ELEMENTS OF THE NATIONAL SPATIAL REFERENCE SYSTEM

NGS CORS FORUM
Savannah, GA
September 16, 2008
ftp://ftp.ngs.noaa.gov/dist/DaveD/ASPS

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NATIONAL SPATIAL REFERENCE SYSTEM (NSRS)

Consistent National Coordinate System

- **Latitude**
- **Longitude**
- **Height**
- **Scale**
- **Gravity**
- **Orientation**

and how these values change with time

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

NATIONAL SPATIAL REFERENCE SYSTEM

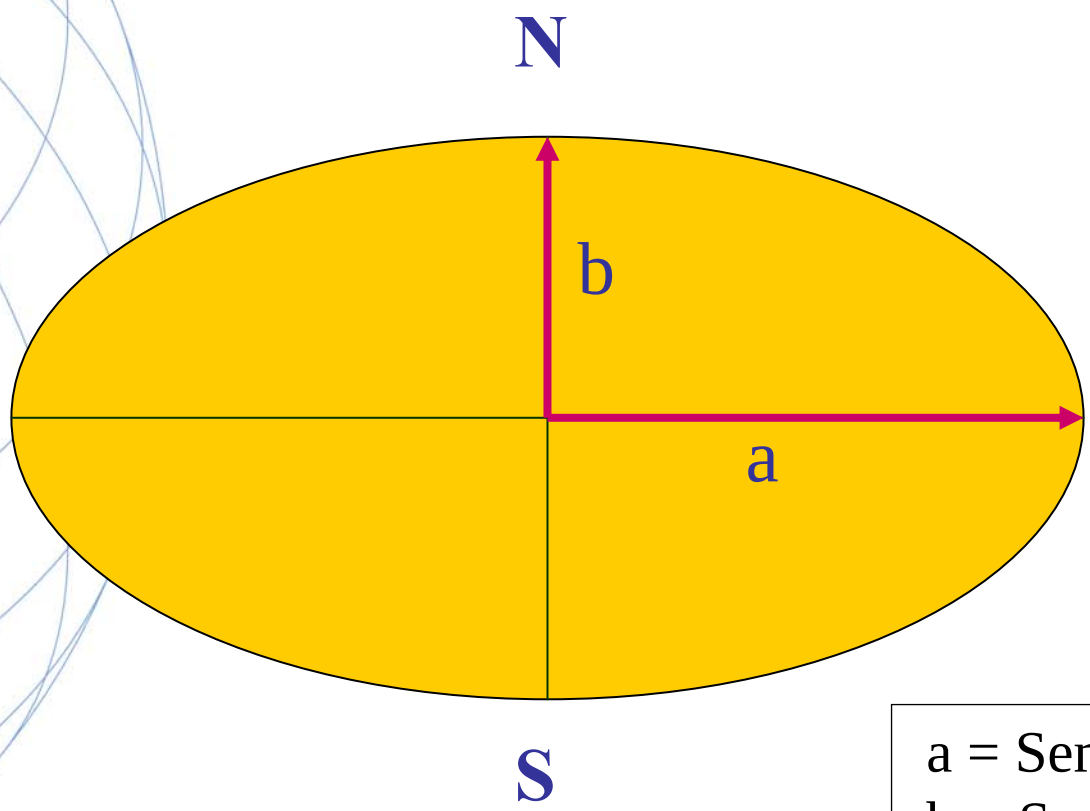
- **MULTIPURPOSE** – Supports Geodesy, Geophysics, Land Surveying, Navigation, Mapping, Charting and GIS
- **ACTIVE** – Accessible through Continuously Operating Reference Stations (CORS) and derived products
- **INTEGRATED** – Related to International services and standards (e.g. International Earth Rotation Service, International GPS Service etc.)
- **DOCUMENTED** – Complete metadata is provided for elements.

DATUMS

A set of constants specifying the coordinate system used for geodetic control, i.e., for calculating coordinates of points on the Earth. Specific geodetic datums are usually given distinctive names. (e.g., North American Datum of 1983, European Datum 1950, National Geodetic Vertical Datum of 1929)

Characterized by:
A set of physical monuments with published horizontal or vertical coordinates

THE ELLIPSOID
MATHEMATICAL MODEL OF THE EARTH



a = Semi major axis
b = Semi minor axis
f = $\frac{a-b}{a}$ = Flattening

UNITED STATES ELLIPSOID DEFINITIONS

CLARKE 1866

a = 6,378,206.4 m 1/f = 294.97869821

GEODETIC REFERENCE SYSTEM 1980 - (GRS 80)

a = 6,378,137 m 1/f = 298.257222101

WORLD GEODETIC SYSTEM 1984 - (WGS 84)

a = 6,378,137 m 1/f = 298.257223563

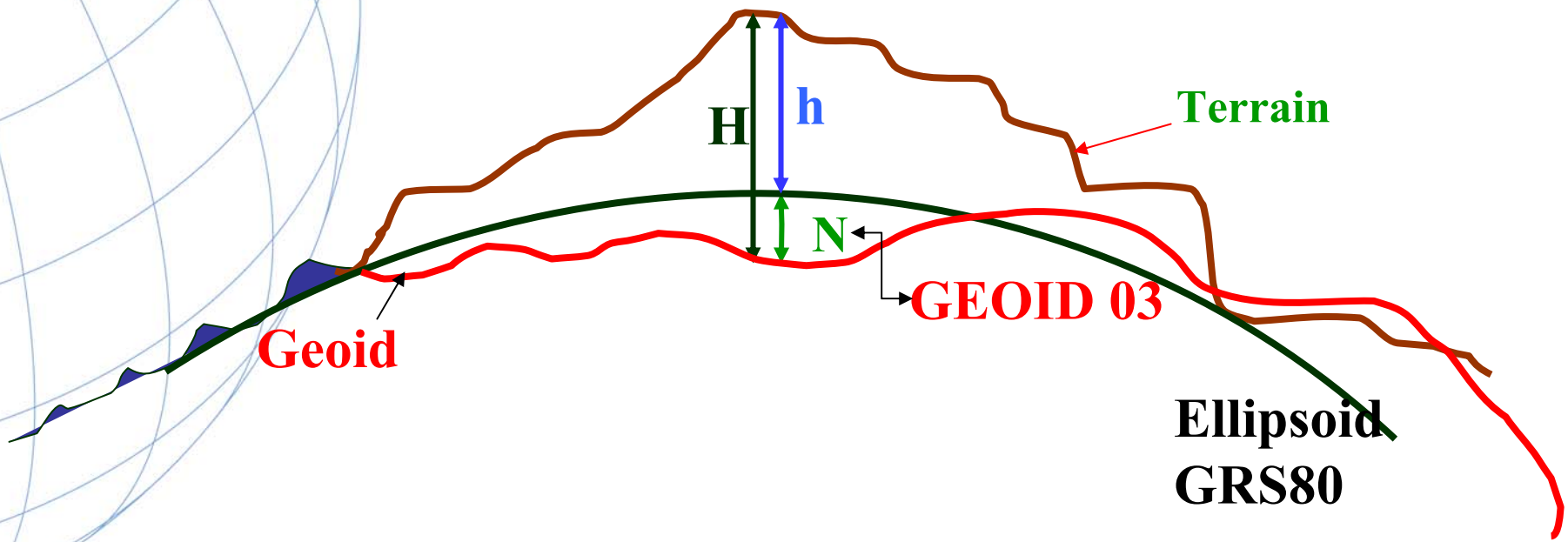
Ellipsoid, Geoid, and Orthometric Heights

