

ANNEX L

GUIDELINES FOR SUBMITTING GPS RELATIVE POSITIONING DATA

Requirements and options are described below for submitting Global Positioning System (GPS) relative positioning data to the National Geodetic Survey (NGS) for inclusion in the National Spatial Reference System (NSRS). The submission may be completely digital on CD. Include a transmittal which inventories the shipment.

Prior to beginning a project, obtain approval for it from NGS, Project Development Branch. Access <http://www.ngs.noaa.gov/PROJECTS/proposals/project1.shtml> or call 301-713-3194. You may also begin this review process with your state advisor.

1.0 GPS RAW OBSERVATIONS (R-files). Optional RINEX files: Submit the raw GPS observations for each occupation of a station. Organize the files in a "RAW" or similar-named folder under which there are session folders, such as 173A, 173B, 176A. If the 4-character ID of a station was not used in the file name[s] for a station, place the file[s] in a sub-folder named for the 4-character ID. Submit RINEX files if they were created, in session folders under a "RINEX" folder.

2.0 GPS VECTOR SOLUTIONS (G-file): Submit one G-file for each project in the formats specified in Bluebook Annex N, which is posted at the Bluebook web site, <http://www.ngs.noaa.gov/FGCS/BlueBook/>. If submitting a B- or higher-order project, consult NGS as to whether multiple-vector solutions with correlations are required. The G-file is created by vendor software or SINEX2G and contains:

- (1) From/to station identification using station serial numbers (SSNs) and 4-character IDs.
- (2) Vector coordinate differences (DX, DY, DZ), standard deviations, and correlations (or covariances)
- (3) Name and version of processing software
- (4) Date of solution
- (5) Source of the ephemerides (GPS orbits)
- (6) Coordinate system (datum) for the vectors
- (7) Solution type
- (8) Method of vector processing (three methods, discussed next)

Single-vector processing uses data from two stations at a time within a session. Mathematical correlations between vectors are not computed. The resulting G-file may include independent and dependent vectors. There will be $n(n-1)/2$ of these (total) for each session, where n is the number of receivers observing. If only $(n-1)$ independent vectors are submitted, select fixed integer bias solutions (typically associated with shorter vectors) in preference to float solutions.

Multiple-vector or session processing generates correlations between vectors in a session. The resulting G-file entries correspond to the $(n-1)$ independent vectors.

The network reduction method combines multiple sessions into one SINEX file from which the G-file is derived. The G-file in this case contains $(s-1)$ independent vectors, where s is the total number of unique stations in the solution.

Specify the solution coordinate reference system used (the reference frame of the GPS orbits) by selecting the associated numeric code from a table in Annex N. Submit NAD 83 station coordinates, which are obtained by transformation from the orbital reference frame, either automatically by vendor software or within ADJUST.

2.1 Four-character station ID (4-char ID), data media identifier, and Serfil:

The submittal process requires that each occupied station be identified by both a 4-char ID and a station serial number (SSN); also that an auxiliary text file, the "Serfil" be created to cross-reference these two items. The format for the Serfil, given in the documentation for one of the required NGS checking programs, COMPGb, is as follows: cc 1-4, 4-char ID; cc 5-7, blank; cc 8-11, SSN.

The 4-char ID is intended to be a shortened version of the full station name for use in naming data files and plotting on the project sketch. The data media identifier is a 10-character text string such as "A1734AMOB1" noting the receiver code, day of year, session and 4-char ID. It is discussed more fully in Bluebook Annex N, p. N-11, and in brief must occur identically in both the B- and G-files for a given occupation of a station.

3.0 GPS PROJECT AND STATION DATA (B-file): Submit one B-file for each project in the formats specified in Bluebook Chapters 1 and 2. Use NGS software CR8BB (documentation in (NGS 2004) or a text editor. The B-file contains:

- (1) project title, location, start/stop dates, etc.
- (2) station occupation information (4-character ID, SSN, data media identifier, observer's initials, receiver and antenna used, vertical antenna height measurements, operator comments, etc.)
- (3) equipment information (make, model and serial number of receivers and antennas)
- (4) station names and best estimates for station coordinates and heights

4.0 STATION DESCRIPTIONS (D-file): Submit one D-file for each project in the formats specified in Bluebook Annex P, http://www.ngs.noaa.gov/PC_PROD/DDPROC4.XX/dformat.documentation.html. The D-file is created by WinDesc, http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml#WinDesc. It contains original descriptions for new marks and recovery information for existing stations. It includes all occupied GPS points, any points connected to the GPS survey using conventional horizontal surveying and/or differential leveling techniques, and (optionally) NSRS points visited but not occupied during the project.

