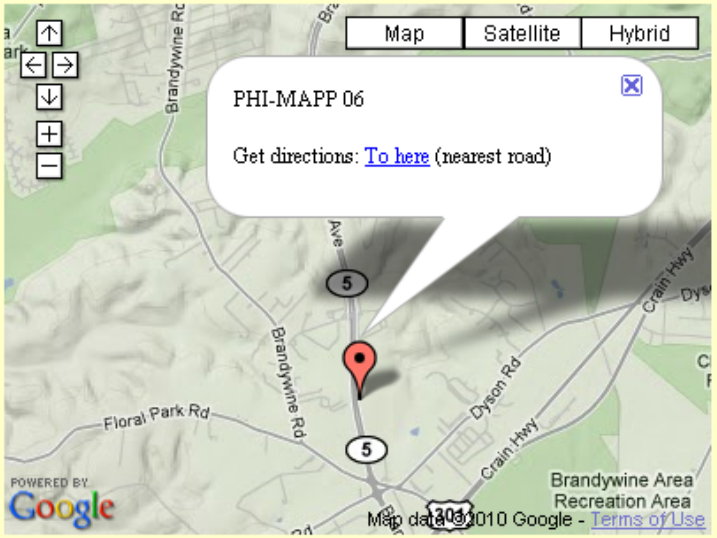
LAT:	38° 42' 29.01738"	± 0.005	m
LON:	-76° 52' 38.92153"	± 0.008	m
ELL HT:	36.589	± 0.016	m
X:	1131467.156	± 0.011	m
Y:	-4853547.261	± 0.014	m
Z:	3967101.525	± 0.007	m
ORTHO HT:	69.367	± 0.030	m

	UTM 18	**SPC** 1900(MD)
NORTHING:	4286053.473m	115605.943m
EASTING:	336753.480m	410656.607m
CONVERGENCE:	-1.17434467°	0.07689886°
POINT SCALE:	0.99992818	0.99995411
COMBINED FACTOR:	0.99992244	0.99994837

CONTRIBUTED BY

rnbenzin
McCrone Inc

Horizon View



Ten-Year Milestones (2018)

1) NGS will compute a pole-to-equator, Alaska-to-Newfoundland geoid model, preferably in conjunction with Mexico and Canada as well as other interested governments, with an accuracy of 1 cm in as many locations as possible

2) NGS redefines the vertical datum based on GNSS and a gravimetric geoid

3) NGS redefines the national horizontal datum to remove disagreements with the ITRF

Predicted Positional Changes in 2022 Vicinity of Catonsville, MD.

(Computed for CCBC, pid AJ7985)

HORIZONTAL = 1.10 m (3.6 ft)

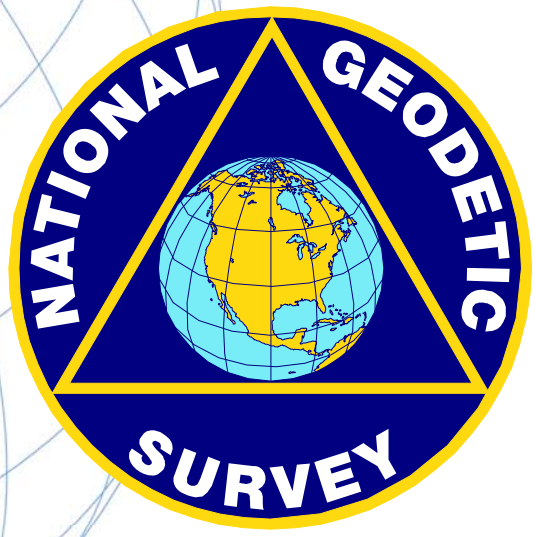
ELLIPSOID HEIGHT = - 1.30 m (- 4.3 ft)

Predicted with HTDP

ORTHOMETRIC HEIGHT = - 0.41 m (- 1.3 ft)

Predicted with HTDP and USGG2009

GOOD COORDINATION BEGINS WITH GOOD COORDINATES



GEOGRAPHY WITHOUT GEODESY IS A FELONY