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**GENERAL GUIDANCE AND SPECIFICATIONS  
FOR AERONAUTICAL SURVEYS**

**VOLUME A**

**ESTABLISHMENT OF GEODETIC CONTROL AND  
SUBMISSION TO THE NATIONAL GEODETIC SURVEY**

FEDERAL AVIATION ADMINISTRATION  
AIRPORT SURVEYS

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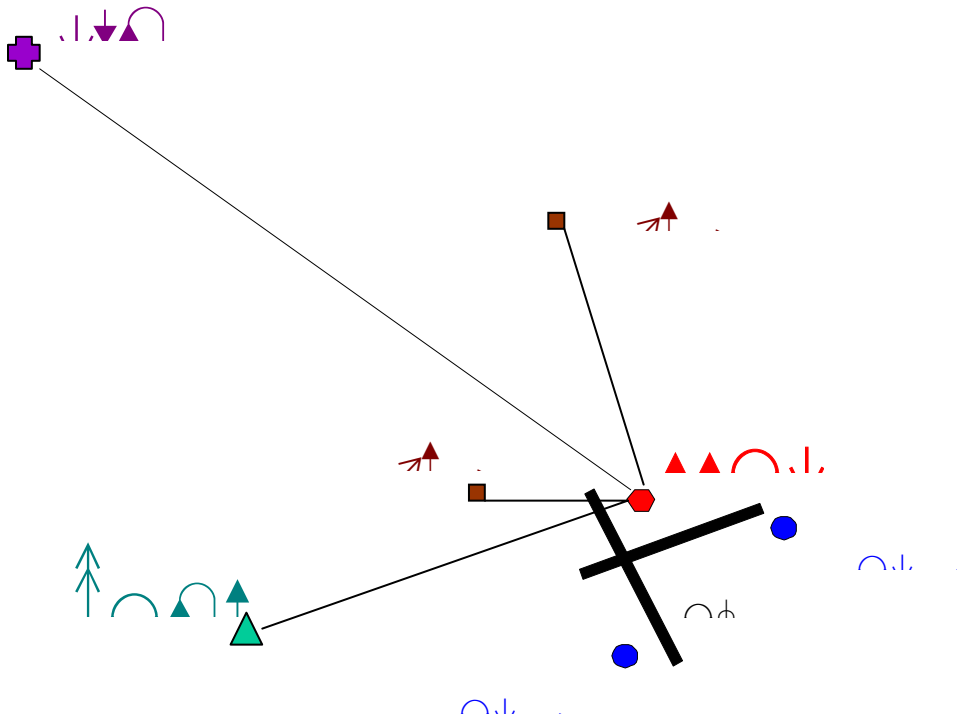
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1. INTRODUCTION

Geodetic control surveys are performed to establish a basic control network from which supplemental surveying and mapping work are performed. The establishment of geodetic control for permanent survey monuments in the airport vicinity is critical to the National Airspace System (NAS). These monuments and their accurate connections to the National Spatial Reference System (NSRS), assure accurate relativity between surveyed points on an airport and between these points and other surveyed points and facilities in the NAS including the navigation satellites. This geodetic control, which consists of a Primary Airport Control Station (PACS) and two or more Secondary Airport Control Stations (SACS), is tied to the NSRS. The survey marks should be used for future aeronautical and engineering projects related to runway/taxiway construction, NAVAID siting, obstruction clearing, road building, and other airport improvement activities. This document provides guidance and specifications for establishing the geodetic control and submitting the data to NGS for publication. FAA No. 405, Fourth Edition, September 1996, Appendix 5 provides the required accuracies. The required accuracy standards for PACS and SACS provided in Attachment 2 *Selection Guidelines for Airport Geodetic Control Surveys* are from FAA Number 405, "Standards for Aeronautical Surveys and Related Products", Fourth Edition, Appendix 5.



Airport Geodetic Control Network

## **2. ADMINISTRATION**

**2.1 SPECIFICATIONS** – This document provides general guidance and specifications for establishing Geodetic Control on airports as required by the FAA. The requirements for reporting deviations, unusual circumstances, etc., described in the following paragraphs, apply to these General Specifications. The specifications presented herein have been developed by the Federal Aviation Administration (FAA) and the National Geodetic Survey (NGS) for selected United States Government aeronautical data and related products. These General Specifications shall be complied with, without deviation, until amended by formal FAA/NGS specification action.

**2.2 CONVENTIONS** - The following conventions have been adopted for these project specifications. The verb “shall” means that compliance is required. The verb “should” denotes a recommendation. The contraction “N/A” means not applicable. The term “position” means horizontal position (latitude and longitude) unless specified otherwise. The term “elevation” means the distance of a point above a specified datum, measured along the direction of gravity. The term “vertical” refers to the direction in which the force of gravity acts. The term “height” means the distance, measured along a perpendicular, between a point and a datum. The term "observation" means the survey observations that result in a position and/or elevation for the survey mark in question, whether the mark is an existing mark or a newly set mark. The term "set" means physically constructed. Use the U.S. Survey Foot (3.28083333333 feet = 1 meter) for any length conversions.

**2.3 GENERAL REQUIREMENTS** - The Contractor shall provide all labor, equipment, supplies, material, and transportation to produce and deliver data and related products as required under these General Specifications.

**2.4 MODIFICATIONS** - All requests for modifications shall be submitted by the Contractor in writing to the Contracting Officer (CO) and NGS Point of Contact (POC) as soon as possible.