Datasheets for existing NSRS points in a project area can be downloaded from the NGS website, [ngs.noaa.gov](http://www.ngs.noaa.gov). The datasheet file can be imported into WinDesc.

5.0 HORIZONTAL CONNECTION SURVEY DATA (T-file): If the project includes any data observed by conventional horizontal surveying techniques (this is unusual), submit one T-file for the project in the formats specified in Bluebook Chapters 1 and 2. The T-file can be created either by MTEN4 (NGS 1991) or by a text editor.

6.0 VERTICAL CONNECTIONS (L-file or other): If leveling that meets FGCS specifications has been observed to points in the GPS project, submit one L-file for each part number in the leveling project in the formats specified in Bluebook Chapters 5 and 6. This is generally first- or second-order work, with the required three- or two-mark ties made. Cross-reference the leveling project and the GPS project to each other in the respective project reports. See Annex K for instructions on the leveling project report and submittal.

Lower-order leveling data should be included in the GPS B-file *45*-47* records and discussed in the GPS project report. This generally occurs when a new mark is tied from only one existing mark and the GPS observations are used as a check.

7.0 LEAST SQUARES ADJUSTMENTS:

7.1 Introduction. This topic is covered only in brief outline here. Refer to the Adjust Guidelines, http://www.ngs.noaa.gov/PC_PROD/ADJUST/guidelinesNov04.pdf, for fuller treatment. Use NGS' program ADJUST, www.ngs.noaa.gov/PC_PROD/ADJUST, to run adjustments which are summarized in sections 7.2-7.6. Prior to ADJUST, run checking programs that validate the input B and G files. Correct all errors and investigate all warnings pointed out by the checking programs.

Create one "A" file for each adjustment to specify adjustment parameters. Run all adjustments in three dimensions ("DD3" record in the four A files). Use "MM3NY" as the Adjustment Mode Record in the A file for all adjustments unless the project is B-order or above. (See section 7.6).

Print ("echo") the B and G files in the output file only in the final free adjustment. To do this, include the following PP record in the A file for the first three adjustments: PP22; omit any PP record in the A file for the final free adjustment.

7.2 Submit a minimally constrained (free) horizontal adjustment (one station arbitrarily selected--generally a CORS if available--and constrained to published NSRS coordinates) in accordance with the Adjust Guidelines.

The *a posteriori* variance of unit weight should ideally be 1 in this adjustment. It may be much higher if the weights are optimistic (standard deviations too small), observations noisy, and/or if there is a blunder, such as wrong station coordinates or two SSNs interchanged.

Investigate large residuals (rule of thumb, use 2 cm horizontal and 3 cm vertical as thresholds for investigation) and attempt to eliminate them. Check that antenna heights and types used in the processing were correct, for example. Possibly reprocess noisy sessions with a higher elevation mask, or edit data from a noisy satellite, etc.; ultimately, reject vectors that exceed project accuracy, but avoid having only one vector to a station (no-check scenario) if at all possible.

7.3 Submit a constrained horizontal adjustment. A constrained adjustment for a project involves adjusting the GPS vector data while constraining stations to the NSRS. Analyze any high residuals. These indicate strain between the project observations and the network. Consult with NGS as to whether stations with high residuals should be readjusted based on the project's observations.

Prior to 2009, the gfile for a first-order project was to be scaled by running MODGEE before any constrained adjustments. The standard deviations in the gfile were then scaled (generally increased) by the standard deviation of unit weight from the free adjustment. Do not run MODGEE any more--leave the gfile unscaled.

7.4 Submit a free vertical adjustment. Determine geoid heights for the marks in the project using "GEOIDxx" (for example, GEOID03, available from http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml), as appropriate for the epoch of the project. Constrain one horizontal position and one published orthometric height. Compare the resulting heights with published heights. Consult with NGS about possibly readjusting heights that do not fit the project's observations.

7.5 Submit a constrained vertical adjustment. Use the output B-file from the free vertical adjustment to run a constrained vertical adjustment. Constrain one horizontal position and all published orthometric heights except those determined to need readjustment. Consult with NGS about possibly also constraining GPS-derived heights. Analyze any high residuals.

7.6 Submit a final free adjustment. Run QORECORD, using option "GFILE DECK" as input. Edit the gfile to place 'y' in column 4 of "MM3YY" in the A file to scale the standard deviations by the a-posteriori standard deviation.

