Positioning

Accuracy

Standards

NC Society of Surveyors

October 16, 2001
New Bern, North Carolina

WORKSHOP
(1/2-Day)
POSITIONING ACCURACY STANDARDS
COURSE DESCRIPTION

This half-day lecture/discussion seminar covers the topic of the newly adopted accuracy standards for survey data developed by the Federal Geodetic Control Subcommittee (FGCS) and expanded to include other types of point spatial data (e.g., photogrammetric) by the Federal Geographic Data Committee. Material presented during the seminar includes a review and explanation of the current FGCS accuracy standards (e.g., first-, second-, B-order, etc.) and why they were inadequate, a description of the newly adopted FGCS accuracy standards, and an explanation of how the accuracy of survey data will be classified and published by NGS using this new system. It is anticipated that this Federal methodology for defining the accuracy of survey data will eventually be adopted at state and local government levels.

Instructor: Edward J. McKay, National Geodetic Survey
Workshop Level: Introductory
Prerequisite: None

Edward J. McKay
National Geodetic Survey
National Ocean Service, NOAA
Silver Spring, Maryland 20910-3282

BIOGRAPHICAL SKETCH

Mr. Edward J. McKay received a B.S. degree in Mathematics in 1964 from Lebanon Valley College, Pennsylvania, and a M.S. degree in Geodetic Science in 1973 from The Ohio State University. He began his career in surveying and mapping with the U.S. Coast and Geodetic Survey, Triangulation Branch, in 1966 and currently holds the position of Chief, Spatial Reference System Division, National Geodetic Survey (NGS). In addition, he is Chair, Methodology Work Group, Federal Geodetic Control Subcommittee, which is responsible for developing standards and specifications for geodetic control surveys.

Mr. McKay is coordinator for the NGS Workshop Program and in October 1989, he received a U.S. Department of Commerce Silver Medal for "outstanding professionalism and dedication in initiating and implementing technology transfer activities within NGS." He received ACSM (American Congress on Surveying & Mapping) Presidential Citations for outstanding service in education in March 1980 and March 1983. He also received a 1996 National Performance Review Hammer Award for contributing to improvement in mapping, geodetic, cultural, and demographic capacities.

He has presented numerous papers and moderated several technical sessions at ACSM conventions. He has served as both President (two times) and Reporter/Editor for the American Association for Geodetic Surveying (AAGS) member organization of ACSM and is currently the Chair, ACSM Communications Committee and AAGS representative to the ACSM Government Affairs Committee. He is a Fellow member of ACSM and a member of URISA (Urban & Regional Information Systems Association) and ION (Institute on Navigation).

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“Geography without geodesy is a felony”

Gunther Greulich
ACSM Bulletin
Jan./Feb. 1996

Positioning Accuracy Standards Workshop Outline

- Introduction
- Definitions
- Evolution of Accuracy Standards
  - Classical Surveying Standards
  - GPS Surveying Standards
- Development of New Accuracy Standard
- Implementation of New Accuracy Standards
  - Guidelines & Procedures Documents
  - Computations/Software
  - Data Publications
- Summary/Future

Definitions

Definitions

- Survey Standard
- Survey Specifications
- Precision
- Accuracy

What is a SURVEY STANDARD?

What is a Survey Standard?

(Some Previous Responses)

- A level of precision of closure
- A reasonably accepted error
- A numerical limit on the uncertainty of coordinates
  - Position relative to other points
    - » Such as 0.1 (units) + X ppm

Survey Standards

- **Survey standards may be defined as the minimum accuracies deemed necessary to meet specific objectives.**

- **For the present, the practice of defining these criteria by the maximum acceptable uncertainty in length and/or position and assigning some nomenclature to them will be continued.**

Why Do Surveyors Need Accuracy Standards?

Why Do Surveyors Need Accuracy Standards?

(Some previous responses)

- To provide quality assurance of accuracy
  - Such as within 8 mm + 1 ppm; 5 cm; 0.5 m
- To provide consistency
- To re-establish survey monuments

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The NGS Data Sheet
See file  dsdata.txt for more information about the datasheet.
DATABASE = Sybase ,PROGRAM = datasheet, VERSION = 6.55
1        National Geodetic Survey,   Retrieval Date = NOVEMBER 13, 2001
 EY5825 ***********************************************************************
 EY5825  FBN          -  This is a Federal Base Network Control Station.
 EY5825  PACS         -  This is a Primary Airport Control Station.
 EY5825  DESIGNATION  -  CRAVEN
 EY5825  PID          -  EY5825
 EY5825  STATE/COUNTY-  NC/CRAVEN
 EY5825  USGS QUAD    -  NEW BERN (1994)
 EY5825
 EY5825                        *CURRENT SURVEY CONTROL
 EY5825  ______________________________________________________________________
 EY5825* NAD 83(1995)-  35 04 34.20103(N)    077 02 36.16027(W)      ADJUSTED
 EY5825* NAVD 88      -         3.854   (meters)      12.64    (feet)  ADJUSTED
 EY5825  ______________________________________________________________________
 EY5825  X            -   1,171,637.430 (meters)                      COMP
 EY5825  Y            -  -5,092,506.158 (meters)                      COMP
 EY5825  Z            -   3,644,766.357 (meters)                      COMP
 EY5825  LAPLACE CORR-          -1.56   (seconds)                     DEFLEC99
 EY5825  ELLIP HEIGHT-         -33.43   (meters)                      GPS OBS
 EY5825  GEOID HEIGHT-         -37.28   (meters)                      GEOID99
 EY5825  DYNAMIC HT   -           3.850 (meters)      12.63   (feet)  COMP
 EY5825  MODELED GRAV-     979,713.9    (mgal)                        NAVD 88
 EY5825
 EY5825  HORZ ORDER   -  A
 EY5825  VERT ORDER   -  SECOND    CLASS II
 EY5825  ELLP ORDER   -  THIRD     CLASS I
 EY5825
 EY5825.This mark is at Craven Co Regional Airport (EWN)
 EY5825
 EY5825.The North Carolina/South Carolina HARNS have been completed but,
 EY5825.due to contractual restrictions, coordinates for these stations
 EY5825.will NOT be published in the near future. In the interim, the
 EY5825.published coordinates in North and South Carolina will not be
 EY5825.consistent with the Continuously Operating Reference Stations
 EY5825.(CORS). The HARN coordinates for these stations are available
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EY5825.upon request. Contact Gary Thompson(919-733-3836), or Lewis
EY5825.Lapine(803-896-7700).
EY5825.
EY5825.In addition, the published North and South Carolina positions
EY5825.(NAD 83 (1986)) are NOT consistent with those determined in
EY5825.adjacent state readjustments. The discontinuity between stations
EY5825.located in North or South Carolina and those in adjacent states
EY5825.which have been adjusted to the HARN may be as much as 5
EY5825.decimeters. This will result in a significant loss of accuracy
EY5825.over lines crossing such state borders.
EY5825
EY5825
EY5825.The horizontal coordinates were established by GPS observations
EY5825.and adjusted by the National Geodetic Survey in April 1994.
EY5825
EY5825.The orthometric height was determined by differential leveling
EY5825.and adjusted by the National Geodetic Survey in July 1999.
EY5825.WARNING-GPS observations at this control monument resulted in a GPS
EY5825.derived orthometric height which differed from the leveled height by
EY5825.more than one decimeter (0.1 meter).
EY5825
EY5825.The X, Y, and Z were computed from the position and the ellipsoidal ht.
EY5825
EY5825.The Laplace correction was computed from DEFLEC99 derived deflections.
EY5825
EY5825.The ellipsoidal height was determined by GPS observations
EY5825.and is referenced to NAD 83.
EY5825
EY5825.The geoid height was determined by GEOID99.
EY5825
EY5825.The dynamic height is computed by dividing the NAVD 88
EY5825.geopotential number by the normal gravity value computed on the
EY5825.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
EY5825.degrees latitude (g = 980.6199 gals.).
EY5825
EY5825.The modeled gravity was interpolated from observed gravity values.
EY5825
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EY5825.The modeled gravity was interpolated from observed gravity values.
EY5825
EY5825;                    North         East     Units   Scale      Converg.
EY5825;SPC NC       -   148,870.044   788,018.548   MT  0.99987726 +1 07 45.5
EY5825;UTM  18      - 3,883,399.321   313,697.815   MT  1.00002778 -1 10 28.5
EY5825
EY5825:                Primary Azimuth Mark                     Grid Az
EY5825:SPC NC       -  SIMMONS NOTT AIRPORT ARP 1960            181 41 17.5
EY5825:UTM  18      -  SIMMONS NOTT AIRPORT ARP 1960            183 59 31.5
EY5825
EY5825|-----------------------------------------------------------------------|
EY5825| PID    Reference Object                    Distance      Geod. Az   |
EY5825|                                                          dddmmss.s  |
EY5825| EY2360 SIMMONS NOTT AIRPORT ARP 1960      426.835 METERS 1824903.0  |
EY5825|-----------------------------------------------------------------------|
EY5825
EY5825                         SUPERSEDED SURVEY CONTROL
EY5825
EY5825  NAD 83(1986)-  35 04 34.20997(N)    077 02 36.17085(W) AD(       ) 1
EY5825  NAD 83(1995)-  35 04 34.19811(N)    077 02 36.15923(W) AD(       ) A
EY5825  ELLIP HT    -         -33.45  (m)                      GP(       ) 4 1
EY5825  NGVD 29     -         4.2     (m)           14.     (f) GPS OBS
EY5825
EY5825.Superseded values are not recommended for survey control.
EY5825.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
EY5825.See file dsdata.txt to determine how the superseded data were derived.
EY5825
EY5825_MARKER: F = FLANGE-ENCASED ROD
EY5825_SETTING: 59 = STAINLESS STEEL ROD IN SLEEVE (10 FT.+)
EY5825_STAMPING: CRAVEN 1992
EY5825_MARK LOGO: NGS
EY5825_PROJECTION: FLUSH
EY5825_MAGNETIC: I = MARKER IS A STEEL ROD
EY5825_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
EY5825_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
EY5825+SATELLITE: SATELLITE OBSERVATIONS - January 30, 2001
EY5825_ROD/PIPE-DEPTH: 9.8  meters
EY5825_SLEEVE-DEPTH  : 0.9 meters
EY5825
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EY5825  HISTORY     - Date     Condition        Report By
EY5825  HISTORY     - 1992     MONUMENTED       NGS
EY5825  HISTORY     - 19921021 GOOD             NOS
EY5825  HISTORY     - 19950322 GOOD             NGS
EY5825  HISTORY     - 19950907 GOOD             NCGS
EY5825  HISTORY     - 19961107 GOOD             NCGS
EY5825  HISTORY     - 19970422 GOOD             NCGS
EY5825  HISTORY     - 19980727 GOOD             NGS
EY5825  HISTORY     - 20010130 GOOD             NGS
EY5825
EY5825                          STATION DESCRIPTION
EY5825
EY5825'DESCRIBED BY NATIONAL GEODETIC SURVEY 1992
EY5825'THE STATION IS LOCATED ABOUT 8.0 KM (4.97 MI) SOUTH OF NEW BERN, AT
EY5825'THE CRAVEN REGIONAL AIRPORT, AND JUST SOUTH OF THE FLIGHT CONTROL
EY5825'TOWER AT THE NORTH END OF THE AIRPORT.  OWNERSHIP--FAA/SF0, 940
EY5825'AVIATION DRIVE, NEW BERN, NC, 28562.  CONTACT MR. JOHN HILL, AF
EY5825'SECTOR FIELD OFFICE MANAGER.  TELEPHONE NUMBER 919-637-2064.
EY5825'TO REACH THE STATION FROM THE JUNCTION OF U.S. HIGHWAY 70 AND WILLIAMS
EY5825'ROAD IN SOUTH NEW BERN, GO WEST ON WILLIAMS ROAD FOR 0.16 KM
EY5825'(0.10 MI) TO A RAILROAD CROSSING.  CONTINUE AHEAD, WESTERLY, FOR 1.3
EY5825'KM (0.81 MI) TO A PAVED ROAD LEFT.  TURN LEFT, SOUTHERLY, ON AVIATION
EY5825'DRIVE FOR 0.32 KM (0.20 MI) TO THE FAA BUILDING.  BEAR RIGHT PASSING
EY5825'THROUGH AN OPEN GATE.  CONTINUE WESTERLY ON TRACK ROAD FOR 0.05 KM
EY5825'(0.03 MI) TO THE END OF A FENCE LINE ON THE LEFT.  TURN LEFT,
EY5825'SOUTHERLY, ON GRASS FOR 0.16 KM (0.10 MI) TO THE STATION.
EY5825'THE STATION IS LOCATED 172 M (564.30 FT) SOUTH FROM THE CONTROL TOWER,
EY5825'38.7 M (126.97 FT) SOUTHEAST FROM A FENCE CORNER, 36.6 M (120.08 FT)
EY5825'NORTHWEST FROM THE CENTERLINE OF A TAXIWAY, 25.6 M (83.99 FT)
EY5825'EAST-NORTHEAST FROM AIRCRAFT PARKING AND 11.9 M (39.04 FT)
EY5825'SOUTH-SOUTHEAST FROM A HYGROMETERIC (PRESSURE) TRANSMITTING UNIT.
EY5825
EY5825                          STATION RECOVERY (1992)
EY5825
EY5825'RECOVERY NOTE BY NATIONAL OCEAN SERVICE 1992 (RWD)
EY5825'RECOVERED IN GOOD CONDITION.
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EY5825
EY5825                          STATION RECOVERY (1995)
EY5825
EY5825'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1995 (CFS)
EY5825'RECOVERED AS DESCRIBED.
EY5825
EY5825                          STATION RECOVERY (1995)
EY5825
EY5825'RECOVERY NOTE BY NORTH CAROLINA GEODETIC SURVEY 1995 (WLL)
EY5825'RECOVERED AS DESCRIBED.
EY5825
EY5825                          STATION RECOVERY (1996)
EY5825
EY5825'RECOVERY NOTE BY NORTH CAROLINA GEODETIC SURVEY 1996 (WLL)
EY5825'RECOVERED AS DESCRIBED. THIS STATION IS DESIGNATED AS THE PRIMARY
EY5825'AIRPORT CONTROL STATION.
EY5825
EY5825                          STATION RECOVERY (1997)
EY5825
EY5825'RECOVERY NOTE BY NORTH CAROLINA GEODETIC SURVEY 1997 (JGG)
EY5825'RECOVERED AS DESCRIBED.
EY5825
EY5825                          STATION RECOVERY (1998)
EY5825
EY5825'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1998 (AJL)
EY5825'RECOVERED AS DESCRIBED, WITH THE FOLLOWING CHANGES.  THE STATION IS
EY5825'172 FT (52.4 M) SOUTH FROM THE CONTROL TOWER.
EY5825
EY5825                          STATION RECOVERY (2001)
EY5825
EY5825'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 2001 (GAS)
EY5825'1.4 KM SOUTHERLY ALONG U.S. HIGHWAY 70 EAST FROM THE JUNCTION OF
EY5825'U.S. HIGHWAY 17 IN NEW BERN, THENCE 1.3 KM WESTERLY ALONG WILLIAMS
EY5825'ROAD, THENCE 0.2 KM SOUTHERLY ALONG AVIATION DRIVE, THENCE 0.1 KM
EY5825'SOUTHWESTERLY ALONG A PAVED ROAD, THENCE 0.2 KM SOUTHERLY
EY5825'ACROSS AN APRON, 52.8 M SOUTH OF THE AIRPORT CONTROL TOWER, 38.9
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EY5825'M SOUTHEAST OF A CHAIN-LINK FENCE CORNER, 36.1 M NORTHWEST OF
EY5825'TAXIWAY E, AND 25.8 M NORTHEAST OF AND LEVEL WITH THE NORTHEAST
EY5825'EDGE OF THE APRON.  NOTE--ACCESS TO THE DATUM POINT IS THROUGH A
EY5825'5-INCH LOGO CAP.  THE SLEEVE DEPTH DOES NOT MEET THE
EY5825'SPECIFICATIONS FOR A CLASS A MARK.  THE MARK IS ON PROPERTY OWNED
EY5825'BY FAA/SFO, 940 AVIATION DRIVE, NEW BERN, NC 28562, CONTACT JOHN HILL,
EY5825'AF SECTOR FIELD OFFICE MANAGER.  THIS IS A FEDERAL BASE NETWORK
EY5825'CONTROL STATION.  THIS IS A PRIMARY AIRPORT CONTROL STATION.
EY5825'
EY5825'