H = Orthometric Height (NAVD 88)

h = Ellipsoidal Height (NAD 83)

N = Geoid Height (Geoid03)

$$H = h - N$$



NAD 83(86) NETWORK PROBLEMS

NOT “GPSABLE”

POOR STATION ACCESSIBILITY

IRREGULARLY SPACED

POSITIONAL ACCURACY

HIGH PRECISION GPS NETWORKS
HIGH ACCURACY REFRENCE NETWORKS
1989 - 1997

"GPSABLE"
Clear Horizons for Satellite Signal Acquisition

EASY ACCESSIBILITY
Few Special Vehicle or Property Entrance Requirements

REGULARLY SPACED
Always within 20-100 Km

HIGH HORIZONTAL ACCURACY
A-Order (5 mm + 1:10,000,000) (3 5.5 hr GPS Sessions)
B-Order (8mm + 1:1,000,000) (2 5.5 hr GPS Sessions)

OBSERVED WITH FEDERAL, STATE AND LOCAL PARTNERS (e.g. State DOTs)

FEDERAL AND COOPERATIVE BASE NETWORKS (FBN/CBN) 1997 - 2004

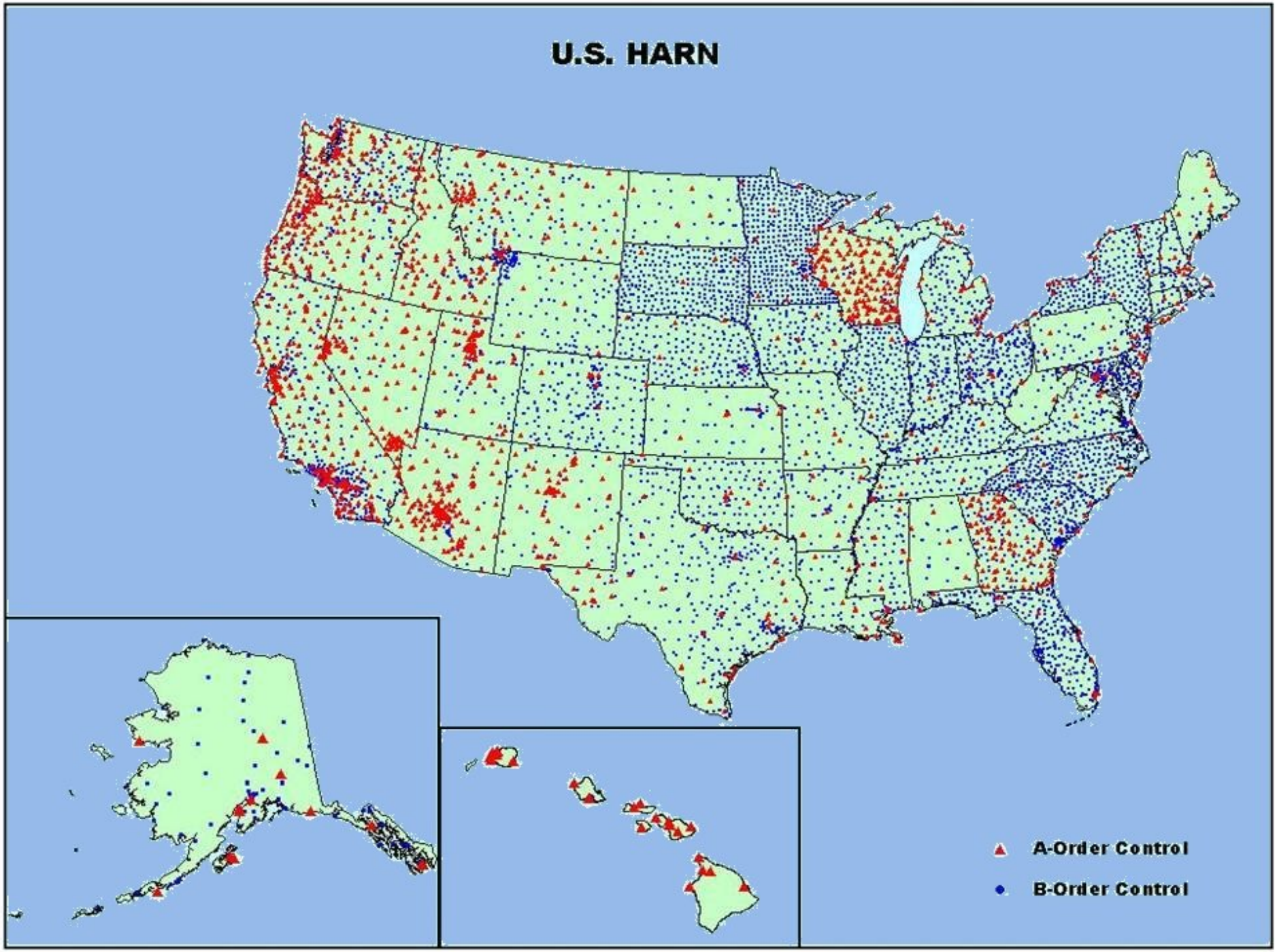
MORE STATE PARTNERSHIPS

REMOVE DISTORTIONS IN EARLY HARNS (3-10 CM)

ENSURE CONNECTIONS TO CORS

IMPROVE ELLIPSOID HEIGHT ACCURACY (Not worse than 2 cm)

ARKANSAS OBSERVED IN 1997 & 2000


U.S. HARN
A-Order Control
B-Order Control

```
        National Geodetic Survey,   Retrieval Date = FEBRUARY 28, 2008
EJ0132 ***********************************************************************
EJ0132  CBN          -  This is a Cooperative Base Network Control Station.
EJ0132  PACS         -  This is a Primary Airport Control Station.
EJ0132  DESIGNATION  -  ADAMS 2
EJ0132  PID          -  EJ0132
EJ0132  STATE/COUNTY-  AR/PULASKI
EJ0132  USGS QUAD    -  SWEET HOME (1986)
EJ0132
EJ0132                        *CURRENT SURVEY CONTROL
EJ0132 ______________________________________________________________________
EJ0132* NAD 83(2007)-  34 43 45.80203(N)    092 13 34.03114(W)     ADJUSTED
EJ0132* NAVD 88      -        77.842  (meters)     255.39   (feet)  ADJUSTED
EJ0132 ______________________________________________________________________
EJ0132  EPOCH DATE   -        2002.00
EJ0132  X            -    -203,835.508 (meters)                    COMP
EJ0132  Y            -  -5,243,669.841 (meters)                    COMP
EJ0132  Z            -   3,613,263.748 (meters)                    COMP
EJ0132  LAPLACE CORR-          -0.03  (seconds)                    DEFLEC99
EJ0132  ELLIP HEIGHT-          51.238 (meters)          (02/10/07) ADJUSTED
EJ0132  GEOID HEIGHT-         -26.59  (meters)                    GEOID03
EJ0132  DYNAMIC HT   -          77.769 (meters)     255.15  (feet)  COMP
EJ0132
EJ0132  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
EJ0132  Type    PID    Designation                      North   East  Ellip
EJ0132  ----------------------------------------------------------------------
EJ0132  NETWORK EJ0132 ADAMS 2                           0.61   0.41   1.80
EJ0132  ----------------------------------------------------------------------
EJ0132  MODELED GRAV-     979,705.8   (mgal)                       NAVD 88
EJ0132
EJ0132  VERT ORDER   -  SECOND    CLASS 0
EJ0132
EJ0132.This mark is at Adams Field Airport (LIT)
EJ0132
EJ0132.The horizontal coordinates were established by GPS observations
EJ0132.and adjusted by the National Geodetic Survey in February 2007.
EJ0132
EJ0132.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
EJ0132.See National Readjustment for more information.
EJ0132.The horizontal coordinates are valid at the epoch date displayed above.
EJ0132.The epoch date for horizontal control is a decimal equivalence
EJ0132.of Year/Month/Day.
```