7.7 Run ELEVUP to get final bfile, then ELLACC and BBACCUR. Run checking programs on the final files and obtain error-free results and/or justifiable warnings. Confirm that the intended project accuracy was met.

8.0 PROJECT SKETCH: Submit a sketch showing all stations occupied during the GPS survey. Show grid ticks for latitude and longitude around the border. Use the following symbols as a guide:

- (a) Squares for existing vertical control
- (b) Open triangles for existing horizontal control stations
- (c) Open triangles within squares for existing horizontal/vertical control
- (d) Solid triangles for GPS stations
- (e) Circles for stations occupied during previous GPS projects

Include a legend showing:

- (a) project name
- (b) general locality
- (c) name of group making observations
- (d) project director
- (e) beginning and ending dates, month/year
- (f) scale of sketch

Show points in a large-scale inset when they are too close together to be depicted clearly at map scale.

9.0 PROJECT REPORT:

The most important document to be included with the shipment is the project report. It describes project goals, conditions and requirements and the personnel, equipment and procedures employed to meet them. The report assists problem resolution and data adjustment by detailed explanation of unusual or special project features. Use the following categories as a guide. NGS-supported projects may require a different report.

9.1 Introduction

A. Agency and Purpose - State the name of the organization which performed the survey and the purpose[s] for which the survey was done.

B. Accuracy standards - Provide the vertical and horizontal accuracy standards specified for the project.

C. Time Period - State the arrival and departure dates for the field crew and dates of first and last observing sessions.

D. Point of Contact - Supply the name, phone number, email address and mailing address of the point of contact within the submitting organization. Supply the same information for all organizations which participated in the survey.

9.2 Location - Describe the geographic location and extent of the project.

9.3 Conditions Affecting Progress - Note any factors which facilitated or impeded the project.

9.4 Field Work--discuss the following:

A. Reconnaissance and mark-setting

B. Chronology, the progress of the project.

C. Instrumentation - Summarize the make and model of the receivers and antennas used in the project. Indicate any unusual or faulty equipment.

D. Weather - List all observing sessions which occurred during periods of changing or severe weather conditions such as passing fronts, storms, etc. Details should be narrated on the field log sheets.

E. Deviation from Instructions - Describe any deviation from the procedures and specifications stated in the project instructions. Specify all stations which were eccentrically occupied and state why the station(s) could not be directly occupied.

9.5 Data Processing Performed - Describe the data processing that was done. Include tasks such as transferring data to different storage media, checking data quality (eg, running teqc or submitting files to OPUS for initial coordinates), analyzing differences in repeat vectors, and writing station descriptions. Specify the ephemeris type used (broadcast, rapid, ultra-rapid, precise, etc.) and the source (IGS, NGS, DMA, etc.).

A. Software Used - Specify all software by name and version which was used to acquire, manage, reduce, adjust, and submit field data. If the project data were reduced or acquired with different versions of a program, specify which version was used with which block of data.

B. Rejected Data - Specify vectors which were rejected and possibly reobserved. Include the reason(s) for the rejection, such as failed equipment or bad weather listed under Field Work sections B or C above.

C. Adjustment - Discuss in detail the adjustments performed. Show weighting technique used, station(s) constrained, method used to estimate orthometric heights and existence of any independent sub-networks. Discuss possible weaknesses or distortions found or suspected in the NSRS.

9.6 Comments and Recommendations

Include comments and recommendations not found elsewhere in the project report.

9.7 Attachments and Enclosures

A. Station List - Include a table which lists the station name, 4-char ID, session(s) occupied, and station type (existing horizontal or vertical, new station, etc.) for all stations occupied.

B. Project Sketch - per section 8.0. If there are multiple copies of the sketch showing different data, attach a copy of each.

C. Project Instructions - Attach a copy of the instructions and/or contract under which the project was performed. Include any revisions or changes to the instructions or specifications.

D. Field Logs - Provide original, scanned or clean copies of observation logs, field notes, record books and any weather observations.

E. Equipment Failure Logs (NGS projects) - Include a failure log for any equipment used to gather data which failed anytime during the project. State the type of component, serial number, date of failure and nature of failure.

F. Project Observing Schedule - Prepare a list containing the following: observing days/sessions, 4-char IDs and station names, session start and stop dates and times (UTC).

*
* All data and material submitted must be neat and legible (typed or *
* clearly written in black ink). DO NOT SEND THE ONLY COPY OF ANY *
* PAPER RECORDS OR DIGITAL DATA FILES. *
* *

10.0 PROJECT SUBMISSION CHECKLIST: Exhibit A is a form that may be used to check for completeness when submitting GPS project data to NGS.