*** retrieval complete.
```

Mark Recovery Entry

This form can be used to submit recoveries of survey marks to the National Geodetic Survey. If the data sheet for this mark shows a recovery within the past year and the status has not changed, please do not report it.

Enter PID:

Select condition of mark:

- ○ Good
- ○ Not recovered, not found
- ○ Poor, disturbed, mutilated, requires maintenance

For Destroyed condition, see **Note** below

Note: For destroyed marks do one of the following:
1) If you found the actual marker separated from its setting, you may report the point as destroyed. To do so please send the report on the destroyed mark as an email to Deb Brown (Deb.Brown@noaa.gov); if you send this email please do not submit the current form; instead Deb will submit the report for you. **In addition, please submit proof of the mark's destruction via actual disk, rubbing, photo or digital picture (preferred) to Deb Brown.** Deb Brown's mailing address is as follows:

Deb Brown, N/NGS143
National Geodetic Survey, NOAA
1315 East West Highway, #8400
Silver Spring, MD 20910

2) If you did not find the actual marker, then you should enter notes concerning evidence of its possible destruction as text records and select "Not recovered, not found" as the condition of mark.

Enter the approved agency code of the organization which recovered the mark. The approved agency code for a private individual is INDIV. If you do not know your approved agency code, you can generate the latest contributors list from NGS' integrated database (NGSIDB). On this list the agency code starts in column 1 and the agency full name follows it. The list is sorted alphabetically by agency code. If your agency is not on this list you must contact NGS to make the appropriate arrangements; you may do this by contacting the person whose name appears at the end of this form.

Enter agency code of the recovering organization/agency:

Enter initials of the person who recovered the mark (Optional):

The date of recovery must be expressed as a numerical month (between 1 and 12), a numerical day of the month, and a four character numerical year. The month, day, and year may be separated by spaces or by commas.
Valid examples are:
`4,25,1998` for April 25, 1998
`4 25 1998` for April 25, 1998
The current program is not valid for dates before 1990.

Enter date of recovery:

Enter your name and email address.
Privacy Statement: Your name and email address will be used only to contact you if there is a problem in loading your recovery. They will not be used for any other purpose.

Enter name:

Enter email address:

You may, if you wish, enter up to 5 lines of text. The following are the only allowed characters: letters, numbers, blank or space ( ), comma (,), period or decimal (.), apostrophe or single quote ('), asterisk (*), plus sign (+), minus sign or hyphen (-), equal sign (=), slash (/), left parenthesis ((), right parenthesis ()).
Warning: Do not enter personal phone numbers.
Note: Text such as RECOVERED AS DESCRIBED, or MARK NOT FOUND, or DESCRIPTION IS ADEQUATE, etc. is not necessary.

submit

For assistance contact Deb Brown
Email: Deb.Brown@noaa.gov

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1        National Geodetic Survey,   Retrieval Date = JANUARY  4, 1999
AW5439
**********************************************************************
AW5439  DESIGNATION -  HGCSD 18
AW5439  PID         -  AW5439
AW5439  STATE/COUNTY-  TX/HARRIS
AW5439  USGS QUAD   -  SATSUMA (1982)
AW5439
AW5439                        *CURRENT SURVEY CONTROL
AW5439  ______________________________________________________________
AW5439* NAD 83(1993)-  29 52 45.31262(N)     095 36 41.68709(W)      ADJUSTED
AW5439* NAVD 88     -         36.28   (meters)      119.0     (feet)  GPS OBS
AW5439  ______________________________________________________________
AW5439  X           -    -541,229.237 (meters)                       COMP
AW5439  Y           -  -5,508,419.298 (meters)                       COMP
AW5439  Z           -   3,158,779.472 (meters)                       COMP
AW5439  LAPLACE CORR-           0.34  (seconds)                      DEFLEC96
AW5439  ELLIP HEIGHT-           8.96  (meters)                       GPS OBS
AW5439  GEOID HEIGHT-         -27.43  (meters)                       GEOID96
AW5439
AW5439  HORZ ORDER  -  FIRST
AW5439  ELLP ORDER  -  THIRD     CLASS I
AW5439
AW5439.The horizontal coordinates were established by GPS observations
AW5439.and adjusted by the National Geodetic Survey in October 1996.
AW5439
AW5439.The orthometric height was determined by GPS observations and a
AW5439.high-resolution geoid model using precise GPS observation and
AW5439.processing techniques.
AW5439
AW5439.The X, Y, and Z were computed from the position and the ellipsoidal ht.
AW5439
AW5439.The Laplace correction was computed from DEFLEC96 derived deflections.
AW5439
AW5439.The ellipsoidal height was determined by GPS observations
AW5439.and is referenced to NAD 83.
AW5439
AW5439.The geoid height was determined by GEOID96.
AW5439
AW5439;                   North         East      Units   Scale      Converg.
AW5439;SPC TXSC     - 4,231,486.301   927,255.302   MT  0.99990823 +1 39 36.1
AW5439;UTM  15      - 3,308,270.740   247,770.501   MT  1.00038501 -1 18 06.2
AW5439
AW5439                          SUPERSEDED SURVEY CONTROL
AW5439
AW5439  NAD 83(1986)-  29 52 45.32657(N)     095 36 41.66906(W) AD(       ) 1
AW5439  NAD 83(1993)-  29 52 45.31197(N)     095 36 41.68755(W) AD(       ) 1
AW5439  ELLIP HT    -          9.33   (m)                        GP(       ) 5
AW5439  NGVD 29     -         36.86   (m)           120.9     (f) LEVELING    3
AW5439
AW5439.Superseded values are not recommended for survey control.
```

Elevation published to centimeters.

Orthometric height determined by GPS.

Survey Specifications

- Specifications can be described as the field operations required to meet a particular survey standard.

- Also included are the specified precision and allowable tolerances for the data collected, the limitations of the geometric form of acceptable figures, monumentation, and description of the points.

Definition of Precision

precision **(1) In statistics, a measure of the tendency of a set of random numbers to cluster about a number determined by the set.**

The usual measure is either the standard deviation with respect to the average, or the reciprocal of the quantity. It is distinguished from accuracy by the fact that the latter is a measure of the tendency to cluster about a number not determined by the set but specified in some other manner.

From: Geodetic Glossary, National Geodetic Survey, September 1986

Standard Error of the Mean

$$\sigma_m = \sqrt{\frac{\Sigma v^2}{n\,(n-1)}}$$

Where σ_m is the standard error of the mean, v is a residual (that is, the difference between a measured length and the mean of all measured lengths of a line), and n is the number of measurements.

The term "standard error" used here is computed under the assumption that all errors are strictly random in nature. The true or actual error is a quantity that cannot be obtained exactly. It is the difference between the true value and the measured value. By correcting each measurement for every known source of systematic error, however, one may approach the true error. It is mandatory for any practitioner using these tables to reduce to a minimum the effect of all systematic and constant errors so that real accuracy may be obtained.