**2.5 UNUSUAL CIRCUMSTANCES** - The Contractor shall notify the CO and NGS of any unusual circumstances that occur during the performance of these General Specifications which might affect the deliverables or their quality (see Section 5).

**2.6 REPORTS** - Thorough reporting is required. The Contractor shall submit a weekly project status report, Quality Control Plan (see Section 5), Project Survey Plan (see Section 9.3) and a Final Project Report (see Section 10) to the CO and NGS POC.

The Contractor shall submit project status reports via email to the NGS POC every Monday afternoon by 2:00 P.M. Eastern Time, from the date of the Task Order until the work is complete. These reports shall include the percentage complete for each of the major portions of the work, the status of other work, where work is underway, where work is completed (with dates completed), and any unusual circumstances and/or deviations from these General Specifications. Include the expected date of completion. This report should be brief, contain the current information and include the prime contractor's firm name on all reports. See Attachment 23 for an example.

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**2.7 ORIGINAL DATA** - Observation logs and other original records generated during this project are legal records which will be retained for data accountability by the Airport Authority. NGS will receive a copy of the original data for quality assurance purposes. Original logs and records shall be submitted and shall be original, legible, neat, clear, accurate, and fully completed in indelible black ink. Original data shall be saved, unmodified, whether in hand-written or computer-recorded form. In the original records (paper or digital), nothing is to be erased or obliterated. All available spaces on the recording forms should be completed. If a mistake is made on a form, draw a single line through the mistake and write the correction above or to the side. If space is too limited to permit a field correction, restart with a new log sheet; however, do not recopy the form in the office in order to make a “clean” copy. An explanatory note should be made for all corrections to the original recorded figures. It is essential that all hand-recorded information be neat and legible. All editing of computer-recorded data shall be done on a copy of the original. Submit the original version of the data, not a handmade copy, a photo-copy, or a digital copy.

**3. NATIONAL SPATIAL REFERENCE SYSTEM (NSRS)** – All surveying and positioning shall be tied to the NSRS

[http://www.ngs.noaa.gov/INFO/OnePagers/One-Pager\\_NSRS.pdf](http://www.ngs.noaa.gov/INFO/OnePagers/One-Pager_NSRS.pdf) .

**3.1 HORIZONTAL CONTROL** - North American Datum of (NAD) 83 (YYYY), where YYYY is the year of the most recent observations. Note: the year of observations is on the NGS Data Sheet next to the latitude and longitude.

**3.2 VERTICAL REFERENCE** - North American Vertical Datum (NAVD) 88; for information on NAVD 88, see: [http://www.ngs.noaa.gov/PUBS\\_LIB/NAVD88/navd88report.htm](http://www.ngs.noaa.gov/PUBS_LIB/NAVD88/navd88report.htm)

Note: In Alaska and other areas outside the continental United States where NAVD 88 bench marks are not available, the Contractor shall make GPS ties to tidal bench marks within the project area.

**3.3 GEOID MODEL** - Use the most recent NGS model, currently GEOID03.

<http://www.ngs.noaa.gov/GEOID/GEOID03/>

Note: Coordinates for North Carolina/South Carolina HARN stations will NOT be published in the near future. The HARN coordinates for these stations are available upon request. Contact Gary Thompson (919-733-3836), or Lewis Lapine (803-896-7700).

For explanations of many of the terms in Section 4, see: <http://www.ngs.noaa.gov:80/faq.shtml> .

## **4. REFERENCES AND GLOSSARY**

### **4.1 REFERENCES –**

A. Input Formats and Specifications of the National Geodetic Survey Data Base, the “Blue Book.” Available on-line at: <http://www.ngs.noaa.gov/FGCS/BlueBook/> .

B. Station Location Sketch and Visibility diagram - For information about the Station Location Sketch and Visibility obstruction diagram, see:  
<http://www.ngs.noaa.gov/PROJECTS/FBN/> (click on AForms,@ then click on AVisibility Obstruction Diagram@).

C. NOAA Manual NOS NGS 1 AGeodetic Bench Marks.@ Available on-line at:  
[http://www.ngs.noaa.gov/PUBS\\_LIB/GeodeticBMs.pdf](http://www.ngs.noaa.gov/PUBS_LIB/GeodeticBMs.pdf) .

D. NGS National Continuously Operating Reference Station (CORS) system. For information on CORS, see: <http://www.ngs.noaa.gov/CORS/> .

E. High Accuracy Reference Network (HARN), for more information on HARN, see:  
<http://www.ngs.noaa.gov:80/faq.shtml> .

F. FAA No. 405, Standards for Aeronautical Surveys and Related Products NGS, 1996.  
<http://www.ngs.noaa.gov/AERO/aerospecs.htm#FAA405>

G. Interim FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems, version. 4.0, 15 Jul 94;

H. Standards and Specifications for Geodetic Control Networks, FGCC, 1984;

I. NOAA Manual NOS NGS 3, Geodetic Leveling, 1981

J. File Naming Convention - See Web site in Section 7.2

K. FAA Airport Identifiers, see: <http://www1.faa.gov/atpubs/lid/lidhme.htm>

### **4.2 GLOSSARY -**

a. GLOSSARY (See Attachment 21)

b. Geodetic Glossary, NGS, 1986 (not available on the WWW). For a printed copy, telephone NGS at (301) 713-3242 or email: [info\\_center@ngs.noaa.gov](mailto:info_center@ngs.noaa.gov)

c. GLOSSARY attached to FAA No. 405, Standards for Aeronautical Surveys and Related Products NGS, 1996. <http://www.ngs.noaa.gov/AERO/aerospecs.htm#FAA405>



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### **5. QUALITY CONTROL**

The Contractor shall check all data to ensure that it is complete, reliable, and accurate. The Contractor's personnel shall become thoroughly familiar with these General Specifications; the Attachments; the definitions of surveying terms; and the material covered in the other references and publications, as required. See Section 4 for a list of References and Glossary.