11.0 DATA TRANSMISSION MEDIA: Submit digital data files to NGS on media approved by NGS at the time of submission--currently CD and floppy disk. These are subject to changes in technology.

To obtain the address for submitting a completed GPS project to NGS and/or if you have questions concerning the above requirements, please contact the Observations and Analysis Division at 301-713-3176.

EXHIBIT A

SUBMISSION CHECKLIST, GPS PROJECTS
Any or all items may be digital

Project Title: _____
Submitting Agency: _____
Observing Agency: _____
Receiver Type: _____

PACKAGE CONTENTS

<u>Project Report and Attachments</u>	<u>Required For</u>
() NGS approval of proposed project, email/memo	All Projects
() Approved Reconnaissance and Project Sketch	All Projects
() Project Instructions or Contract Specifications	All Projects
() Final Station List	All Projects
() Station Visibility Diagrams	All Projects
() Final Observing Schedule	All Projects
() Observation Logs	All Projects
() Equipment Failure Logs	NGS Projects
() Loop Misclosures	Optional
() Free Horizontal Adjustment with Analysis (NAD83)	All Projects
() Free Horizontal Adjustment with Accuracies	All Projects
() Constrained Horizontal Adjustment (NAD83)	All Projects
() Free Vertical Adjustment (NAVD 88 Heights)	All Projects
() Constrained Vertical Adjustment (NAVD 88 Heights)	All Projects
() Meteorological Instrument Comparison Logs	If Specified
() Photographs or Rubbings of Station Marks	All Projects
() Photographs of Views from Stations	Recommended
() COMPGB Output (Validation program--B/G files)	All Projects
() OBSDES Output (Validation program--B/D-files)	All Projects
() OBSCHK Output (Validation program--B/G-files)	All Projects
() WCHKDESC Output (Validation program--D-file)	All Projects
() NEWCHKOB Output (Validation program--B-file)	All Projects
() ELLACC Output	All Projects
() BBACCUR Output	All Projects
() Project Report	All Projects
() Raw Phase Data (R-files)	All Projects
() Base Line Vectors (G-file)	All Projects
() Project and Station Occupation Data (B-file)	All Projects
() Descriptions or Recovery Notes (D-file)	All Projects
() Serfil	All Projects
() Terrestrial Horizontal Observations (T-file)	If Applicable
() Differential Leveling Observations (L-file)	If Applicable

Comments - Enter on the reverse side of this form.

REFERENCES:

Defense Mapping Agency, 1987: "Department of Defense World Geodetic System 1984 - its definition and relationships with local geodetic systems." DMA Technical Report, DMA TR 8350.2, 30 September 1987, Washington, DC.

Federal Geodetic Control Committee (FGCC), 1989: "Geometric Accuracy Standards and Specifications for GPS Relative Positioning Surveys, version 5.0", reprinted with corrections August 1, 1989, www.ngs.noaa.gov/FGCS/tech_pub/GeomGeod.pdf.

Federal Geodetic Control Subcommittee (FGCS): "Input Formats and Specifications of the National Geodetic Survey Data Base", www.ngs.noaa.gov/FGCS/BlueBook/.

NGS, 1991: "MTEN4, A System for Use with the National Geodetic Survey Data Base Input Formats and Specifications", version 20, December, 1991, <ftp://ftp.ngs.noaa.gov/pub/pcsoft/mten4>.

NGS, 2001: "COMPGB Documentation," www.ngs.noaa.gov/PC_PROD/COMPGB/.

NGS, 2004: "CR8BB Documentation," www.ngs.noaa.gov/PC_PROD/pc_prod.shtml#CR8BB.

NGS, 1989: "PCvOBS Software and Documentation, "version 2.00: October 10, 1989, www.ngs.noaa.gov/PC_PROD/pc_prod.shtml#PCVOBS.

NGS, 2003: "The WDDPROC Software Suite - Description Processing Software," www.ngs.noaa.gov/PC_PROD/DDPROC4.XX/dformat.documentation.html.

Vincenty, T., 1987: "On the use of GPS vectors in densification adjustments," Surveying and Mapping (Journal of the American Congress on Surveying and Mapping), Vol. 47, No. 2, pp. 103-108.

NOTE: National Geodetic Survey and Federal Geodetic Control Subcommittee publications are available online as listed above and/or from:

NOAA, National Geodetic Information Branch, N/NGS12
voice: 301-713-3242
fax: 301-713-4172

http://www.ngs.noaa.gov/PUBS_LIB/pub_index.html