Definition of Accuracy

accuracy **(1) Closeness of an estimated (e.g., measured or computed) value to a standard or accepted value of a particular quantity.**

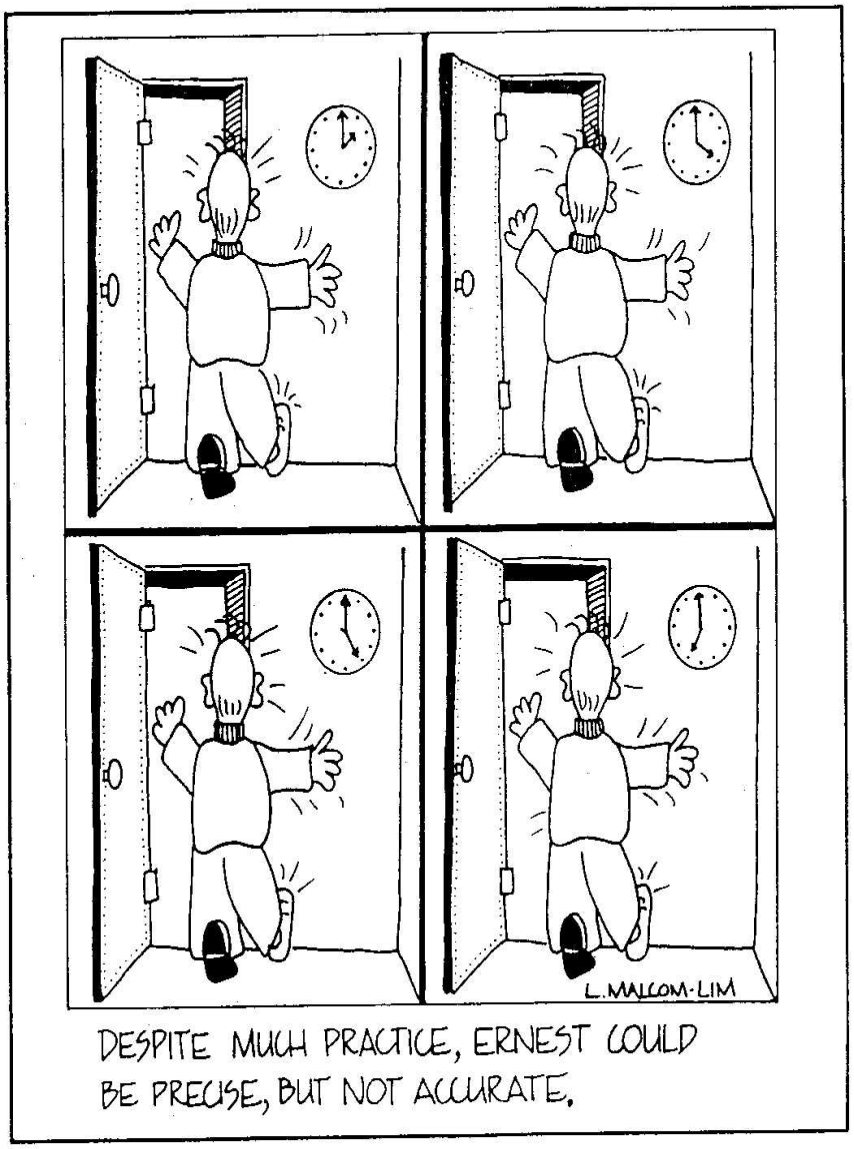
Accuracy is commonly referred to as "high" or "low" depending on the size of the differences between the estimated and the standard values.

(2) The square root of the average value of the sum of the squares of the differences between the values in a set and the corresponding values that have been accepted as correct or standard.

(3) The reciprocal of the quantity defined in (2).

Accuracy cannot be calculated solely from values based on measurements. A standard value or set of standard values must be available for comparison somewhere in the chain of calculations. The standard of reference may be: (a) an exact value, such as the sum of the three angles of a plane triangle being exactly 180°; (b) a value of a conventional unit as defined by a physical representation thereof, such as the international meter; (c) a value determined by refined methods and deemed sufficiently near the ideal or true value to be held constant, such as the adjusted elevation of a permanent bench mark or the graticule of a map projection.

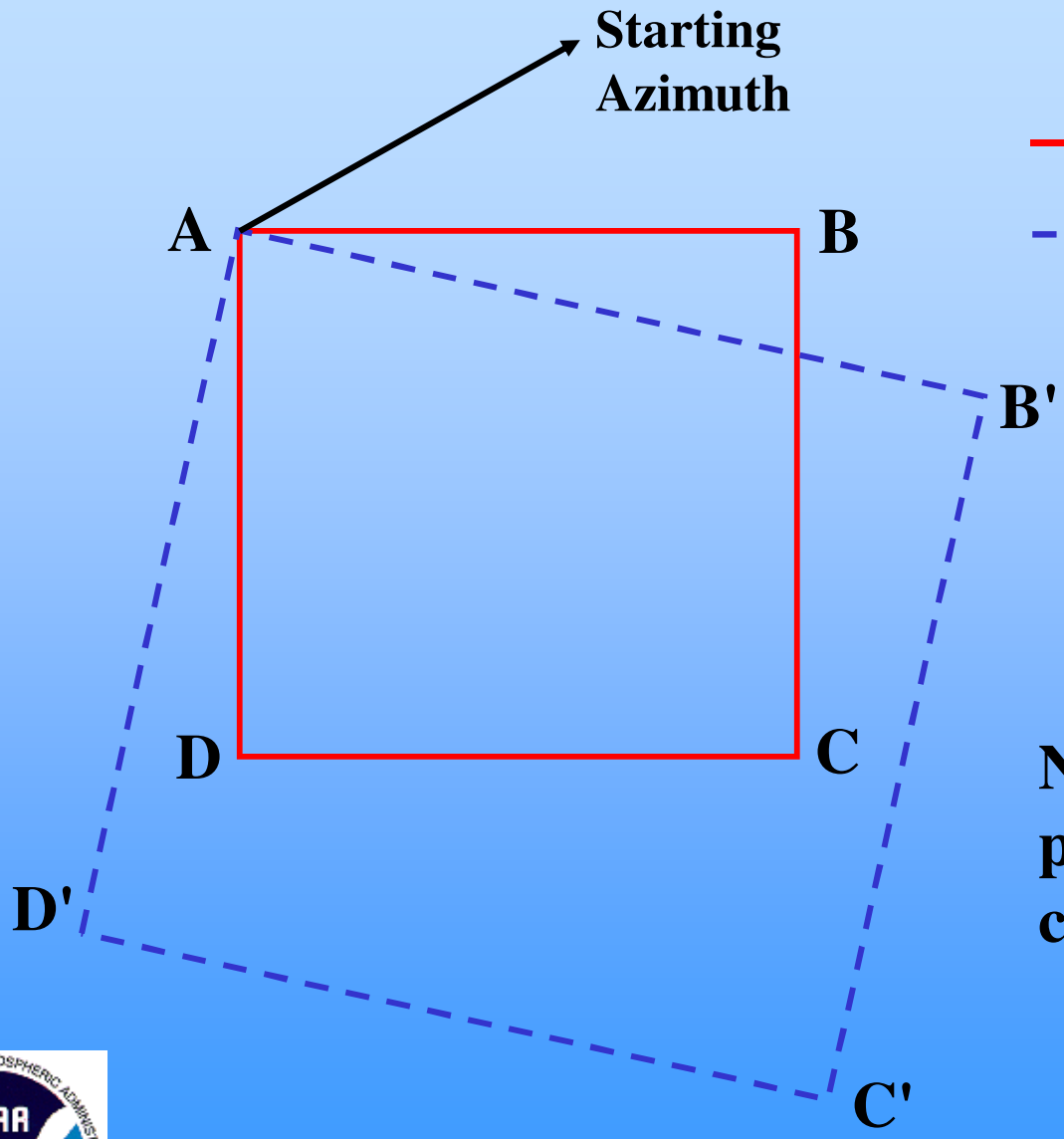
From: Geodetic Glossary, National Geodetic Survey, September 1986


L.MALCOM-LIM
DESPITE MUCH PRACTICE, ERNEST COULD BE PRECISE, BUT NOT ACCURATE.

CLOSURE

Is it a Standard
or
is it a Specification?

Examples of Closure



Accurate Survey

Survey with starting azimuth error and systematic distance error

Note that both surveys produce excellent closures

EVOLUTION OF ACCURACY

STANDARDS

U.S. DEPARTMENT OF COMMERCE
LEWIS L. STRAUSS, Secretary
COAST AND GEODETIC SURVEY
H. ARNOLD KARO, Director

Special Publication No. 247

Revised Edition

MANUAL OF GEODETIC TRIANGULATION

By
Commander F. R. Gossett

First Edition 1950
Reprinted With Minor Corrections 1955
Revised With New Specifications 1959
Reprinted 1971

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1959

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington , D. C. 20402 - Price $3.55 (paper cover)

CLASSIFICATION OF CONTROL

The foregoing data concerning control classification may be tabulated as follows:

	First Order	Second Order	Third Order	Fourth Order
Triangulation …..	Average triangle closure 1”, check on base 1/25,000.	Average triangle closure 3”, check on base 1/10,000.	Average triangle closure 5”, check on base 1/5,000.	Plane table or transit.
Traverse ……...	Position check 1/25,000.	Position check 1/10,000.	Position check 1/5,000.	Stadia, tape, or wheel.
Leveling ……	Error of closure of section 0.017 ft. □— miles or 4 mm. □—— kilometers.	Error of closure of section 0.035 ft. □— miles or 8.4 mm. □—— kilometers.	Error of closure of section 0.05 ft. □— miles or 12 mm. □—— kilometers.	Flying wye levels, vertical angles.

Special Publication No. 247
Manual of Geodetic Triangulation (1950)

Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys

Prepared By:
Federal Geodetic Control Committee

U. S. DEPARTMENT OF COMMERCE
Frederic B. Dent, secretary

National Oceanic and Atmospheric Administration
Robert M. White, Administrator

Federal Coordinator for Geodetic Control and related Surveys
David H. Wallace

National Ocean survey
Allen L. Powell, Director

Rockville, Md.
February 1974
Reprinted June 1980

Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys

Federal Geodetic Control Committee
John O. Phillips, Chairman

Rockville, Md.
July 1975
Revised June 1980

U. S. DEPARTMENT OF COMMERCE
Phillip M. Klutznick, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

Federal Coordinator for Geodetic Control and Related Surveys
Thomas B. Owen

National Ocean Survey
R. R. Lippold, Director

Standards and Specifications for Geodetic Control Networks

Federal Geodetic Control Committee
Rear Adm. John D. Bossler, Chairman

Rockville, Maryland
September 1984

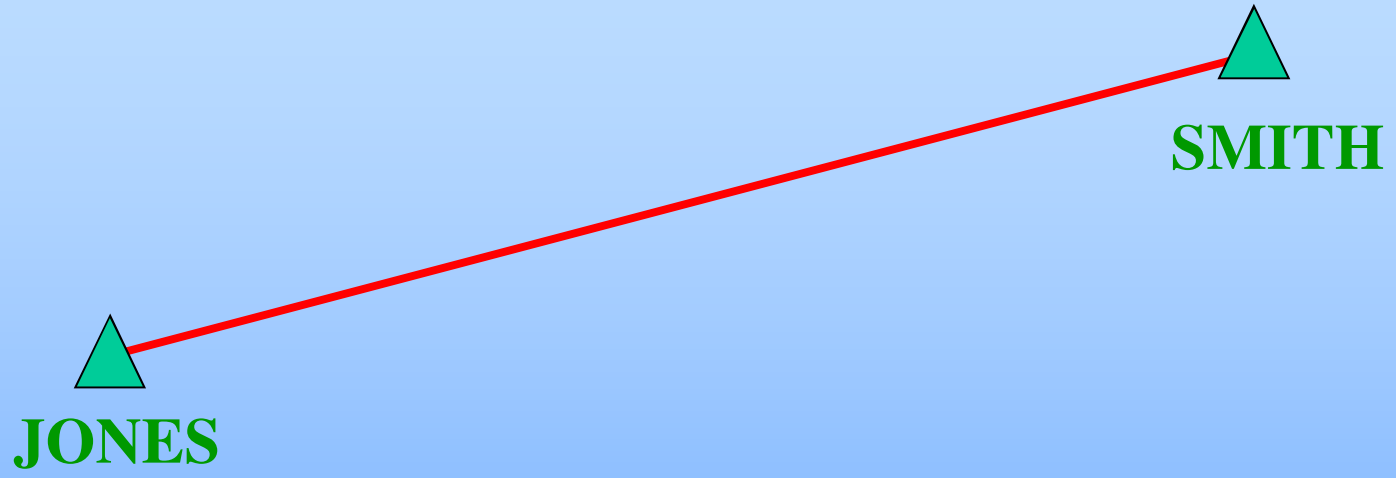
Reprinted August 1993

HORIZONTAL CLASSIFICATIONS

ORDER OF ACCURACY	MAXIMUM CLOSURE
FIRST	1:100,000
SECOND - CLASS I	1: 50,000
SECOND - CLASS II	1: 20,000
THIRD - CLASS I	1: 10,000
THIRD - CLASS II	1: 5,000

NOTE: WE DO NOT HAVE FOURTH-ORDER STANDARDS SUCH AS MANY COUNTRIES DO.

What Does First-Order Horizontal Accuracy Mean?