**QUALITY CONTROL PLAN** - Prior to beginning survey work on this project, the Contractor shall submit a written Quality Control Plan (QCP) **covering all work**. The QCP shall describe how the Contractor shall meet the technical specifications required for the project. The QCP shall include at least the following requirements: a check of all manual computations (including check marks and initials), a check of all manual data computer entries, a check of file formats, and a check of all reports and data submitted. The contractor shall also describe how data will be backed up and how it will be ensured that original data are not modified. See section 9.3 Project Survey Plan and section 11 Deliverables to NGS.

Comments on quality control and a copy of the Quality Control Plan shall be included in the Final Project Report.

### **6. DATA FORMATS**

**6.1 ORIGINAL DATA** - Original, raw digital data shall be submitted and their formats shall be documented in the Final Project Report. Original paper records shall also be submitted; see Section 2.7. Observations for positioning PACS and SACS shall be submitted in Blue Book format.

**6.2 FINAL DATA** - Final project data shall be submitted in Blue Book format, or in other formats specified by these General Specifications (for example, digital photographs).

### **7. DATA MEDIUM AND FILE NAMING CONVENTION**

**7.1 DATA MEDIUM** - CD-ROM or other pre-approved medium.

**7.2 FILE NAMING CONVENTION FOR GPS GROUND SURVEYS** - See the naming convention for FBN projects on NGS= Web site at: <http://www.ngs.noaa.gov/PROJECTS/FBN/>

**8. SURVEY METHODOLOGY** - GPS ground surveying methods shall be used for Airport Geodetic Control survey work specified in Section 9.

### **9. SURVEY WORK**

**9.1 PURPOSE** – To establish geodetic control on the airports across the United States. The establishment of geodetic control will provide accuracy standards for engineering surveys and

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maps used to support planning, design, construction, operation, maintenance, and management of airport facilities and to establish a tie to the National Spatial Reference System (NSRS). The NSRS can provide Airports with a common, consistent set of geographical coordinates (reference points). A project may include: planning, reconnaissance, mark recovery, mark setting, GPS observations, spirit leveling, data processing, data analysis, data adjustment, data submittal in specified formats and preparing reports.

### 9.2 RECONNAISSANCE

Reconnaissance activities for each survey shall include the following: Review of station descriptions in the NGS Data Base; coordination with airport authorities; mark recovery; selection of PACS, SACS, and NSRS ties; preparation of required descriptions, sketches, photographs, and other documentation; and compilation of a Project Survey Plan.

**a. CONTROL STATIONS** - The following types of control stations (survey marks) shall be considered for use in these projects:

1. HORIZONTAL:

- All control stations with a stability code of A, B or C (see Attachment 2 for an explanation of stability codes), and
- All high accuracy GPS control stations including: CORS, FBN, CBN, HARN, and PACS.

2. VERTICAL:

- All first-order and second-order NAVD 88 vertical control stations (bench marks) within the project area, sufficient to provide vertical control for the project.

All horizontal and vertical points used as control shall be part of the NSRS.

**b. DATABASE SEARCH** - NGS and U. S. Coast and Geodetic Survey (USC&GS) (former name for NGS) station descriptions are contained in the NGS database and are available via the NGS Web site. A database search shall be made for all control stations on and around the airport meeting any of the above criteria prior to performing the field reconnaissance. The review should be used to form a "priority listing" of candidate High Accuracy Reference Network (HARN) stations and Bench Marks stations for use in NSRS ties. Many airports have existing monuments which may be suitable for use as PACS/SACS. Suitable stations are defined as a survey disk, rod, or similar type monument, meeting at least a stability code of "C" with a known history of stability, considered suitable for GPS observations, and recovered in good condition. Directly access the NGS Integrated Data Base (NGSIDB) using the NGS Web site at: <http://www.ngs.noaa.gov/datasheet.html>.

**c. CONTACT WITH AIRPORT AUTHORITIES** - Close communication with airport management is a critical element of the reconnaissance. Appointments with airport management should be made well in advance to ensure a qualified airport representative is available to discuss the survey and the procedures for working on the airport. Proper clearances to work in the aircraft operations areas must be obtained before performing any

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work at an airport. A security and safety briefing may be required before field crews are allowed to work on the airfield. Follow standard safety procedures and equip all vehicles with flashing yellow lights and aircraft radios. Contact with the airport traffic control tower is mandatory during surveys at controlled airports unless an escort is provided.

Inquire about planned construction or changes in the airport layout. Briefly summarize any future construction plans in the Project Survey Plan. Discuss optimal locations for the practical use and survivability of the monuments and finalize the PACS and SACS monument site selections with airport management. Inquire about underground utilities and other hazards to setting monuments. Emphasize the importance of keeping the area surrounding the monuments, especially the PACS, clear of any future equipment installations or construction that may block intervisibility between the monuments, visibility to GPS satellites, or become a source of multipath interference.