$H = h - N$

$77.84 = 51.24 - (-26.59)$

$77.84 \neq 77.83$

```
EJ0132.The orthometric height was determined by differential leveling
EJ0132.and adjusted in June 1991.
EJ0132
EJ0132.The geoid height was determined by GEOID03
EJ0132;                    North          East      Units Scale Factor Converg.
EJ0132;SPC AR S      -   628,811.392   379,290.398   MT  0.99999190   -0 07 35.6
EJ0132;SPC AR S      - 2,063,025.38  1,244,388.58   sFT  0.99999190   -0 07 35.6
EJ0132;UTM  15       - 3,843,306.653   570,850.314   MT  0.99966187   +0 26 27.2
EJ0132
EJ0132!              -  Elev Factor  x  Scale Factor =   Combined Factor
EJ0132!SPC AR S      -   0.99999196  x   0.99999190  =   0.99998386
EJ0132!UTM  15       -   0.99999196  x   0.99966187  =   0.99965383
EJ0132
EJ0132|-----------------------------------------------------------------------|
EJ0132| PID    Reference Object                          Distance      Geod. Az  |
EJ0132|                                                                dddmmss.s |
EJ0132| EJ0133 ADAMS 2 RM 3                               31.108 METERS 02853     |
EJ0132| EJ1681 N LITTLE ROCK POWER LT TK                APPROX. 3.6 KM 0432512.3 |
EJ0132| EJ1697 LITTLE ROCK ADAM FLD ASR 4 RAD           315.516 METERS 15002     |
EJ0132| AI3581 LIT A                                    APPROX. 0.6 KM 1905833.5 |
EJ0132| CY5139 ADAMS 2 AZ MK                                           2160709.4 |
EJ0132| CY5138 ADAMS RM 2                                11.198 METERS 22244     |
EJ0132| EJ1709 LITTLE ROCK GAINES ST SPIPE              APPROX. 5.0 KM 2760221.9 |
EJ0132| EJ1692 LITTLE ROCK ADAMS FIELD AIRPORT BEA      APPROX. 1.4 KM 2871238.7 |
EJ0132| EJ1695 ADAMS                                     25.630 METERS 30531     |
EJ0132|-----------------------------------------------------------------------|
EJ0132
EJ0132                          SUPERSEDED SURVEY CONTROL
EJ0132
EJ0132  ELLIP H (09/21/01)   51.249  (m)                        GP(       ) 4 2
EJ0132  NAD 83(1997)-  34 43 45.80192(N)    092 13 34.03136(W) AD(       ) B
EJ0132  ELLIP H (09/19/97)   51.233  (m)                        GP(       ) 4 1
EJ0132  NAD 83(1986)-  34 43 45.81560(N)    092 13 34.01421(W) AD(       ) 1
EJ0132  NAD 27       -  34 43 45.48272(N)    092 13 33.47632(W) AD(       ) 3
EJ0132  NAVD 88 (09/19/97)   77.84   (m)          255.4    (f) LEVELING    3
EJ0132  NGVD 29 (??/??/92)   77.893  (m)          255.55   (f) ADJ UNCH    2 0
EJ0132
EJ0132.Superseded values are not recommended for survey control.
EJ0132.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
EJ0132.See file dsdata.txt to determine how the superseded data were derived.
```

www.ngs.noaa.gov/NationalReadjustment

National Readjustment

"..the re-adjustment provides a foundation for helping NGS achieve our vision of positioning *anyone, anytime, anywhere*."

The NAD83(NSRS) readjustment team anticipates completion of the free adjustment analysis phase by the end of August 2006.

Reasons for Readjustment

- Multiple epoch dates
- Inconsistencies between states
- Need to be consistent with CORS
- Compute Network and Local accuracies

Orthometric Height (NAVD 88) adjustment will not be attempted

NAD 83 National Readjustment

- Early GPS observations (prior to 1992) did not benefit from high accuracy GPS orbit data.
- Early GPS observations (prior to 1995) did not have access to CORS.
- HARN observations prior to 1997 did not focus on the vertical.
- Some HARNs exhibit 4 – 7 cm difference with CORS
- Different NAD 83 adjustment tags (e.g., NAD 83 1992, NAD 83 1997 etc.) in adjoining states causes confusion.

Project Adjustment Analysis

- 3375 Projects complete
  - Free Adjustment
  - Residual Plot
  - Outliers Rejected
  - Connectivity to A/B Order Network Verified
  - Summary sheet with Project Information Created
  - 67693 stations

NAD 83 READJUSTMENT

ONLY GPS DATA WAS USED

CONTINUOUSLY OPERATING REFERENCE STATIONS
FEDERAL BASE NETWORK (A & B)
COOPERATIVE BASE NETWORK (B)
USER DENSIFICATION NETWORK (First)
AIRPORT SURVEYS (B & First)