JONES to SMITH = 13,786 meters

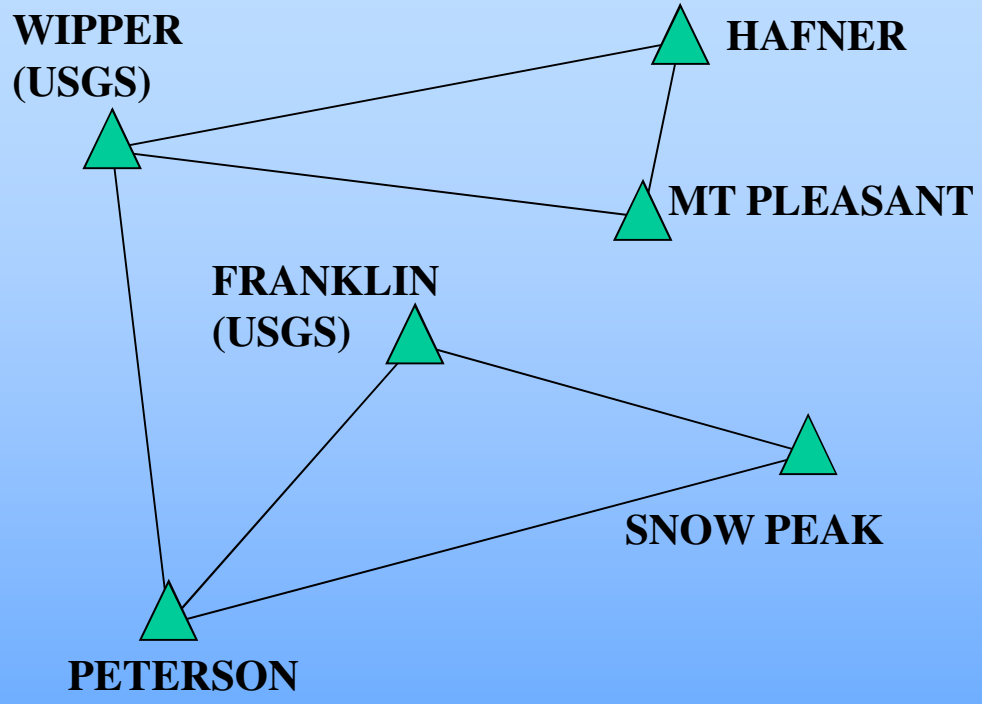
Therefore, the accuracy of the relationship between JONES and SMITH is:

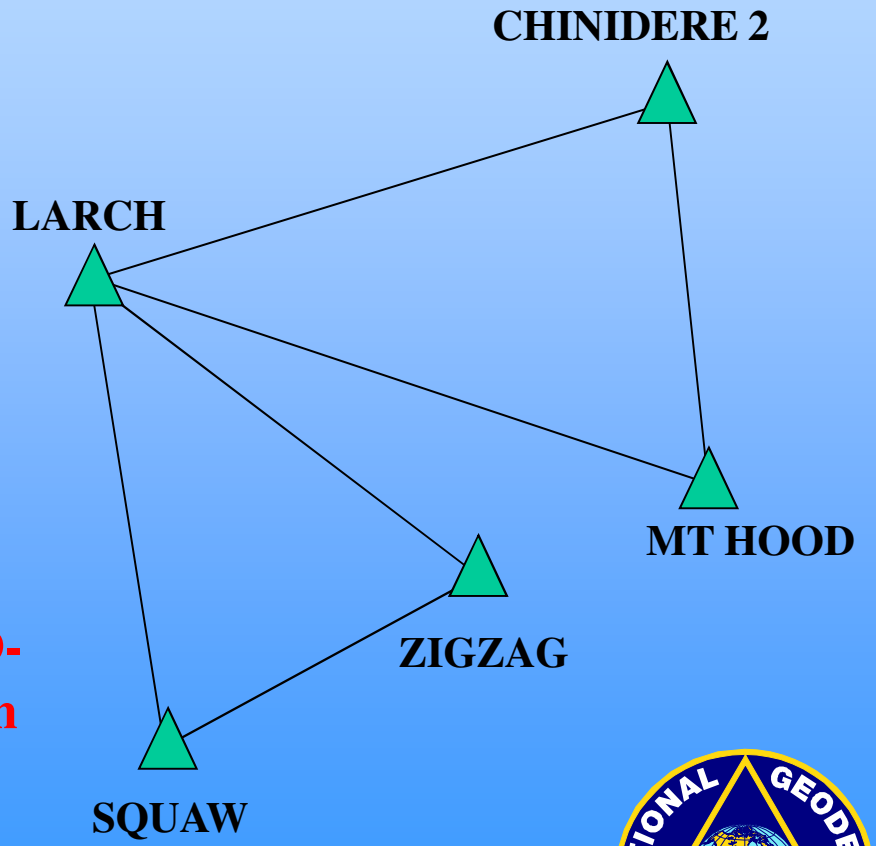
13,786/100,000 = 0.138 meters

20 Percent Rule

Whenever the distance between two new unconnected survey points is less than 20 percent of the distance between those points traced along existing or new connections, then a direct connection must be made between those two survey points.

Types of Figures Where It May Be Difficult to Obtain Satisfactory Closures

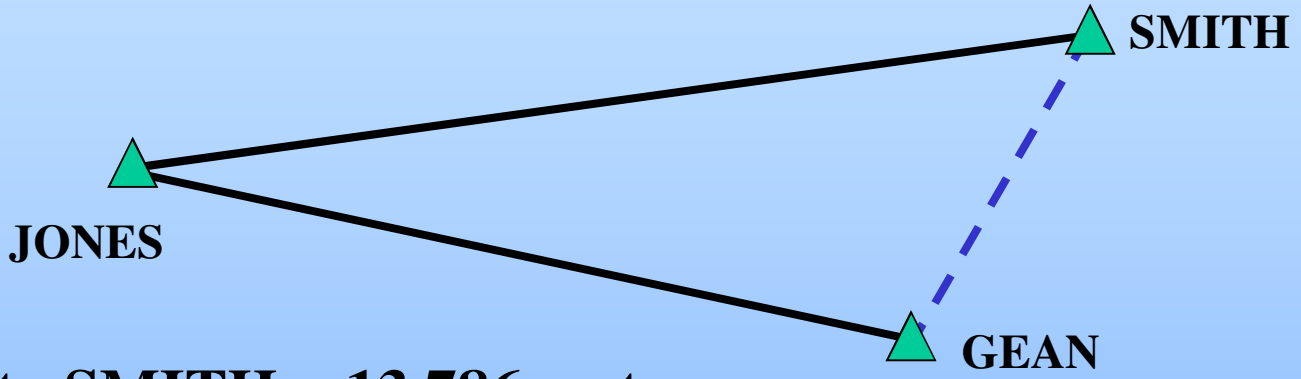




Surveys between MT PLEASANT-FRANKLIN (USGS) and MT HOOD-ZIGZAG might not close to minimum stated standards of points involved.

What Does First-Order Horizontal Accuracy Mean?

(When the points aren't directly connected)



JONES to SMITH = 13,786 meters
JONES to GEAN = 11,420 meters
SMITH to GEAN* = 4,725 meters (* not observed)

The accuracy of the relationship between SMITH and GEAN is:

$$\sqrt{[(0.138)^2 + (0.114)^2]} = 0.179 \text{ meters}$$

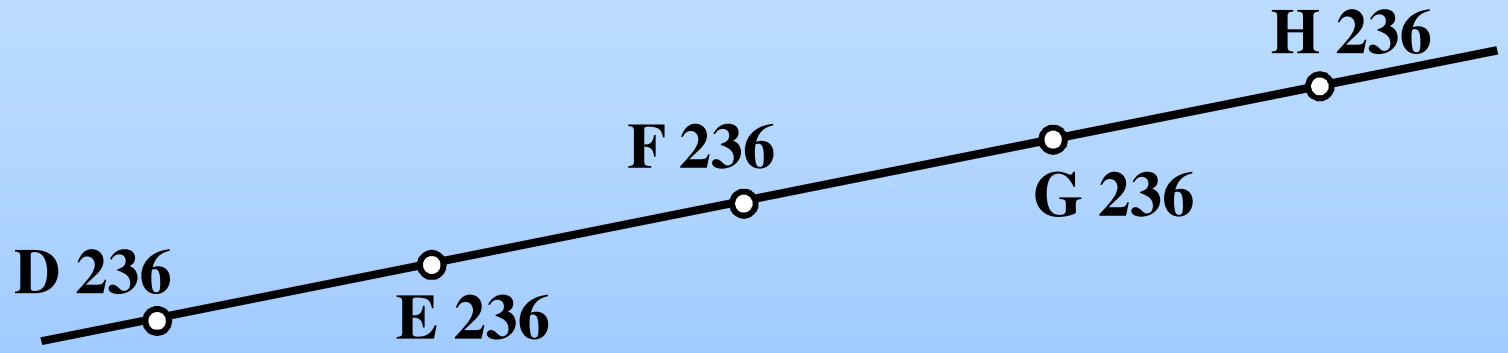
NOT 4,725 /100,000 = 0.047 meters

Accuracy Standards for Vertical Control

Classification	Relative Accuracy Between Directly Connected Points or BenchMarks (Standard Error)
First - Order, Class I	0.5 mm □K
First - Order, Class II	0.7 mm □K
Second - Order, Class I	1.0 mm □K
Second - Order, Class II	1.3 mm □K
Third - Order	2.0 mm □K

(K is the distance in kilometers between points)

What Does First-Order, Class II Accuracy Mean?



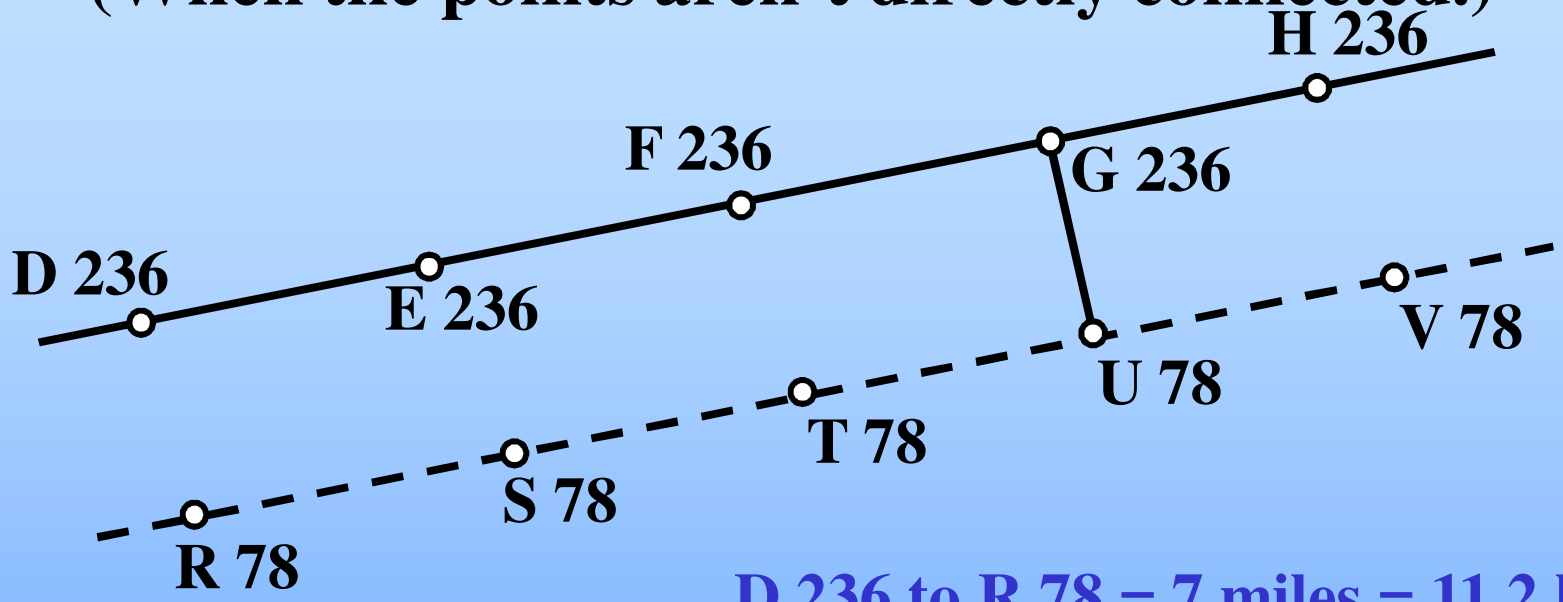
D 236 to G 236 = 3 miles = 4.8 km

Therefore, the accuracy of the vertical relationship between D 236 and G 236 is:

$$0.7 \sqrt{4.8} = 1.5 \text{ mm}$$

What Does Second-Order, Class I Accuracy Mean?