### **d. MARK RECOVERY**

**1. SEARCH** - The contractor shall make an extensive physical search in the field for the “suitable” control stations found during the database search performed in section 9.2b (priority listing). See Attachment 1 for diagrams of NOAA survey disks. Existing marks should be used if they meet the PACS and SACS requirements. Use of existing marks reduces the proliferation of marks on airports, reduces mark setting costs, and makes it easier to maintain an accurate, up-to-date survey data base. For a discussion of "Existing Monumentation in the Vertical Network" see page 43-44, *Geodetic Bench Marks*, NGS, 1978.

Before an existing mark is used, its description shall be thoroughly checked to confirm the station's identity, stability, and location, and to provide input for an updated description or recovery note. Stamping shall not be done on existing disks or logo caps.

A or B-order marks have been set at many airports by NGS. These marks should be used if they meet PACS requirements. If there is an existing "A" or "B" order station just off an airport, and it has visibility onto the airport, an exception to the rule that a PACS must be on the airport may be granted. Make a recommendation, with justification, in the Project Survey Plan.

If there is an existing "A" or "B" order station just off an airport, and it does not see onto the airport, an exception to the rule may also be granted if an intermediate station (a third SACS) can be set providing visibility from the "A" or "B" order station through the third SACS to the other two SACS on the airport. The third SACS may be off the airport. Again, make a recommendation, with justification, in the Project Survey Plan.

The contractor shall prepare digital updated descriptions or recovery notes in

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WDDROC format for all NSRS marks searched for and all marks used in the project. See paragraph below entitled "MARK RECOVERY DEFINITION."

**2. MARK RECOVERY DEFINITION** – The "recovery" of a control station includes a physical visit to the station to determine its usability by checking its identity, ascertaining its unmoved position, and determining its condition, stability, visibility, etc. and to prepare a digital updated description or recovery note in NGS format. To ascertain its identity, check the mark type, disk type, and stamping against the NGS data sheet. To ensure its position, measure the distances from the reference marks and/or the distances from the reference points and Witness Post. Also, the angle between the reference marks should be checked. Station descriptions and recovery notes shall be submitted in computer-readable form using WDDPROC software available on-line at: [http://www.ngs.noaa.gov/PC\\_PROD/DDPROC4.XX/ddproc.index.html](http://www.ngs.noaa.gov/PC_PROD/DDPROC4.XX/ddproc.index.html). See detailed instructions in Attachment 5.

**3. MARKS OF OTHER ORGANIZATIONS** - An existing mark of another organization may be used as a **PACS** if it meets all siting, construction, and intervisibility requirements. Normally this would be limited to a disk set in a drill hole in bedrock, or a stainless steel rod if there is an indication that the rod was driven to NGS driving requirements. Marks previously established by other organizations may be used for a **SACS** if they meet all siting, construction, and intervisibility requirements, and are stability A, B, or C.

**4. MARKS ON PRIVATE PROPERTY** - The Contractor shall contact property owners and obtain permission before using or setting a mark on private property. Take care to return the landscape to the original condition. Do NOT include the name and phone number of the property owner in the station description unless the land is owned by a business, or the owner requests to have the information included in the description.

**5. DESTROYED SURVEY MARKS** - Metal survey disks which have been moved, are very loose, or otherwise damaged so that they can no longer serve as survey marks are to be removed, have updated recovery notes written describing the mark as destroyed, and the disk sent to NGS. A mark shall not be described as destroyed unless the disk is found and returned to NGS.

**6. DAMAGED SURVEY MARKS** - Any existing disk which is selected to be used as a PACS or a SACS should be repaired if found loose or with edges exposed. Any work done to repair a disk shall be described completely in the digital recovery note. Extreme care shall be taken not to alter the existing horizontal or vertical position of the disk. Disk longevity can be increased substantially by simply adding highway epoxy or equivalent when the edges of a disk are exposed, thus preventing ice from forming under the disk and/or a vandal from prying the disk from its location.

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For all marks used in this survey, perform mark maintenance as stated above, including replacing logo cap lids if missing. Contact NGS for recommendations in unusual cases. Notify NGS of any other marks that need mark maintenance. Examples of mark maintenance problems include: loose disk, exposed edge of disk, missing logo cap, missing logo cap lid, exposed edge of concrete monument, or imminent danger of destruction.

**7. MARKS NOT FOUND** - The contractor shall report any marks not found. If the mark is not found, enter the number of person-hours spent searching into the digital recovery note. Do not state that the mark is destroyed simply because it was not found. If strong evidence exists that the mark has been destroyed, state the evidence.

**8. MARKS RECOVERED BUT NOT USABLE** - For marks which are recovered but are positively not usable due to complete tree canopy, etc., the recovery requirements may be reduced to just a simple recovery note such as, "RECOVERED AS DESCRIBED. THE MARK CAN NOT BE OCCUPIED BY GPS DUE TO COMPLETE TREE CANOPY." For marginally usable marks, fulfill the normal recovery requirements including Visibility Diagram, photographs, etc. because the mark may be needed depending on other marks in the area.

**e. BENCH MARK SPIRIT LEVEL TIES** - If the reconnaissance indicates that the number and/or distribution of bench marks with good sky visibility is inadequate, spirit level ties may be made to transfer an elevation from a bench mark to a nearby existing or new survey point that does have good sky visibility. Every effort should be made to recover existing bench marks before using this method. Transferring elevations to existing horizontal control marks is preferable to setting new marks. Temporary marks shall not be used. See Attachment 20 for further details.