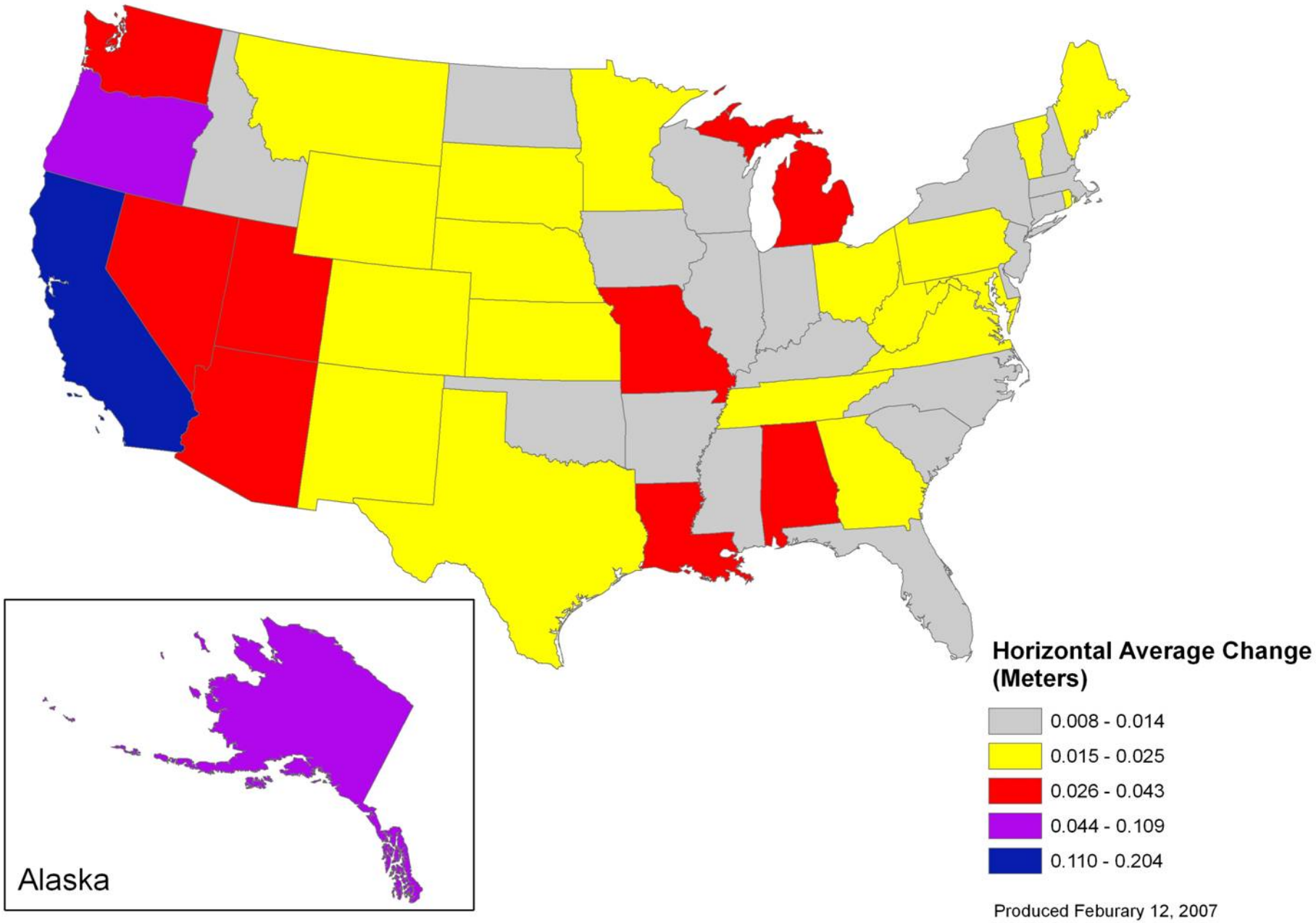
TRASH

Projects Not Recommended for Inclusion

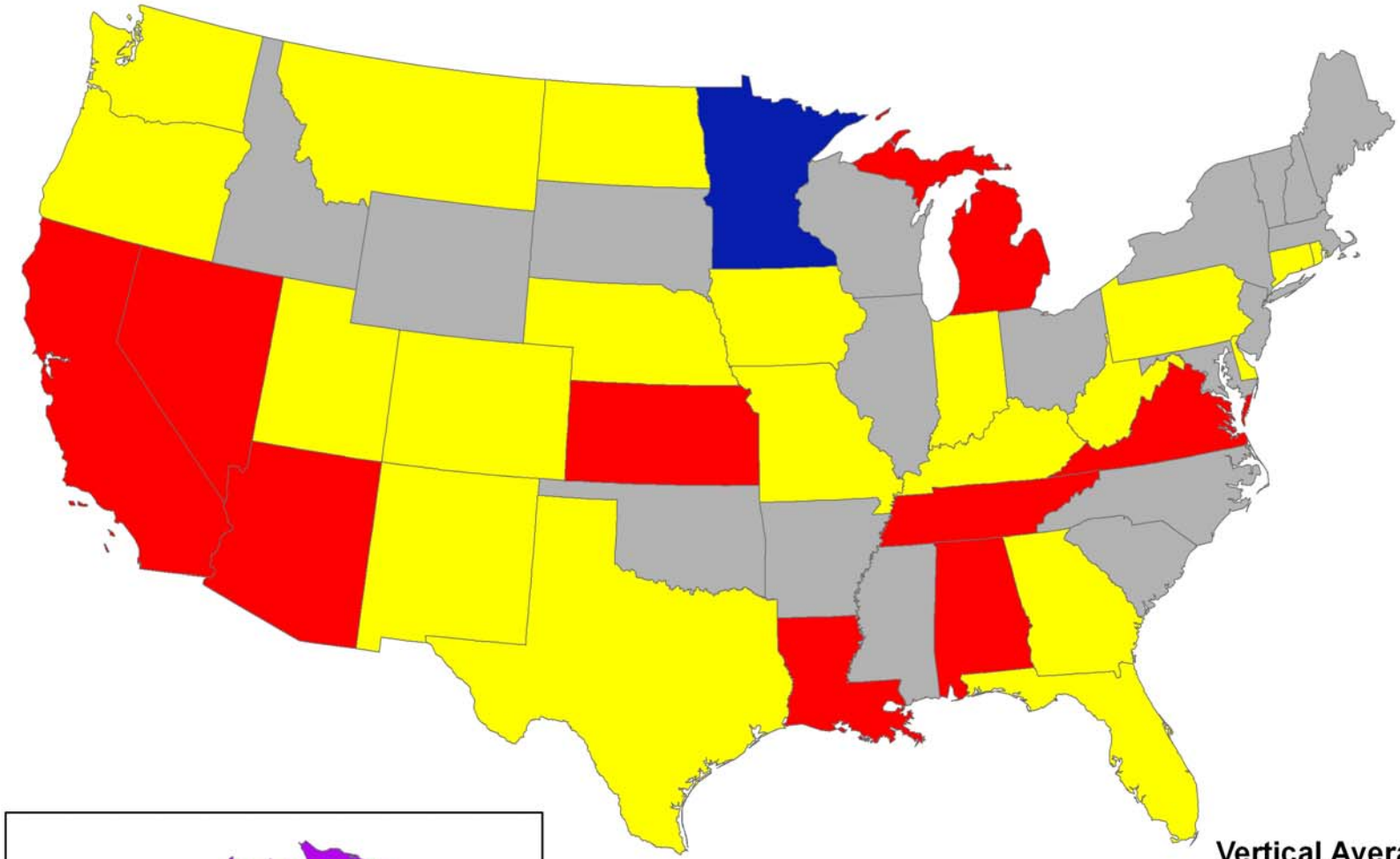
- **Currently 149 Projects with 9903 stations**
  - **Many Third Order FAA Projects from 1980's**
  - **Some Projects that have no ties to the Network**
  - **Original TN HARN (Macrometer Data in 1990)**
  - **Original Eastern Strain Network Project**