(When the points aren't directly connected.)



D 236 to R 78 = 7 miles = 11.2 km

Therefore, the accuracy of the vertical relationship between D 236 and R 78 is:

$$1.0 \square\sqrt{11.2} = 3.3 \text{ mm}$$

NOT: $1.0 \square\sqrt{1.6} = 1.3$ mm

GEOMETRIC GEODETIC ACCURACY STANDARDS AND SPECIFICATIONS FOR USING GPS RELATIVE POSITIONING TECHNIQUES

FEDERAL GEODETIC CONTROL COMMITTEE
Rear Adm. Wesley V. Hull, Chairman

Version 5.0: May 11, 1988
Reprinted with corrections: August 1, 1989

Note: This is a preliminary document. Use only as a guideline for the planning and execution of geodetic surveys using GPS relative positioning techniques.

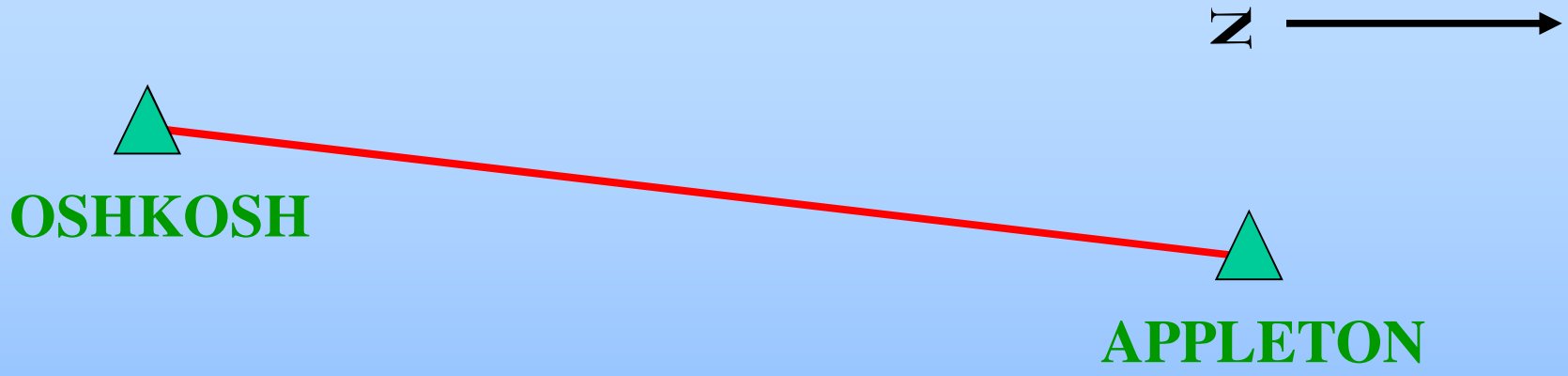
Accuracy Standards for GPS

Classification	Minimum Geometric Accuracy Standard*
AA - Order	0.3 cm + 1:100,000,000
A - Order	0.5 cm + 1: 10,000,000
B - Order	0.8 cm + 1: 1,000,000
First - Order	1.0 cm + 1: 100,000
Second - Order, Class I	2.0 cm + 1: 50,000
Second - Order, Class II	3.0 cm + 1: 20,000
Third - Order	5.0 cm + 1: 10,000

NOTE: At the 95 Percent Confidence Level

What Does B-Order GPS Accuracy Mean?

(for "long" lines)



OSHKOSH to APPLETON = 42,236 meters

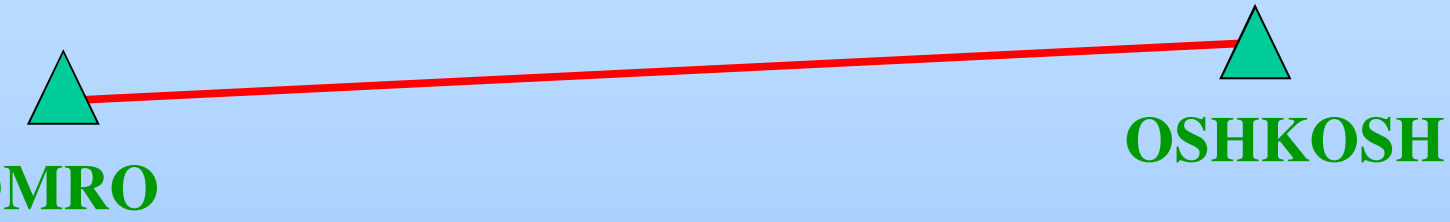
Therefore, the accuracy of the relationship between OSHKOSH and APPLETON is:

$$\pm\sqrt{[(0.008)^2 + (42{,}236/1{,}000{,}000)^2]} = 0.043 \text{ meters}$$

At the 95 Percent Confidence Level

What Does B-Order GPS Accuracy Mean?

(for "short" lines)



OMRO to OSHKOSH = 5,632 meters

(approximately 3.5 miles)

Therefore, the accuracy of the relationship between OMRO and OSHKOSH is:

$$\pm\sqrt{[(0.008)^2 + (5{,}632/1{,}000{,}000)^2]} = 0.010 \text{ meters}$$

ANNEX G
ELLIPSOID HEIGHT ORDER-AND-CLASS (OC) CODES

This annex contains ellipsoid height Order and Class (OC) codes. These two-digit codes are used to classify each ellipsoid height value observed and adjusted at horizontal control points.
The first character of the OC code indicates the order and the second character the class, in accordance with the following draft standards for classifying ellipsoid height determinations:

OC Code	Classification	b = Maximum Height Difference Accuracy
11	First Order, Class I	0.5
12	First Order, Class II	0.7
21	Second Order, Class I	1.0
22	Second Order, Class II	1.3
31	Third Order, Class I	2.0
32	Third Order, Class II	3.0
41	Fourth Order, Class I	6.0
42	Fourth Order, Class II	15.0
51	Fifth Order, Class I	30.0
52	Fifth Order, Class II	60.0

continued……..

ANNEX G (continued)

The ellipsoid height difference accuracy (b) is computed from a minimally constrained, correctly weighted, least squares adjustment by the formula:

b = s / sqrt(d)

where: **d = horizontal distance in kilometers between control points.**

s = propagated standard deviation of ellipsoid height difference in millimeters between control points obtained from the least squares adjustment.

The following table lists the standard errors of ellipsoid height differences at various distances:

	OC Codes									
	11	12	21	22	31	32	41	42	51	52
Distance (km)	Standard Error (mm)									
1	0.5	0.7	1.0	1.3	2.0	3.0	6.0	15	30	60
5	1.1	1.6	2.2	2.9	4.5	6.7	13	34	67	134
10	1.6	2.2	3.2	4.1	6.3	9.5	19	47	95	190
25	2.5	3.5	5.0	6.5	10	15	30	75	150	300
50	3.5	4.9	7.1	9.2	14	21	42	106	212	424
75	4.3	6.1	8.7	11	17	26	52	130	260	520
100	5.0	7.0	10	13	20	30	60	150	300	600

Summary of Previously Existing Accuracy Standards

- **Triangulation & Traverse**
  - **Directly Proportional to Distance Between Points**
    i.e., 1 part per 100,000, 1:100,000
  - **"Seldom to Exceed"**
- **Leveling**
  - **Directly Proportional to SQRT of Distance Leveled**
    i.e., Y mm X SQRT [Distance in km]
  - **"Seldom to Exceed"**
- **GPS**
  - **Base Error + Directly Proportional to Distance Between Points**
    i.e., 0.8 cm +1:1,000,000
  - **At 95% Confidence Level**

Development of New Accuracy Standards

- Federal Geodetic Control Subcommittee
- Federal Geographic Data Committee

Proposal for Geodetic Accuracy Standards

1. A local accuracy standard AND a network accuracy standard.
2. Both stated as numeric quantities (centimeters or millimeters).
3. Do NOT use distance dependent expression.
4. Separate accuracy measures for: horizontal, ellipsoid height, and orthometric height.
5. Local and network accuracies computed for all points (new, old, bench marks, terrestrial, GPS, …).
6. Accuracy bands or ranges for specifications, NOT for standards.
7. Network accuracy with respect to CORS sites.
8. Local accuracy an "average" of observation accuracy to directly connected points.
9. Individual observational accuracies for each directly connected point in a box score.
10. Vertical accuracy at linear (1-D) 95% confidence level.
11. Horizontal accuracy at 2-D, 95% circular error confidence level.
12. Network accuracies for new survey points from adjustments with weighted constraints at the old points.
13. Weights of constraints use published 1-sigma network accuracies of old control.

Approved: FGCS Methodology Work Group 08/15/94

DRAFT

Standards for Geodetic Control Networks

DRAFT

Federal Geodetic Control Subcommittee
Lewis A. Lapine, Chairman
Version 1.0
May 23, 1995

For information write:
Chairman
Federal Geodetic Control Subcommittee
1315 East-West Highway
Silver Spring, Maryland 20910

DRAFT

Contents

Table 2.1 - - Accuracy Standards
Horizontal, Ellipsoid Height, and Orthometric Height

Classification Range	95-Percent Confidence
	(Meters)
Range 0	reserved for CORS
Range I	< 0.001
Range II	0.001 - 0.002
Range III	0.002 - 0.005
Range IV	0.005 - 0.010
Range V	0.010 - 0.020
Range VI	0.020 - 0.050
Range VII	0.050 - 0.100
Range VIII	0.100 - 0.200
Range IX	0.200 - 0.500
Range X	0.500 - 1.000
Range XI	1.000 - 2.000
Range XII	2.000 - 5.000
Range XIII	5.000 - 10.000
Range XIV	> 10.000 ***

*** Ranges larger than XIII will be developed jointly with other subcommittees within FGDC.

Table 2.1 - - Accuracy Standards
Horizontal, Ellipsoid Height, and Orthometric Height

Classification Range	95-Percent Confidence
	(Meters)
1-Millimeter	< 0.001
2-Millimeter	0.001 - 0.002
5-Millimeter	0.002 - 0.005
1-Centimeter	0.005 - 0.010
2-Centimeter	0.010 - 0.020
5-Centimeter	0.020 - 0.050
1-Decimeter	0.050 - 0.100
2-Decimeter	0.100 - 0.200
5-Decimeter	0.200 - 0.500
1-Meter	0.500 - 1.000
2-Meter	1.000 - 2.000
5-Meter	2.000 - 5.000
10-Meter	5.000 - 10.000

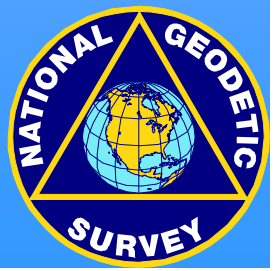
Table 2.1 - - Accuracy Standards

Horizontal, Ellipsoid Height, and Orthometric Height

Classification Range	95-Percent Confidence Less Than or Equal to:	
1-Millimeter	0.001	meters
2-Millimeter	0.002	"
5-Millimeter	0.005	"
1-Centimeter	0.010	"
2-Centimeter	0.020	"
5-Centimeter	0.050	"
1-Decimeter	0.100	"
2-Decimeter	0.200	"
5-Decimeter	0.500	"
1-Meter	1.000	"
2-Meter	2.000	"
5-Meter	5.000	"
10-Meter	10.000	"

FGDC Subcommittees

- Base Cartographic (Interior - NMD)
- Bathymetric (Commerce - NOS)
- Cadastral (Interior - BLM)
- Cultural and Demographic (Commerce - Census)
- *Geodetic (Commerce - NOS)*
- Ground Transportation (Transportation - FHA)
- (State - Cartography) International Boundaries
- Soils (Agriculture - SCS, NRCS)
- Vegetation (Agriculture - Forest Service)
- Wetlands (Interior - Fish & Wildlife)



Why New Accuracy Standards Are Needed

- **Accuracy of different types of spatial data (e.g., survey, cartographic, etc.) were described differently**
- **Accuracy of geodetic (survey) spatial data determined using different methodologies**
  - **Classical horizontal (e.g., triangulation and traverse)**
  - **Classical vertical (e.g., leveling)**
  - **GPS**
- **Accuracy of new survey technology (i.e., GPS) is not consistent with classical accuracy methodology, (i.e., based on distance)**
- **Accuracy classification of survey data under old system not consistent with what GIS users want**
  - **Local accuracy**
  - **Network accuracy**

New Direction

FGDC Document:

Geospatial Positioning Accuracy Standards

(Only applies to POINT DATA !!!)