**f. VISIBILITY** - All horizontal and vertical stations selected shall have adequate GPS satellite visibility. The visibility should be minimally restricted from 15 degrees above the horizon to the zenith, in all directions; see Attachment 2 for details. Minor obstructions are acceptable, but shall be depicted on the Station Location Sketch and Visibility Diagram (see section 9.2h). For new stations, select a site relatively free of present and future anticipated obstructions. Utility poles in the GPS field of view are tolerable, and they provide security and a reference to help locate the mark. Set new marks at least 2 meters from a pole, to the south if possible. Likewise, existing marks within 2 meters of a pole should not be used. Marks should not be set or used if within 5 meters of a chain link fence.

**g. NATIONAL SPATIAL REFERENCE SYSTEM (NSRS) TIES** - Each PACS shall be tied to at least one "A" or "B" order High Accuracy Reference Network (HARN)

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station and two First or Second order North American Vertical Datum (NAVD88) bench mark stations. The stations selected for these ties shall be recovered during the field reconnaissance. Details for selecting and positioning the PACS (and CTCORS) ties are listed in section 9.5.3 “GPS OBSERVATION REQUIREMENTS.” All reconnaissance deliverables required for “Suitable” stations are also required for the NSRS ties.

**h. STATION LOCATION SKETCH AND VISIBILITY DIAGRAM** - For all marks, observed and proposed, the contractor shall prepare and submit a station location and visibility diagram (See Attachment 4). The form is also available at: <http://www.ngs.noaa.gov/PROJECTS/FBN/> (click on “Forms,” then click on “Visibility Obstruction Diagram”). The station location sketch and visibility diagram should show the survey marks relation to nearby features such as runway ends, taxiways, airport lights, fence lines, buildings, etc. Label prominent features and draw dashed lines along the reference measurements to indicate the reference objects that are listed in the D-FILE description for the station. Complete the visibility diagram and sketch the inscription and stamping detail of the disk in the space provided. The form shall be neatly and accurately completed.

**i. PENCIL RUBBINGS** - Rubbings are not required during the recovery of a survey mark. However, rubbings are required at the time of each observation at that station. See Section 9.5.4.3 for details.

**j. PHOTOGRAPHS**

1. RECOVERED STATIONS- The contractor shall take at least three photographs of each existing control station per Attachment 3.
2. PROPOSED SITES OF NEW STATIONS - Two photos, see Section 9.2k.
3. NEW STATIONS, AFTER SET - Three photos
4. CONCRETE MARK HOLE - One photo

**k. PROPOSED NEW STATION SITES** - It is highly preferable to use existing marks rather than set new marks. If required, the contractor shall propose sites for new stations and propose the type of mark to be set in the “Comments/recommendations” column of the “Station Table”, see Section 9.3b. Preliminary digital descriptions shall be prepared as well as station location sketch and visibility diagrams. Take two photographs of proposed sites, one at eye level, oriented vertically downward showing the ground in the area of the proposed mark (photo #2) and one oriented horizontally showing the nearest satellite obstruction or identifying feature if no obstructions (photo #3). After the mark is set, capture photo #1 and update others as required. Note, see Attachment 3 for digital photograph requirements. Proposed sites for new PACS and SACS shall be approved by NGS prior to setting the marks. NGS may approve station selections based on preliminary Project Survey Plans to facilitate efficient field operations. New PACS and SACS should only be set if no existing mark can meet the requirements. See section 9.4, MARK SETTING, for mark setting guidelines.



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**I. GPS POSITIONS** - Obtain a hand-held GPS (pseudo-range) position for all marks found and for proposed sites for new marks. Include this position in the text of recovery notes and descriptions. Data format: DDD MM SS.ss. Upon returning to the station, the Contractor shall use the description to find the station as a check and not rely strictly on the GPS position.

### 9.3 PROJECT SURVEY PLAN

After reconnaissance but prior to mark setting or observations, the contractor shall submit a Project Survey Plan to NGS. NGS recommends that the data be submitted via the internet using the NGS Project Proposal Form available at <http://www.ngs.noaa.gov/PROJECTS/proposals/project1.shtml>, however the contractor may send the data (one paper copy and one digital copy) to the NGS Point of Contact (POC). NGS will review the Plan as soon as possible, normally within five workdays, and will send the contractor written comments and/or approval. The contractor shall not begin mark setting or data collection until the Plan is approved by NGS. The Plan shall include at least the following sections:

- a) Airport Summary Report - A separate paragraph for each airport to include: Airport contact and access information; whether airport is controlled; whether escort is required; airport radio frequencies; intervisibility conditions between the PACS and SACS; comments on any future construction, unusual circumstances, use of witness posts, and any other miscellaneous information. Include any comments or deviations from these General Specifications. The Airport Summary Report can be combined with the Station Table described below.
- b) Station Table - For each airport, submit a table which lists station designation name, PID (Permanent Identifier), establishing agency, order, stability, condition at recovery, and Comments for each station. For new stations, include the proposed name in the "Name" column, identify them as "proposed" in the "Type" column, and indicate the proposed type of mark (rod, concrete, disk in bedrock) in the "Comments / Recommendations" column. For existing stations, the name and PID shall be used exactly as listed in the NGS database and shall be this way in all survey records. For existing stations found but not proposed to be used, state the reason(s) in the "Comments/Recommendations" column. Identify the PACS, SACS, and all NSRS ties for the airport. Give status of marks not used and the reason. See Attachment 6 for an example.
- c) Airport Control Plot - Plot all "suitable" control that is on or near each airport on an airport map. Label each station with its designation and indicate if it is a PACS, SACS, Bench Mark, HARN Tie, or subsidiary control. Hand plotting on 8.5 x 11 paper is acceptable. See Attachment 6 for an example.
- d) Photographs – Submit photographs in accordance with section 9.2j and Attachment 3 for all suitable stations recovered during the survey, and for all new monuments that will be set.