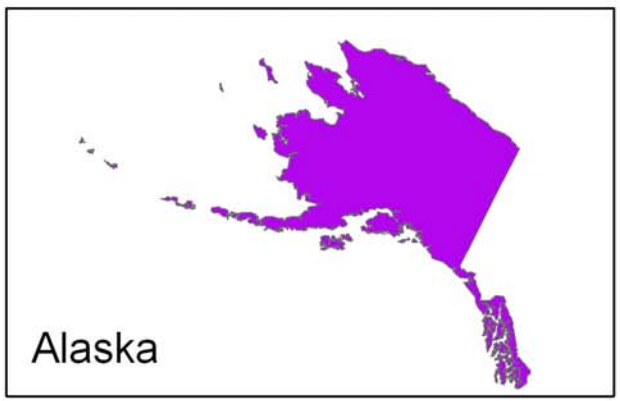
ARKANSAS STATISTICS

- **Total # of Stations: 396**
- **Max Horizontal Shift: 0.041 (m)**
- **Average Hz Shift: 0.012 (m)**
- **Max Vertical Shift: 0.064 (m)**
- **Average Vt. Shift: 0.010 (m)**


Alaska
Horizontal Average Change (Meters)
0.008 - 0.014
0.015 - 0.025
0.026 - 0.043
0.044 - 0.109
0.110 - 0.204
Produced Feburary 12, 2007

NAD 83 Adjustment 2007 - Ellipsoid Height





Vertical Average Change (Meters)

- 0.008 - 0.015
- 0.016 - 0.023
- 0.024 - 0.042
- 0.043 - 0.073
- 0.074 - 0.395

Produced Feburary 12, 2007

NGS' Adjustment Team (1986)

NGS' Adjustment Team (2007)

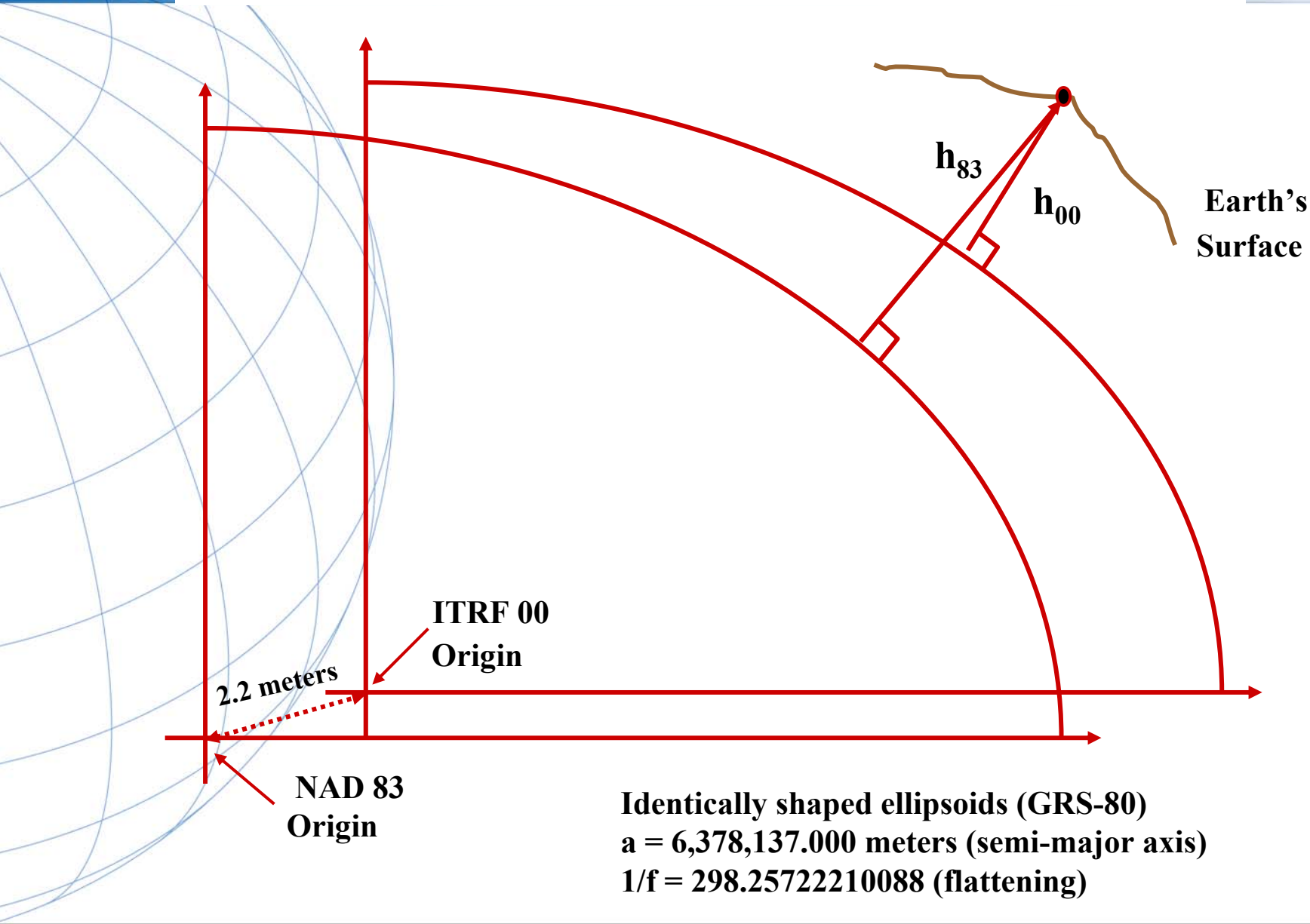
ITRF and WGS 84

Agreement with ITRF

The WGS 84 (G1150) Reference Frame, after the adjustment of a best fitting 7-parameter transformation and accounting for epoch differences (ITRF2000 is referenced to epoch 1997.0), compared to ITRF2000 shows a RMS difference of one centimeter per component. To quantify differences between the WGS 84 (G1150) and ITRF2000 reference frames, comparisons were made between the NGA and USAF stations and a subset of the IGS stations that were used to develop ITRF2000. Subsequent comparisons between the NGA GPS precise ephemerides, referenced to WGS 84 (G1150), and IGS GPS precise ephemerides, referenced to ITRF2000, validate that the two reference systems are consistent. This indicates that these two reference frames are essentially identical with differences being statistically insignificant for most applications

http://earth-info.nga.mil/GandG/publications/tr8350.2/Addendum%20NIMA%20TR8350.2.pdf