- Introduction
- Accuracy Standard
- Part 1 - Geodetic Networks
  - Geodetic Subcommittee
- Part 2 - National Standard for Spatial Data Accuracy
  - National Spatial Data Accuracy Standard
  - Map Accuracy Standards
  - Base Cartographic Subcommittee

(continued)

FGDC Document: (continued)
Geospatial Positioning Accuracy Standards

- **Part 3 - Navigation Charts and Hydrographic Surveys**
  - **Bathymetry Subcommittee**
- **Part 4 - Engineering, Construction & Facilities Management**
  - **Facilities Working Group**
- **Part 5 - Cadastral and Boundary Surveys & Plats**
  - **Cadastral Subcommittee**
- **Others ???**
- **FGDC = Federal Geographic Data Committee**

Accuracy Standard

- **Components:**
  - **Horizontal:**
    - » **Radius of circle**
    - » **95-percent confidence level**

      [Leenhouts, P. P. (1985) "On the computation of bi-normal radial error" *Navigation*, 32(1), 16-28]
  - **Vertical:**
    - » **Linear value**
    - » **95-percent confidence**
- **Reported in:**
  - **Metric units (preferred)**
  - **English units (permitted)**

(continued)

Accuracy Standard (continued)

- **Methodology used to determine accuracy values**
  - **For example: least squares adjustment**
  - **Must define how accuracies are achieved**
- **Accuracy level versus application**
- **Connection to National Datums:**
  - **NAD83**
  - **NAVD88 (preferred) / NGVD29 (permitted)**
  - **Other ??**
  - **Must state datum or include transformations**

FGDC-STD-007-1998

Geospatial Positioning Accuracy Standards

Federal Geodetic Control Subcommittee
Federal Geographic Data Committee

Federal Geographic Data Committee
Department of Agriculture•Department of Commerce•Department of Defense•Department of Energy
Department of Housing and urban Development•Department of the Interior•Department of State
Department of Transportation•Environmental Protection Agency
Federal Emergency Management Agency•Library of Congress
National Aeronautics and Space Administration•National Archives and Records Administration
Tennessee Valley Authority

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data

Status of FGDC Standards

as of November 14, 2000

See also Standards Documents by Sponsoring Organization

Final Stage - FGDC Endorsed Standards
Review Stage
Draft Stage
Proposal Stage
Discontinued from FGDC Standards Process

Final Stage - FGDC Endorsed Standards

Content Standard for Digital Geospatial Metadata (version 2.0), FGDC-STD-001-1998

Content Standard for Digital Geospatial Metadata, Part 1: Biological Data Profile, FGDC-STD-001.1-1999

Spatial Data Transfer Standard (SDTS), FGDC-STD-002
(a modified version was adopted as ANSI NCITS 320:1998)

Spatial Data Transfer Standard (SDTS), Part 5: Raster Profile and Extensions, FGDC-STD-002.5

Spatial Data Transfer Standard (SDTS), Part 6: Point Profile, FGDC-STD-002.6

SDTS Part 7: Computer-Aided Design and Drafting (CADD) Profile, FGDC-STD-002.7-2000

Cadastral Data Content Standard, FGDC-STD-003

http://www.fgdc.gov/standards/status/textstatus.html

Classification of Wetlands and Deep Water Habitats, FGDC-STD-004

Vegetation Classification Standard, FGDC-STD-005

Soils Geographic Data Standard, FGDC-STD-006

Geospatial Positioning Accuracy Standard, Part 1, Reporting Methodology, FGDC-STD-007.1-1998

Geospatial Positioning Accuracy Standard, Part 2, Geodetic Control Networks, FGDC-STD-007.2-1998

Geospatial Positioning Accuracy Standard, Part 3, National Standard for Spatial Data Accuracy, FGDC-STD-007.3-1998

Content Standard for Digital Orthoimagery, FGDC-STD-008-1999

Content Standard for Remote Sensing Swath Data, FGDC-STD-009-1999

Utilities Data Content Standard, FGDC-STD-010-2000

Review Stage

Completed Public Review

Facility ID Data Standard

Geospatial Positioning Accuracy Standard, Part 4: Architecture, Engineering Construction and Facilities Management

Content Standard for Framework Land Elevation Data

Metadata Profile for Shoreline Data

http://www.fgdc.gov/standards/status/textstatus.html

Hydrographic Data Content Standard for Coastal and Inland Waterways

Digital Geologic Map Symbolization

Out for Public Review
Note: "(month date, year)" indicates closing date for public review.

Geospatial Positioning Accuracy Standard, Part 5: Standard for Hydrographic Surveys and Nautical Charts (February 16, 2001) ←

In Review by SWG Prior to Public Review

Address Content Standard

NSDI Framework Transportation Identification Standard

U.S. National Grid for Spatial Referencing

Draft Stage

Content Standard for Digital Geospatial Metadata: Extensions for Remote Sensing Metadata

Earth Cover Classification System

Encoding Standard for Geospatial Metadata

Geologic Data Model

Governmental Unit Boundary Data Content Standard

Biological Nomenclature and Taxonomy Data Standard

FGDC-STD-007.2-1998

Geospatial Positioning Accuracy Standards
Part 2: Standards for Geodetic Networks

Federal Geodetic Control Subcommittee
Federal Geographic Data Committee

Federal Geographic Data Committee
Department of Agriculture•Department of Commerce•Department of Defense•Department of Energy
Department of Housing and urban Development•Department of the Interior•Department of State
Department of Transportation•Environmental Protection Agency
Federal Emergency Management Agency•Library of Congress
National Aeronautics and Space Administration•National Archives and Records Administration

CONTENTS

Table 2.1 -- Accuracy Standards
Horizontal, Ellipsoid Height, and Orthometric Height

Accuracy Classification	95-percent confidence
	Less Than or Equal to:
1-Millimeter	0.001 meters
2-Millimeter	0.002 "
5-Millimeter	0.005 "
1-Centimeter	0.010 "
2-Centimeter	0.020 "
5-Centimeter	0.050 "
1-Decimeter	0.100 "
2-Decimeter	0.200 "
5-Decimeter	0.500 "
1-Meter	1.000 "
2-Meter	2.000 "
5-Meter	5.000 "
10-Meter	10.000 "

Local Accuracy

The *local accuracy* of a control point is a number, expressed in centimeters, that represents the uncertainty, at the 95% confidence level, in the coordinates of this control point relative to the coordinates of other directly connected, adjacent control points.

The reported *local accuracy* is an approximate average of the individual local accuracy values between this control point and other observed control points used to establish the coordinates of the control point. Extremely high or low individual local accuracies are not considered in computing the average local accuracy of a control point.

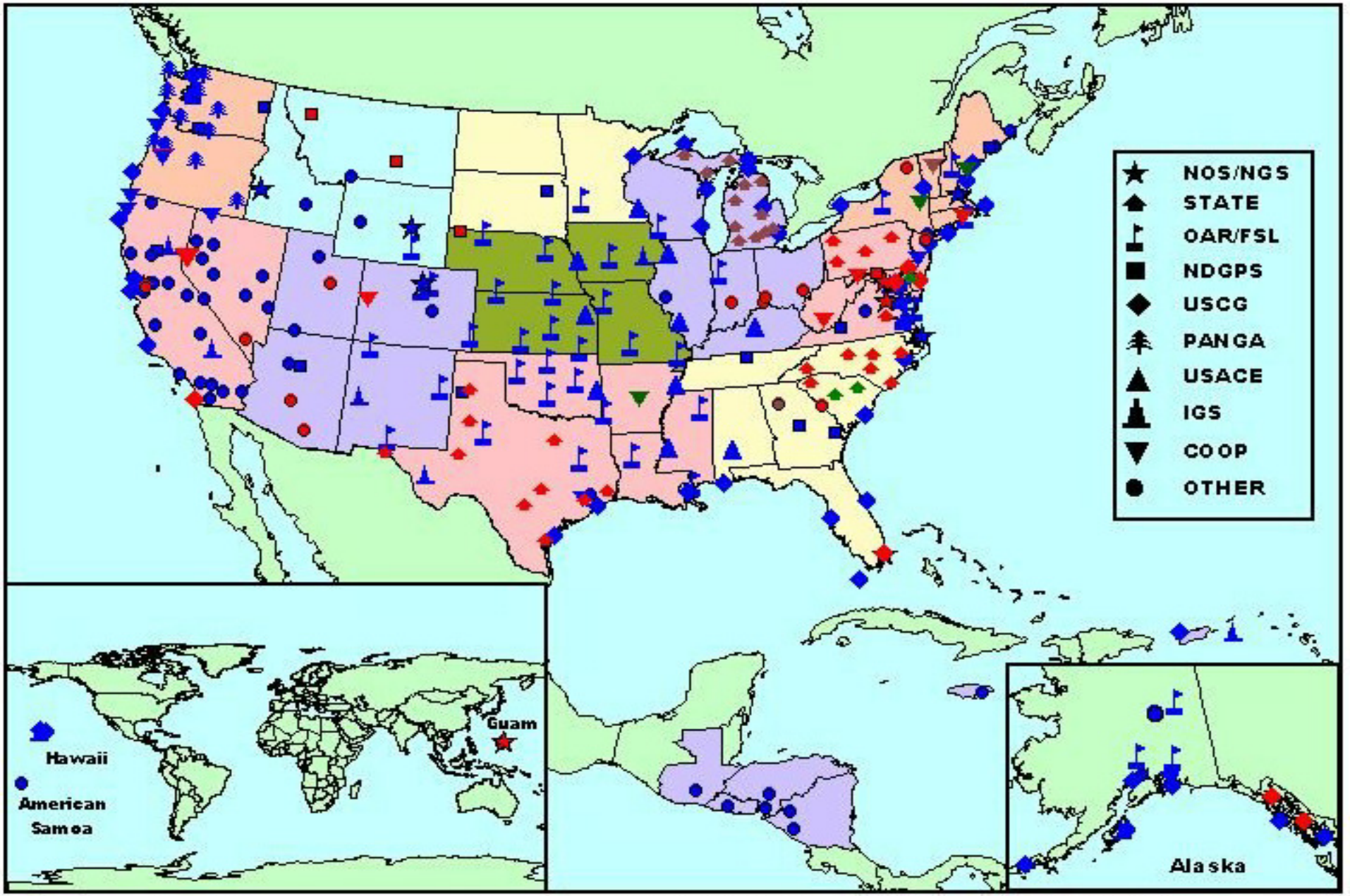
Network Accuracy

The *network accuracy* of a control point is a number, expressed in centimeters, that represents the uncertainty in the coordinates, at the 95% confidence level, of this control point with respect to the geodetic datum.