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- e) Station Location Sketch and Visibility Diagrams - Submit for all suitable stations recovered during the survey, and for all new monuments that are set (See section 9.2h).
- f) Station Descriptions - Submit Recovery Notes or Descriptions for existing marks. Encode the descriptions using WDDPROC software. Note, these descriptions should be reviewed and corrected by GPS observers when they travel to marks. See section 9.2d2 and Attachment 5 for details on writing station descriptions.
- g) GPS observing scheme – If applicable, group airports together that will be observed/processed simultaneously. Include length of sessions and number of occupations. List CORS, HARN, Bench Mark, and any A-order ties for each airport. See Attachment 12 for an example.
- h) Project Vector Diagram - Depict the entire project area showing all occupied stations, except SACS (because of scale). Symbolically distinguish whether each station is a CORS, PACS, HARN Tie, Bench Mark or combination. Include 300km (or appropriate scale) dashed circles around CORS and CTCORS, and 50 km circles around PACS. Show the GPS vectors that will be processed. Recommend one sheet of large size and additional smaller sheets depicting individual airports or airports grouped together for GPS observations. Provide a scale or note distances from the PACS to the CORS, HARN, and Bench Mark Ties.
- i) Proposed instrumentation list – Tabulate the brand and model numbers of GPS equipment.
- j) Data Processing Software – Specify software name and version for the software used. Ensure that the current version of all software is used.
- k) Quality Control Plan – See section 5.

Note, printouts of the NGS station data sheets are not required.

### 9.4 MARK SETTING

After the Project Survey Plan is approved by NGS, the Contractor may begin field work. Marks shall be set to NGS specifications for type, length, material, stability, stamping, driving, etc. outlined in *Geodetic Bench Marks* and Attachments 7, 8, and 9.

The importance of setting quality monuments cannot be over emphasized. Monuments that are properly located and set can provide decades of valuable use for surveying operations. Proper attention and workmanship shall be given to all the steps in the process including the basic tasks of hole digging, rod driving, concrete mixing and pouring, and finishing the monument. The only physical evidence remaining after a survey has been completed are the monuments; therefore, permanency and neatness of the monument and the surrounding area are of utmost importance.

Where new marks are required, PACS and SACS shall be monumented in accordance with the



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following criteria: the paragraphs below, the attachments to this document, and FAA No. 405, Fourth Edition, Appendix 3. Additional requirements are found in: *Federal Base Network Station Selection Guidelines*; and *NOAA Manual NOS NGS1, Geodetic Bench Marks*, Floyd, 1978.

Proposed sites for new marks should be discussed with airport management after existing marks have been recovered. Inquire about underground utilities and future construction that might affect mark longevity. "MISS UTILITY" type services should be contacted before driving rod or digging, and may be required by state or local regulation.

**PACS** - New PACS shall meet stability code A or B requirements as defined in Attachment 2, *Selection Guidelines for Airport Geodetic Control*. New rod marks shall meet the "Quality Code B" requirements found in Attachment 9 and *Geodetic Bench Marks*.

**SACS** - New SACS shall meet stability code A, B, or C requirements as defined in Attachment 2, *Selection Guidelines for Airport Geodetic Control*. Bronze disks set in rock outcrops, massive structures, or as concrete monuments shall be used for new SACS.

The preliminary station descriptions and sketches shall be updated after the mark is set, and photograph #1 (close-up, see Attachment 3) shall be captured along with updates of other photographs, as required. For concrete marks, take a photograph after the hole is dug and before the concrete is poured showing a level rod in the hole (to show the depth of the hole). The file name for this photo shall start with "RE" for reconnaissance; see Attachment 3.

### **9.4.1 STAMPING**

New PACS and SACS shall have a unique stamping. Marks set at an airport with an official FAA location identifier shall be stamped with that identifier, followed by a sequential letter, followed by the year the mark was set; see requirements in FAA No. 405, Fourth Edition, Appendix 3. Disks and "logo caps" shall be stamped before they are set in place.

### **9.4.2 BRONZE DISKS**

Standard bronze, horizontal disks shall be used for rock outcrop, massive structure, and concrete marks. A rock outcrop in which a disk is set shall be hard and a part of the main ledge and NOT a detached fragment. A disk set in a drill hole shall be well counter-sunk and adequately fixed in place using highway epoxy or equivalent. The disks shall be fastened so that they will effectively resist: extraction, change of elevation, or rotation. Disks shall be well countersunk, especially in areas where snow plowing is possible. If the top of the disk is not below the level of the surrounding material, a snow plow can scrape off the brass from the top of the disk, or worse, break the disk off the stem. Traditionally, NGS has set disks so that the lettering can be read normally (correct side up) when the observer is south of the disk and facing north across the disk.