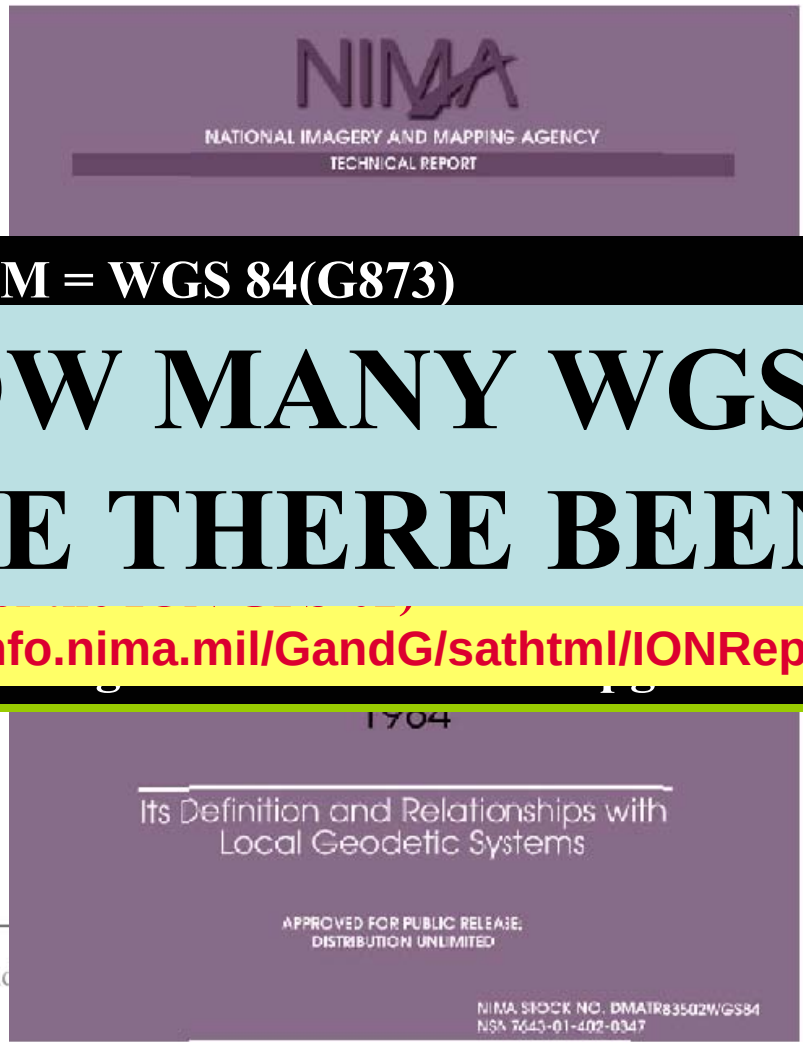
Simplified Concept of ITRF 00 vs. NAD 83



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

WORLD GEODETIC SYSTEM 1984

http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html



D DATUM = WGS 84(G873)

HOW MANY WGS 84s HAVE THERE BEEN????

http://earth-info.nima.mil/GandG/sathtml/IONReport8-20-02.pdf

MY SOFTWARE SAYS I'M WORKING IN WGS 84

Unless you're doing autonomous point positioning you're probably not in WGS 84

Project tied to WGS-84 control points obtained from the Defense Department -- Good Luck!

You're really working in the same reference frame as your control points -- NAD 83?

Appendix B.6
Transformation Parameters
Local Geodetic Datums to WGS 84

Continent: NORTH AMERICA												
Local Geodetic Datums		Reference Ellipsoids and Parameter Differences			No. of Satellite Stations Used	Transformation Parameters						
Name	Code	Name	Δa(m)	Δf x 10^4		Cycle Number	Pub. Date	ΔX(m)		ΔY(m)		ΔZ(m)	
NORTH AMERICAN 1983 (cont'd)	NAR	GRS 80	0	-0.00000016									
CONUS	NAR-C				216	0	1987	0	±2	0	±2	0	±2
Hawaii	NAR-H				6	0	1993	1	±2	1	±2	-1	±2
Mexico and Central America	NAR-D				25	0	1987	0	±2	0	±2	0	±2

Federal Register Notice: Vol. 60, No. 157, August 15, 1995, pg. 42146
"Use of NAD 83/WGS 84 Datum Tag on Mapping Products"

CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

1300+ Installed and Operated by various Federal-State-local Agencies

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

CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

Dual-Frequency Antennas and Receivers

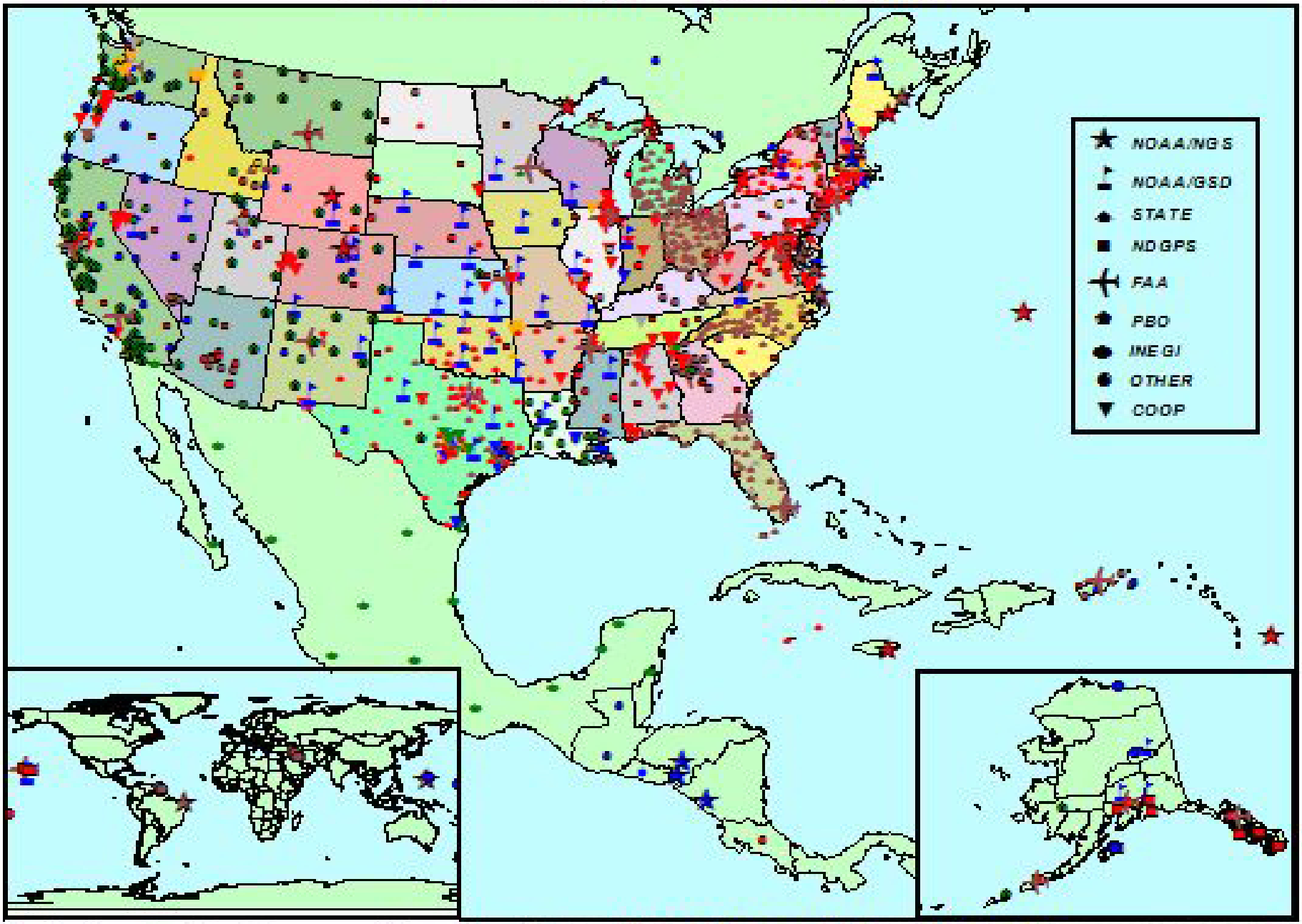
Allen-Osborne
Ashtech
Leica
Topcon
Trimble

CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

NGS PROVIDES

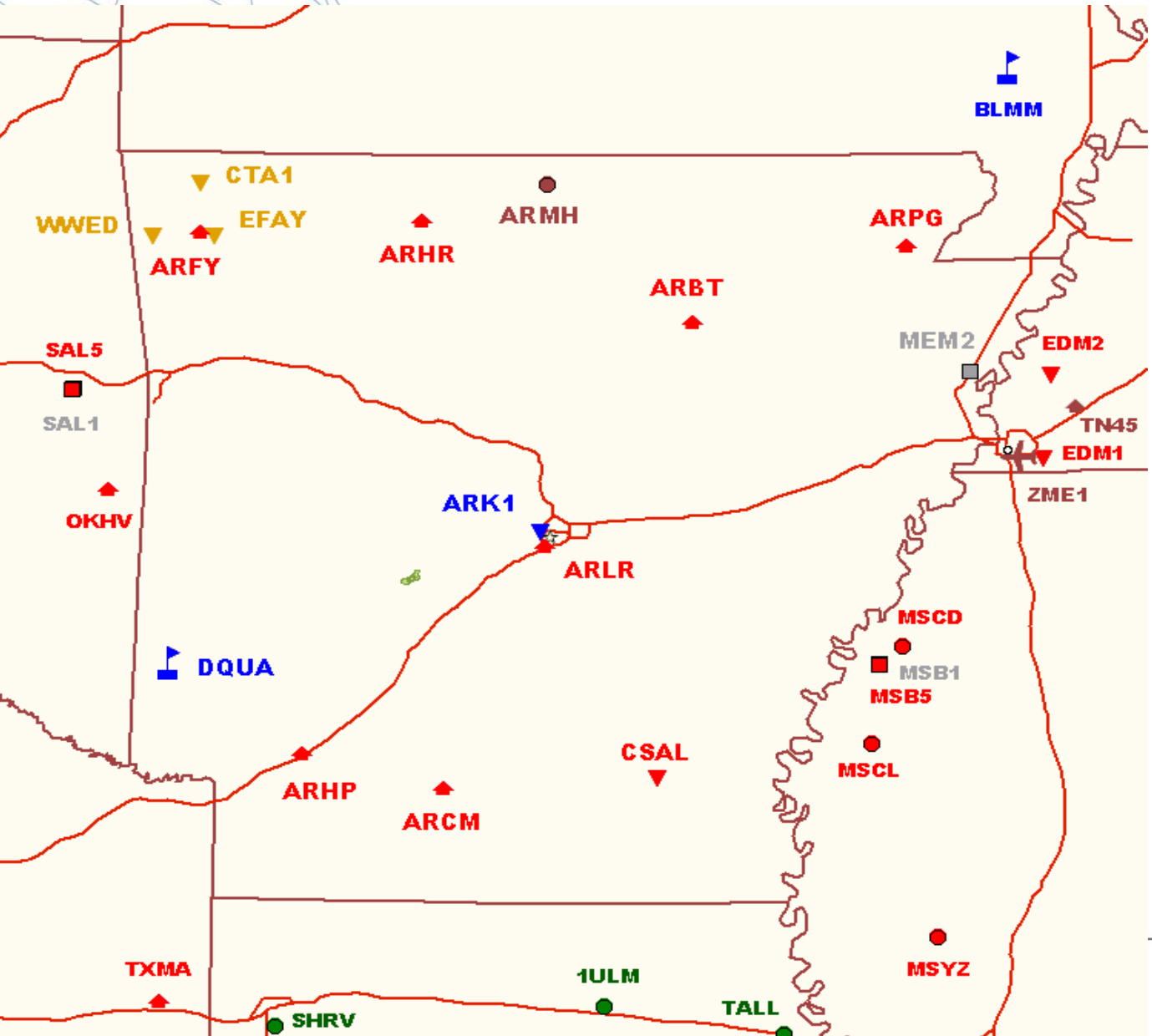
Horizontal and Vertical NSRS Connections
NAD 83 and ITRF00 Coordinates
Network Data Collection - Hourly & Daily
Daily 3D Network Integrity Adjustment
Public Data Distribution - Internet
13 Year On-Line Data Holding

CORS Coverage



Symbol color denotes sampling rates: (1 sec) (5 sec) (10 sec) (15 sec) (30 sec) (Decommissioned)

REGIONAL CORS NETWORK



Operator:

- *NOAA/NGS*
- *NOAA/GSD*
- *STATE*
- *NDGPS*
- *FAA*
- *PBO*
- *INEGI*
- *OTHER*
- *COOP*

Sampling Rate:

- *1 second*
- *5 seconds*
- *10 seconds*
- *15 seconds*
- *30 seconds*
- *Decommissioned*

DEQUEEN 1 (DQUA), ARKANSAS

Antenna Reference Point(ARP): DEQUEEN 1 CORS ARP

PID = AF9579

ITRF00 POSITION (EPOCH 1997.0)
Computed in Aug. 2001 using every third day of data through 2000.

X =	-395447.441 m	latitude	= 34 06 38.36705 N
Y =	-5271714.169 m	longitude	= 094 17 23.63190 W
Z =	3556711.140 m	ellipsoid height	= 169.731 m

ITRF00 VELOCITY
Computed in Aug. 2001 using every third day of data through 2000.

VX =	-0.0135 m/yr	northward	= -0.0034 m/yr
VY =	0.0002 m/yr	eastward	= -0.0135 m/yr
VZ =	-0.0036 m/yr	upward	= -0.0013 m/yr

NAD_83 POSITION (EPOCH 2002.0)
Transformed from ITRF00 (epoch 1997.0) position in Mar. 2002.