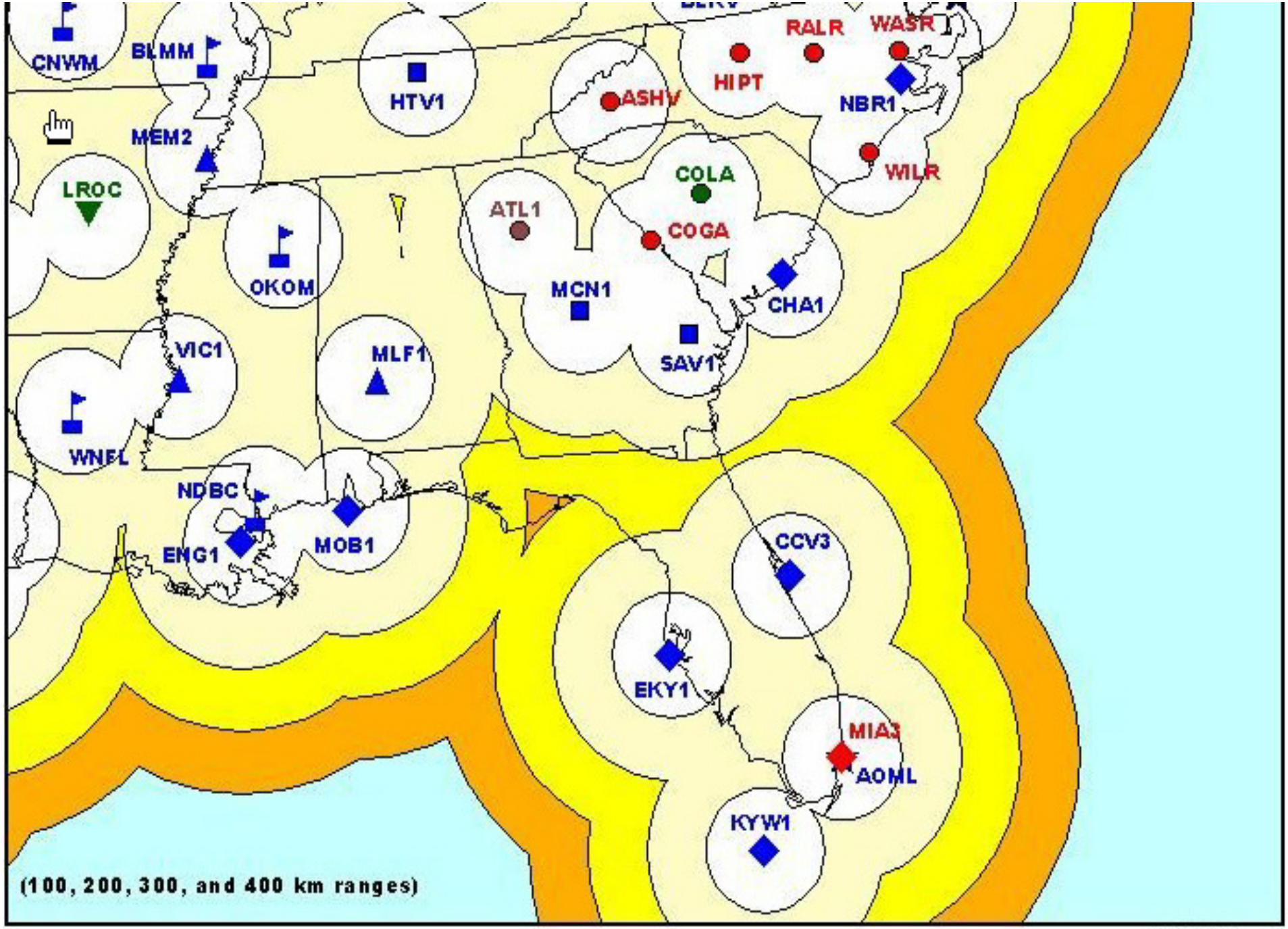
For NSRS *network accuracy* classification, the datum is considered to be best expressed by the geodetic values at the CORS supported by NGS.

By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.

CORS Coverage - September 2001



Symbol color denotes sampling rates: (1 second) (5 seconds) (15 seconds) (30 seconds)


CNVM
BLMM
HTV1
RALR
WASR
HIPT
ASHV
NBR1
MEM2
WILR
LROC
COLA
ATL1
COGA
OKOM
MCN1
CHA1
VIC1
MLF1
SAV1
WNEL
NDBC
MOB1
EMG1
CCV3
EKY1
MIA3
AOML
KYW1
(100, 200, 300, and 400 km ranges)
04/2001
Symbol color denotes sampling rates: (1 second) (5 seconds) (15 seconds) (30 seconds)

Improving Positional Accuracy

Network	Time Span	Network Accuracy	Local Accuracy
NAD 27	1927 - 1986	10 meters	First-order (1 part in 0.1 million)
NAD 83	1986 - 1991	1 meter	First-order (1 part in 0.1 million)
HARN	1991 - 1997	0.1 meter	B-order (1 part in 1 million) A-order (1 part in 10 million)
CORS	1996 -	0.01 meter*	0.01 meter*

*The best we have; so they are assumed to be zero.

SUMMARY
New Standards for Geodetic Control Networks

- **Two accuracy standards**
  - **Local accuracy (adjacent points)**
  - **Network accuracy (relative to CORS)**
- **Numeric quantities, units of cm (or mm)**
  - **Both are relative accuracy measures**
  - **Do not use distance dependent expression**
- **Accuracies for horizontal, ellipsoidal, and orthometric height**
  - **Horizontal accuracies are radius of 2-D 95% error circle**
  - **Height accuracies are 1-D (linear) 95% error**

IMPLEMENTATION OF NEW ACCURACY STANDARDS

Implementation of New Accuracy Standards

- Information Material/Workshop
- Guidelines & Procedures Documents
  - Technical Memorandums
  - In-house Procedures
- Computations/Software
  - Program ADJUST
  - Blue Book
  - Readjustment of NAD 83
- Data Publication
  - Data Base
  - Data Sheet

NGS WORKSHOP PROGRAM

CURRENT SCHEDULE (updated February 15, 2001)

NGS conducts the following workshops throughout the United States, involving the cooperation of professional societies, universities, and international, Federal, state, and local organizations. NGS also develops new workshops upon request, provided it has the necessary resources, and the material is within NGS' mission.

NOAA Technical Memorandum NOS NGS-58

GUIDELINES FOR ESTABLISHING GPS-DERIVED ELLIPSOID HEIGHTS (STANDARDS: 2 CM AND 5 CM) VERSION 4.3

David B. Zilkoski
Joseph D. D'Onofrio
Stephen J. Frakes

Silver Spring, MD

November 1997

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Ocean Service / National Geodetic Survey

Available On-Line at the NGS Web Site:

www.ngs.noaa.gov

SPECIFICATIONS:
Project requirements for the FBN observations are to ensure 2-centimeter local accuracy in the horizontal component, as well as 2-centimeter local accuracy for the ellipsoid heights.

Project Instruction- Maryland, Delaware, District of Columbia FBN, 2001

PURPOSE:
In order to meet America's accelerating positioning and navigation needs, the existing coordinate reference system must be continually enhanced to provide the accessibility and high accuracy required for use with GPS. The digital revolution in mapping, charting, and surveying requires a National Spatial Reference System (NSRS) consisting of, among other components, a network of monumented points having four-dimensional positions. The FBN fulfills the requirements for this component. NGS is charged with the Federal responsibility for establishment, observation, monitoring, and maintenance of the FBN. The FBN provides the critical network foundation for an accurate, consistent, reliable NSRS.
The NSRS, in turn, provides the common geographic framework for America's spatial data infrastructure. As such, the NSRS serves as the basis for mapping, charting, navigation, boundary determination, property delineation, infrastructure development, resource evaluation surveys, and scientific applications, including crustal motion monitoring, modeling of flooding, storm surge, pollution trajectories, and agricultural runoff. A modernized, accurate, consistent, reliable NSRS is of enormous benefit to state, county, tribal, local, and Federal authorities, as well as to the private sector.
The reference marks established at each of the five CORS sites will provide a very accurate tie to the antenna as an aid to reposition the antenna should that become necessary. The FBN/CBN tie to the reference marks will also provide site station coordinates relative to the local FBN/CBN, thus reducing the potential for relative error between the reference marks and the local network. It will also provide a check on the FBN/CBN, relative to the CORS coordinates. The eight tide site surveys will provide GPS-derived ellipsoid heights, accurate to 2 cm, on tide site water level marks along the Atlantic Ocean coast.

SPECIFICATIONS:
Project requirements for the FBN observations are to ensure 2-centimeter local accuracy in the horizontal component, as well as 2-centimeter local accuracy for the ellipsoid heights.

NETWORK AND LOCAL ACCURACIES (COMPUTED USING A PRIORI STANDARD DEVIATION OF UNIT WEIGHT)

STATION ISN	SSN	NAME	TO STATION TYPE	ISN	SSN	NAME	ACCURACIES (CM.) HORIZ	ELLIP	ORTHO
1	1050	1050 GALILEE	NETWORK				2.1	7.6	
			LOCAL	102	920	ZERO GALILEE	0.6	7.6	
			LOCAL	47	800	HILL 2	2.0	7.0	
			LOCAL	88	9620	SK 020	2.0	7.5	
			LOCAL AVERAGE				1.5	7.4	
2	600	342 RESET	NETWORK				2.5	6.6	
			LOCAL	99	8018	WK 018	3.1	6.7	
			LOCAL	26	9804	EX 004	2.4	6.7	
			LOCAL	38	1002	FO 002	2.5	5.4	
			LOCAL AVERAGE				2.7	6.2	
3	951	4036	NETWORK				108.2	105.0	
			LOCAL	23	950	CT 001	107.5	7.3	
			LOCAL	11	953	BEACH	108.2	94.2	
			LOCAL AVERAGE				107.8	50.7	
4	952	4720	NETWORK				3.1	7.3	
			LOCAL	23	950	CT 001	0.6	7.3	
			LOCAL AVERAGE				0.6	7.3	
5	940	746	NETWORK				2.8	7.2	
			LOCAL	35	9813	EX 013	0.8	7.1	
			LOCAL	23	950	CT 001	1.6	7.3	
			LOCAL	89	9621	SK 021	2.9	7.0	
			LOCAL AVERAGE				1.7	7.1	
6	9300	845 0954 TIDAL D	NETWORK				0.8	7.1	
			LOCAL	50	170	HUMMOCK 2 RESET	0.8	13.6	
			LOCAL	93	9106	TI 006	0.4	7.0	
			LOCAL	67	9309	PO 009	0.6	7.0	
			LOCAL AVERAGE				0.6	9.2	

Input Formats and Specifications
of the
National Geodetic Survey Data Base
The NGS "Bluebook"

Volume I - Horizontal Control (2000 version)
Preface and Content 19KB
1 - Horizontal Control Data 21KB
2 - Horizontal Observation Data 328KB
3 - Geodetic Control Descriptive Data 46KB
(also includes Vertical and Gravity Data)
Changes -
Changes between 1994 and 1998 versions 176KB
Changes between 1998 and 2000 versions 72KB

Volume II - Vertical Control
Preface and Content 370KB
5 - Vertical Control Data 680KB
6 - Vertical Observation Data 3.0MB
Part 1 - (Pages 6-1 through 6-16) 1.6MB
Part 2 - (Pages 6-17 through 6-40) 1.4MB

Volume III - Gravity Control
Preface and Content 617KB
9 - Gravity Control Data 455KB
10 - Gravity Observation Data 2.8MB
Part 1 - (Pages 10-1 through 10-16) 1.4MB

Annexes
A - NGS Country, State and County Codes
Updated [2]
Original 7KB
B - State Plane Coordinates Zone Codes 6KB
C - Contributors of Geodetic Control Data
Updated [2]
Original 52KB
D - Guidelines for Geodetic Control Point Designations 36KB
E - Station Order and Type Codes 8KB
F - NGS Survey Equipment Codes 18KB
G - Ellipsoid Height Order and Class Codes 6KB
H - Standard Time Zones 26KB
I - Summary of Codes Used in Geodetic Survey Point Desc. 13KB
J - GPS Antenna Codes *(Superceded by Annex M)*
Updated [2] | Original 4KB
K - Project Report Instructions 13KB
L - Guidelines for Submitting GPS Relative Positioning Data 21KB
M - NGS GPS Antenna Codesa *(Supercedes Annex J)* 7KB
N - Global Positioning System Data Transfer Format 35KB
O - Gravity Control Formulas 269KB

NAD 83 READJUSTMENT

HARN COMPLETION - SEPTEMBER 1997
(Indiana)