For detailed instructions on setting bronze disks, see Section 9.4, Attachment 7 and Attachment 8.

### **9.4.3 STAINLESS STEEL ROD MARKS**

A NGS 3-D rod mark meeting stability code "B" for stability, may be set for PACS. A 1 meter long, grease filled, finned sleeve shall be used with this mark. Instructions are in Attachment 9,

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"SETTING A NGS 3-D MONUMENT." See also, Attachment 10, "PHOTOGRAPHIC DOCUMENTATION OF SETTING A NGS 3-D GEODETIC CONTROL MONUMENT."

Note, either a 5 inch or a 6 inch diameter PVC pipe may be used as long as the logo cap fits correctly. One manufacturer's version of the logo cap will fit inside one diameter and outside the other diameter.

The rod shall be driven until the rod refuses to drive further, or until a driving rate of 60 seconds per foot is achieved. Record the length of rod driven for entry into the station description. Note, the minimum acceptable length of rod is 4 meters (see Table 3, page 27, *Geodetic Bench Marks Manual*) unless the rod becomes embedded in rock and cannot be extracted. New rod marks should be allowed to settle for at least 1 day before observations.

If bedrock is found only a few feet beneath the surface, a concrete mark may be set instead of a rod mark if the concrete will rest directly on the bedrock. Drill several holes in the bedrock so that the concrete monument will be affixed to the bedrock. Utilize rebar to anchor the monument if feasible. The area of the bedrock where the concrete will be placed shall be brushed or washed off thoroughly. Install a standard concrete monument with brass disk. See Attachment 7.

### **9.4.4 CONCRETE MARKS**

New concrete marks, with standard bronze disks, may be used for SACS only. Construction requirements are in Attachment 7, Setting Concrete Marks. New concrete marks should be set slightly recessed with the ground and should be allowed to settle for at least 1 day before observations. Disks set in concrete shall be centered in the top of the concrete surface, shall be flush or slightly recessed with the surface of the concrete, and the top of the disk shall be free of concrete. A round form shall be used for the top of all concrete marks and logo cap protective collars. This will help ensure a neat finish and help protect against "mushrooming" which could result in frost heave. Black tar paper (felt paper) or ready made cardboard frames (available at home supply stores) can be used to easily construct a form. All loose concrete and other debris around the construction site shall be removed and the site left in **excellent** condition.

### **9.4.5 WITNESS POSTS**

Placement of witness posts on airport property shall be pre-approved by the airport manager. Witness posts should be used on an airport only when they can be placed in a non-obtrusive area such as a fence line or no-mow/snowplow area, and should be driven as deep as practical so they do not obstruct any restricted safety areas. Witness posts should not be used when the property owner objects, when the post cannot be driven, or when the mark should not be made easily visible because of a high risk of vandalism.

### **9.5 GPS POSITIONING PROCEDURES**

GPS observation requirements are summarized in Attachment 11 and detailed in the paragraphs below. A GPS equipment list and GPS observation scheme shall be approved by NGS prior to commencing the field observations. Observing windows shall be selected, and modified as

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necessary, to maximize satellite visibility and minimize Positional Dilution of Precision (PDOP) for each session. Incorporate any information from Notice Advisory to NAVSTAR Users (NANU) messages, available from the USCG Navigation Center web page, when scheduling GPS observations to ensure optimal survey conditions.

### **9.5.1 CORS SELECTION**

The CORS sites selected shall be included in the NGS National CORS system. Use as many National CORS sites in the project area as feasible. Position each PACS directly to the nearest National CORS station. In areas such as Alaska where a PACS is not within 300km of a CORS, a CTCORS shall be established.

CORS maps, data, and information are available on the NGS National CORS web site (See Attachment 15 for access). Each CORS is designated by a three or four letter name, followed by the antenna number. The correct antenna name shall be used when downloading data and the antenna's coordinate information. Each CORS site usually has two or more antennas. Check the "data availability" feature on the NGS CORS web site to determine which CORS antenna was in use during observations, and to see if there are any gaps in the data. The CORS station coordinate file contains several positions based on different Antenna Reference Points (ARP), and either the ITRF or NAD 83 reference system. Ensure the proper coordinates are used when processing the data.

The survey disks (usually two) at each CORS site may have names similar to the antenna names. Take care not to confuse the disk names and positions with the antenna names and positions.

The weekly "CORS NEWSLETTER" is available through the NGS CORS web page described above. The Newsletter provides information on the status of the CORS system. Users may subscribe to the newsletter at this site.

### **9.5.2 CTCORS SELECTION**

A Central Temporary Continuously Operating Reference Station (CTCORS) shall be used if the nearest CORS is more than 300 km from the PACS. The CTCORS shall be established by setting up a GPS receiver on a suitable existing horizontal NSRS station, and shall provide the CORS function in the positioning of the PACS. The position of the CTCORS shall be verified by using the GPS observation requirements in section 9.5.3.1. Because of the long distances involved and the additional stations which will be positioned from the CTCORS, extreme care should be taken during the observation and processing of this data. Separate tripod set-ups are required at both the CTCORS and the PACS for each session. During all CTCORS operations, ensure that the CTCORS antenna remains fixed. Sandbags are recommended to stabilize the tripod and frequent checks should be made of the antenna's centering and height.

CTCORS Station Selection Criteria are listed below. The CTCORS station selection shall be approved by NGS prior to commencing field observations.