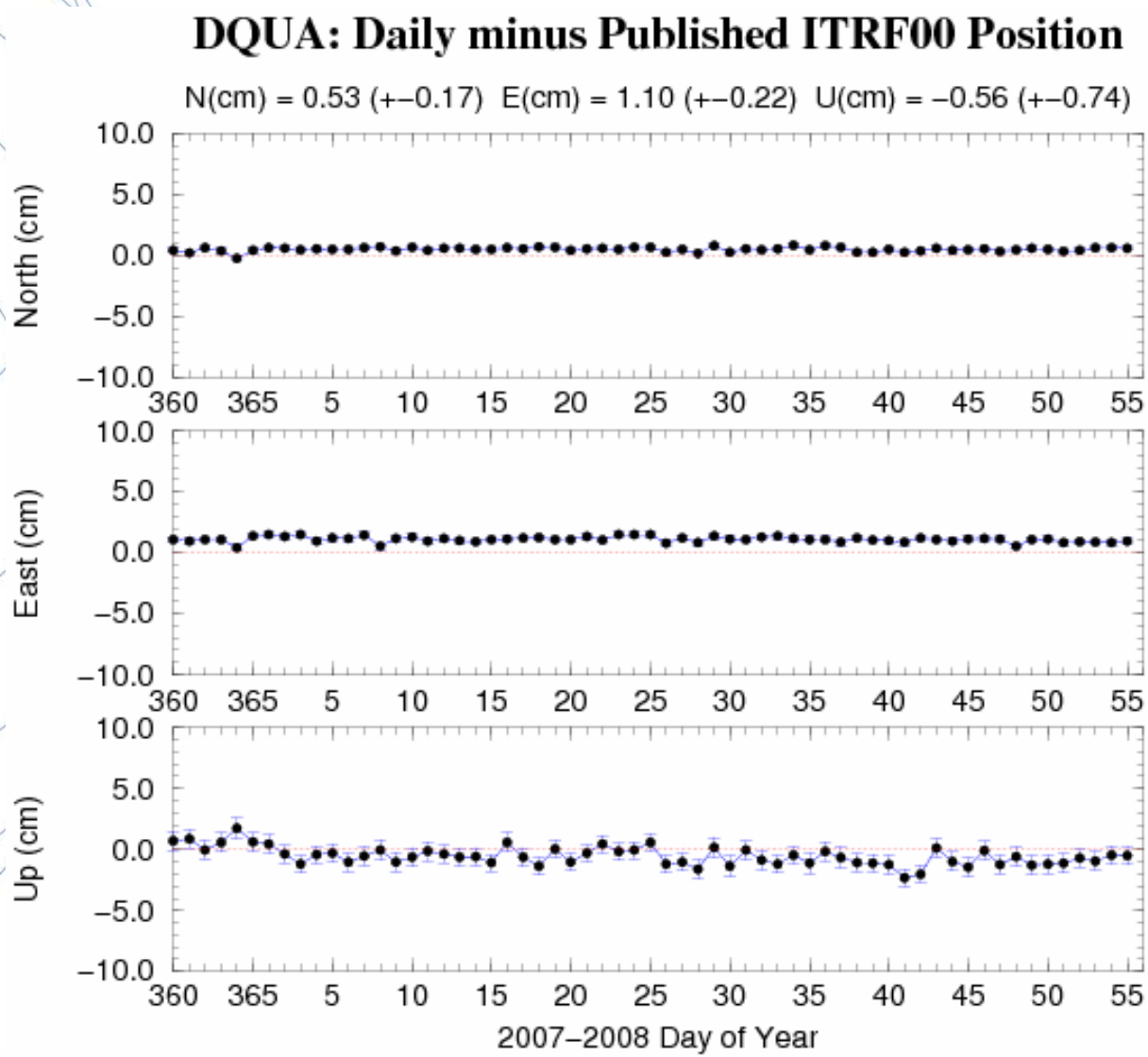
X =	-395446.897 m	latitude	= 34 06 38.34515 N
Y =	-5271715.597 m	longitude	= 094 17 23.60654 W
Z =	3556711.262 m	ellipsoid height	= 170.945 m

NAD_83 VELOCITY
Transformed from ITRF00 velocity in Mar. 2002.

VX =	0.0016 m/yr	northward	= 0.0004 m/yr
VY =	0.0015 m/yr	eastward	= 0.0015 m/yr
VZ =	-0.0006 m/yr	upward	= -0.0017 m/yr

ITRF00 – NAD 83(CORS96)
ΔHoriz = 0.937m
ΔEHt = 1.214m

CORS STABILITY



NAD 83 (2007) and NAD 83 (CORS)

```
National Geodetic Survey,   Retrieval Date = NOVEMBER 30, 2007
KG0640 ***********************************************************************
KG0640  FBN          -  This is a Federal Base Network Control Station.
KG0640  DESIGNATION  -  MEADES RANCH RESET
KG0640  PID          -  KG0640
KG0640  STATE/COUNTY-  KS/OSBORNE
KG0640  USGS QUAD    -  MEADES RANCH (1978)
KG0640
KG0640                        *CURRENT SURVEY CONTROL
KG0640
KG0640* NAD 83(2007)-  39 13 26.71218(N)    098 32 31.74604(W)     ADJUSTED
KG0640* NAVD 88      -        600.3    (meters)    1969.     (feet)  GPS OBS
KG0640
KG0640  EPOCH DATE   -          2002.00
KG0640  X            -      -4,972.580 (meters)                     COMP
KG0640  Y            -      -4,188.504 (meters)                     COMP
KG0640  Z            -       4,01    2.822 (meters)                 COMP
KG0640  LAPLACE CORR-              .96  (seconds)                    DEFLEC99
KG0640  ELLIP HEIGHT-             5
KG0640  GEOID HEIGHT-            -2
```

```
National Geodetic Survey,   Retrieval Date = NOVEMBER 30, 2007
DI3428 ***********************************************************************
DI3428  CORS         -  This is a GPS Continuously Operating Reference Station.
DI3428  DESIGNATION  -  KSU1_KSUN_KS2006 CORS ARP
DI3428  CORS_ID      -  KSU1
DI3428  PID          -  DI3428
DI3428  STATE/COUNTY-  KS/RILEY
DI3428  USGS QUAD    -  SWEDE CREEK (1982)
DI3428
DI3428                        *CURRENT SURVEY CONTROL
DI3428
DI3428* NAD 83(CORS)-  39 06 02.67730(N)    096 36 34.09342(W)     ADJUSTED
DI3428* NAVD 88      -
DI3428
DI3428  EPOCH DATE   -          2002.00
DI3428  X            -     -570,503.804 (meters)                     COMP
DI3428  Y            -   -4,923,592.374 (meters)                     COMP
DI3428  Z            -    4,001,208.587 (meters)                     COMP
DI3428  ELLIP HEIGHT-          326.622 (meters)          (01/??/07) ADJUSTED
DI3428  GEOID HEIGHT-          -29.93  (meters)                     GEOID03
DI3428  HORZ ORDER   -  SPECIAL (CORS)
DI3428  ELLP ORDER   -  SPECIAL (CORS)
```

WHAT'S IN THE FUTURE?

NGS 10 Year Plan

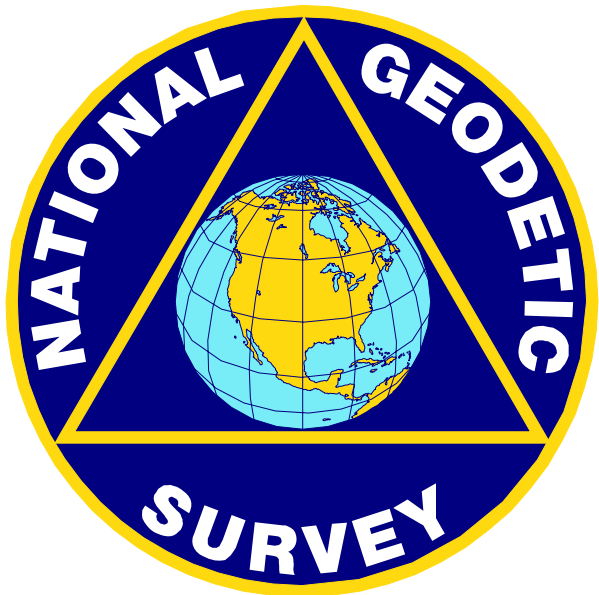
http://www.ngs.noaa.gov/INFO/ngs_tenyearplan.pdf

A new horizontal datum that removes significant offset with ITRF

A new vertical datum based on GNSS and a gravimetric geoid

The gavimetric geoid used in defining the NSRS should have an absolute accuracy of less than 1 cm any place at any time.

GOOD COORDINATION BEGINS WITH GOOD COORDINATES



GEOGRAPHY WITHOUT GEODESY IS A FELONY