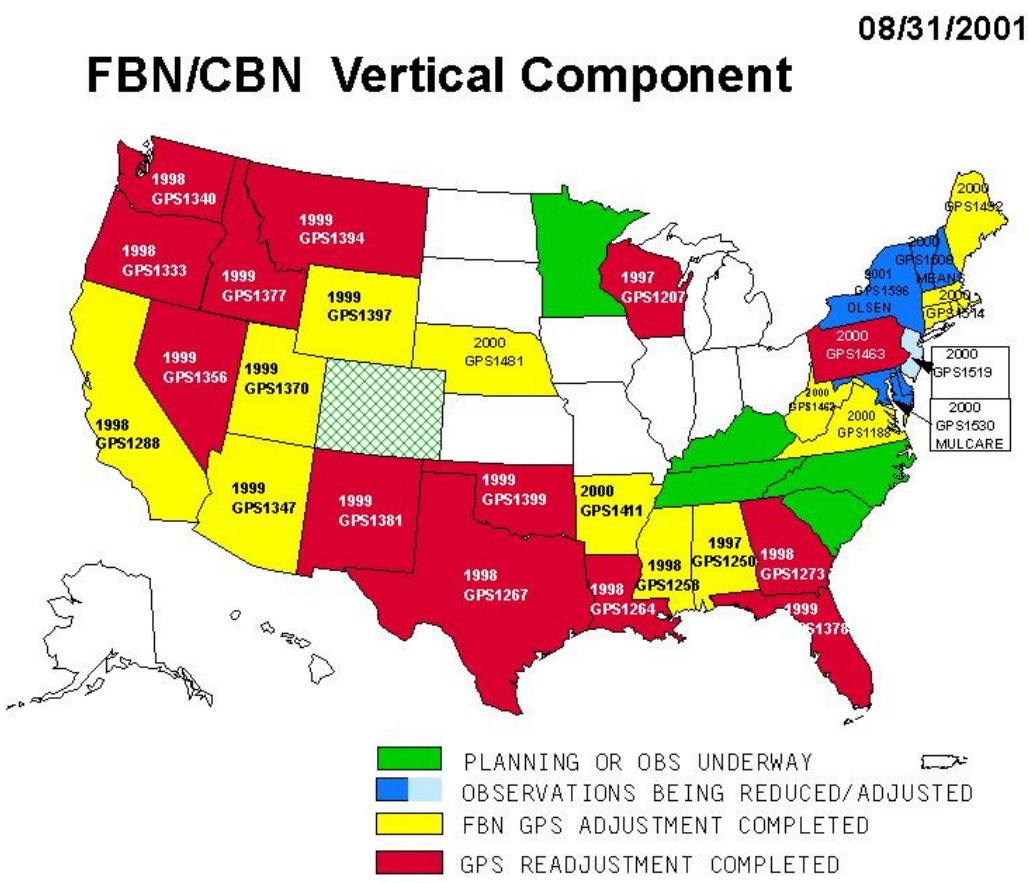
GPS HEIGHT MODERNIZATION OBSERVATIONS
(1997 - 2004?)
(Oklahoma Observed 1999)
(http://www.ngs.noaa.gov/initiatives/height_modernization.shtml)

COMPLETE GPS NAD 83 3-D ADJUSTMENT
(http://www.ngs.noaa.gov/initiatives/new_reference.shtml)
(2005?)

REMOVAL OF SMALL REGIONAL DISTORTIONS
(3 - 6 CM)

UNIFORM COORDINATE TAG
NAD 83 (NSRS)

NAD 83 READJUSTMENT



NAD 83 READJUSTMENT

ONLY GPS DATA

CONTINUOUSLY OPERATING REFERENCE STATIONS

FEDERAL BASE NETWORK

COOPERATIVE BASE NETWORK

AIRPORT SURVEYS

USER DENSIFICATION NETWORK

SPECIAL SURVEYS

NAD 83 READJUSTMENT

NAD 83 data that is NOT part of NSRS must be readjusted by contractor/user with original observations

NEW STANDARDS FOR GEODETIC CONTROL

Two accuracy standards

(http://fgdc.er.usgs.gov/standards/status/swgstat.html)

local accuracy ---------- adjacent points

network accuracy ---------- relative to CORS

Numeric quantities, units in cm (or mm)

Both are relative accuracy measures

Do not use distance dependent expression

Horizontal accuracies are radius of 2-D 95% error circle

Ellipsoidal/Orthometric heights are 1-D (linear) 95% error

```
MN0298 ****************************************************************************
MN0298  CBN            This is a Cooperative Base Network Control Station
MN0298  DESIGNATION -  PUMKIN
MN0298  PID         -  MN0298
MN0298  STATE/COUNTY-  NE/BANNER
MN0298  USGS QUAD   -  HARRISBURG (1979)
MN0298
MN0298                        *CURRENT SURVEY CONTROL
MN0298 ______________________________________________________________________________
MN0298* NAD 83(1995)-  41 35 00.11733(N)     103 39 51.50003(W)      ADJUSTED
MN0298* NAVD 88     -      1365.195  (meters)     4478.98   (feet)  ADJUSTED
MN0298 ______________________________________________________________________________
MN0298  X           -  -1,128,920.060 (meters)                      COMP
MN0298  Y           -  -4,643,586.598 (meters)                      COMP
MN0298  Z           -   4,211,995.805 (meters)                      COMP
MN0298  LAPLACE CORR-          -4.40  (seconds)                     DEFLEC96
MN0298  ELLIP HEIGMN-        1346.13  (meters)                      GPS OBS
MN0298  GEOID HEIGMN-         -18.99  (meters)                      GEOID96
MN0298  DYNAMIC MN  -         1364.220 (meters)    4475.78   (feet) COMP
MN0298  MODELED GRAV-      979,862.1   (mgal)                       NAVD 88
MN0298
MN0298########## Accuracy Estimates (at 95% Confidence Level) (cm) ##########
MN0298#  Type    PID     Designation                        Horz   Ellip   Ortho #
MN0298#  ------------------------------------------------------------------------ #
MN0298#  NETWORK MN0298  PUMKIN                             6.6    12.7    10.0  #
MN0298#  ------------------------------------------------------------------------ #
MN0298#  LOCAL   MN0643  WILDCAT                           9.4*                  #
MN0298#  LOCAL   MN0526  LOGAN                            24.1*                 #
MN0298#  LOCAL   MN0644  GERING HWY PATROL RAD TWR       137.9*                 #
MN0298#  LOCAL   MN0645  EDWARDS                         23.1*                 #
MN0298#  LOCAL   MN0642  BIG HORN                        19.0*                 #
MN0298#  LOCAL   MN0633  KIMPORT                          4.4     0.3*         #
MN0298#  LOCAL   MN0606  CUB                             44.0*    4.0          #
MN0298#  LOCAL   MN0216  T 76                            4.7*    0.3*          #
MN0298#  LOCAL   MN0080  AP STA A                        77.7*   13.2*         #
MN0298#  LOCAL   MN0654  AP STA B                        33.6*    8.7          #
MN0298#  LOCAL   MN0654  GPS BASE 11699 GSS             11.2*    6.4          #
MN0298#  LOCAL   MN2269  PUMKIN AZ MK                                  0.1   #
MN0298#  LOCAL   MN2270  E 55                                          0.2   #
MN0298#  ------------------------------------------------------------------------ #
MN0298#  LOCAL - AVERAGE                                  4.6     6.4     0.2   #
MN0298#  *NOTE: NOT USED IN COMPUTING AVERAGE                                   #
MN0298##############################################################################
MN0298
MN0298  HORZ ORDER  -  B
MN0298  VERT ORDER  -  SECOND     CLASS I
MN0298  ELLP ORDER  -  FIRST      CLASS I
MN0298
```

PROPOSED:
Data Sheet
Accuracy Statement

Numbers from empirical model or adjustment

Continued for old points

Data Sheet Issues That Need Resolving

- **Network Accuracies**
  - How to compute horizontal accuracies for points determined by "classical" methods, e.g., triangulation and traverse stations
  - What value to publish for orthometric heights determined by leveling
  - How to identify the source of the accuracies, e.g., results of a rigorous least-squares adjustment, empirical formula, etc.
- **Local Accuracies**
  - How to compute horizontal accuracies for points determined by "classical" methods, e.g., triangulation and traverse; should they be included in the "average"
  - How to compute orthometric height accuracies for points determined by "classical leveling methods
  - What values to include in computing the "average"
  - How to identify the source of the accuracies, e.g., results of a rigorous least-squares adjustment, empirical formula, etc.

Tasks To Complete To Implement New Accuracy Standards

- Specify new data base elements
- Extend data base tables
- Update data sheet programs
- Define Blue Book accuracy records
- Update data base loading software
- Finalize "ADJUST/NETERR" program
- Develop new software adjustment program to compute accuracy estimates for orthometric heights from geodetic leveling measurements

(Continued)

Tasks (Continued)

- Identify CORS
- Develop realistic weights for GPS
  - "New" GPS better than "old" GPS
  - Depends upon processing/reductions
  - Relative weight differences between horizontal and vertical
  - Work supports writing GPS specifications
  - Don't need complete FBN/CBN to begin
  - Work supports future scientific datum studies
- Error propagation of FBN/CBN network
  - Network accuracies on points fixed in states
  - May be possible on regional basis
  - Work support future scientific datum studies

Summary/Future

Relationships to the Old Standards

- **Local Accuracies**
  - **Nearly identical to the old relative accuracies**
  - **Do not use distance dependent expression**
  - **Use weighted constrained adjustment instead of free adjustment**
- **Network Accuracies**
  - **New measure --- represents confidence of that point with respect to geodetic datum**
  - **Smaller values from distance dependent equations**
  - **Compute by weighted constrained adjustment**
  - **Compute by formulas for simple survey geometries**

Where Do We Go from Here?

- **Classification By:**
  - **Order and Class is OUT**
  - **Actual accuracy is IN**
- **Accuracy Expressed As:**
  - **Proportional Part is OUT**
  - **Linear units (cm) is IN**
- **Classification Scheme:**
  - **Single classification is OUT**
  - ***Local* and *Network Accuracies* are IN**

(continued)

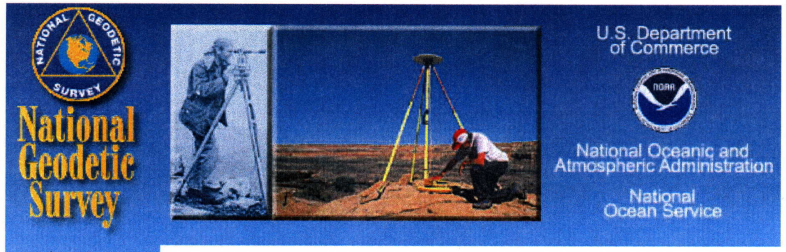
Where Do We Go from Here? (continued)

- **Accuracy Criteria:**
  - **Using different methods for stating the accuracy of horizontal and vertical coordinates is OUT**
  - **Using the same accuracy statement for horizontal and vertical coordinates is IN**

(continued)

Where Do We Go from Here? (continued)

- **FGDC Publication:**
  - **Defines just the accuracy standards**
  - **Includes: Geodetic, Cartographic, Bathymetric, Engineering, and Cadastral**
- **NGS Publications:**
  - **Uses FGDC accuracy standards**
  - **Further explains FGDC standards as they apply to geodetic networks**
  - **Provides guidelines, procedures, and specifications to meet various accuracy levels**



NGS Internet Connection

www.ngs.noaa/gov

Information Center

(301) 713-3242

Points of Contact

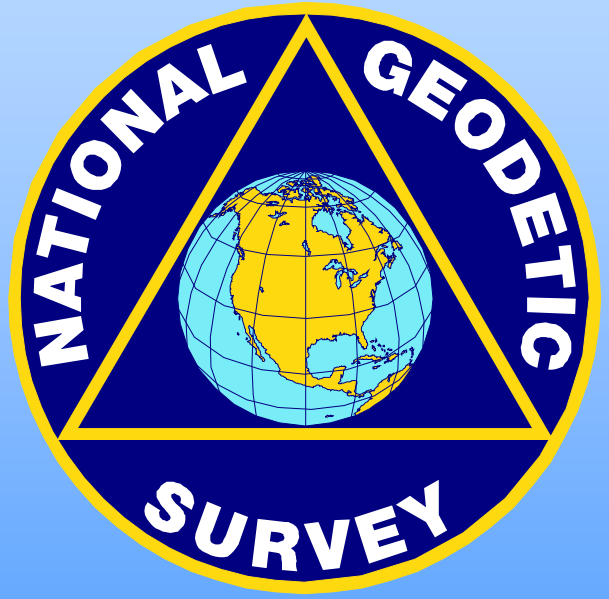
- **National Geodetic Survey**
  NOAA, N/NGS12
  Geodetic Services Division
  Bldg. SSMC3, Station 9202
  1315 East-West Highway
  Silver Spring, MD 20910-3282
  Phone: 301-713-3242
  Fax: 301-713-4171

- Edward J. McKay
  N/NGS2, SSMC-3, Room 8813
  National Geodetic Survey, NOAA
  1315 East-West Highway
  Silver Spring, MD 20910-3282
  Phone: 301-713-3191 Ext. 102
  Fax: 301-713-4324
  E-mail: Ed.McKay@noaa.gov

- Internet Web Site:
  - http://www.ngs.noaa.gov

Geospatial Positioning Accuracy Standards available at:
http://www.fgdc.gov/standards/documents/standards/accuracy

GOOD COORDINATION BEGINS WITH GOOD COORDINATES



GEOGRAPHY WITHOUT GEODESY IS A FELONY

The End!!!!!