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<u>PRIORITY</u>	<u>TYPE OF STATION</u>	<u>STATION IS BENCH MARK</u>	<u>STATION IS AT AIRPORT</u>
1.	WAAS, USCG, or USACE CORS mark	YES	YES
2.	"	YES	NO
3.	"	NO	YES
4.	"	NO	NO
5.	A-ORDER HARN STATION	YES	YES
6.	"	YES	NO
7.	"	NO	YES
8.	"	NO	NO
9.	B-ORDER HARN STATION	YES	YES
10.	"	YES	NO
11.	"	NO	YES
12.	"	NO	NO

### Acronyms:

Wide Area Augmentation System (WAAS); FAA

U. S. Coast Guard (USCG)

U.S. Army Corps of Engineers (USACE)

High Accuracy Reference Network (HARN)

### 9.5.3 GPS OBSERVATION REQUIREMENTS

GPS observation requirements are described in the sections below for each type of mark. Note that when 4 hour sessions are specified, at least 4 hours of data are required in the final computer reductions. Therefore, observation of sessions longer than 4 hours is highly recommended, as well as for 1.5 hour sessions. Separate tripod set-ups are required for each session.

#### 9.5.3.1 CTCORS SITES

- The position of the CTCORS shall be checked by observing three or more independent, continuous, simultaneous observation sessions of at least 4 hours with a CORS station. These three sessions should be the first sessions observed while positioning various PACS. In addition, one 4 hour session shall be used as a check at the end of the project. If the distance between the CORS and CTCORS is greater than 300 km, or at extreme latitudes, contact NGS for guidance on increasing the length of observation sessions. All CTCORS shall be tied by GPS surveys to nearby, GPS-suitable, North American Vertical Datum of 1988 (NAVD 88) bench mark(s). See specific requirements in the Bench Mark Ties section below.

#### 9.5.3.2 PACS AND HARN TIE

If a CTCORS is required for connections, substitute CTCORS for CORS in the following paragraphs.

- Each PACS shall be positioned from the CORS in two or more independent, continuous, observation sessions of at least 4 hours in length. The observations to position the PACS shall be performed simultaneously with the CORS observations. The start time of a PACS

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observing session on subsequent days, should be at least 2.5 hours different than the previous PACS session to incorporate different satellite geometry.

- All PACS shall have a separate positional check by simultaneously observing at least one session of 4 hours or more in length with an "A" or "B" order HARN station. The HARN station should be within 100 km of the PACS and should be at least 50 km from the CORS. Tie to as many "A" order stations as possible during the project.
- A single HARN station can satisfy the tie requirements for more than one PACS if it meets the distance requirements for each PACS. Generally, no more than two PACS should be tied to a single HARN station in one session. Use additional observation sessions on the same HARN, or occupy an additional HARN station to satisfy the HARN tie to other PACS in the same area.
- An existing "A" or "B" order HARN station on an airport should be used as a PACS if it meets the siting, construction, and intervisibility requirements. The station shall be checked with at least one 4 hour session to a CORS. A tie to an additional HARN station is not required.
- The vector processing results of the two PACS sessions shall check within 3 cm. The final adjusted positions of the HARN ties should check within 5 cm horizontal and 10 cm ellipsoidal height with their published positions.

### 9.5.3.3 SACS

Each SACS shall be observed in two or more independent, continuous sessions of at least 1.5 hours. The session start times shall be separated by at least 2.5 hours to ensure a significant change in satellite geometry.

- These observations shall be simultaneous with PACS observations for that airport.
- If a SACS is also one of the bench marks or a HARN tie, the two or more 1.5 hour sessions are adequate for the tie, rather than the normal 4 hour requirement. This is due to the short distance from the PACS to the SACS.
- The vector processing results for the two SACS sessions must check within 3 cm.

### 9.5.3.4 BENCH MARK TIES

- Ties to two separate NSRS NAVD 88 bench marks are required for each PACS and CTCORS station. The ties shall be performed by observing each bench mark for at least one session of 4 hours or more in length simultaneously with the PACS or CTCORS. The two bench marks do not need to be observed during the same session.

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- Bench mark ties shall be selected in accordance with the Bench Mark Priority Table on the following page. Use of first order bench marks is highly desirable. The two bench marks should be as close as possible to, and no further than 50km from, the PACS or CTCORS. Bench marks should be at least 1 km apart, to help ensure that they are not both affected by the same upheaval or subsidence effect. If the PACS or CTCORS has a published bench mark elevation, that elevation satisfies one of the bench mark tie requirements.
- A single bench mark may satisfy one of the tie requirements for more than one PACS if it meets the distance requirements for each PACS. Generally, no more than two PACS should be tied to a single bench mark station in one session. Occupy additional bench marks, or use additional observation sessions on the same bench mark to satisfy the bench mark ties for other PACS in the same area.
- Bench mark ellipsoidal heights should agree within 10 cm and bench mark orthometric heights within 15 cm of published elevations.
- All bench mark elevations used in this survey shall be published NSRS NAVD 88 bench mark elevations, in meters.

### BM PRIORITY TABLE:

PRIORITY	DISTANCE TO CLOSEST FIRST-ORDER BM	SELECTION CRITERIA
1	< 25 KM	Use first-order BM.
2	25 – 50 KM	Use first-order BM if closest; Second-order BM may be used if it is less than ½ the distance to the first-order BM.
3	> 50 KM	Use a second-order BM if it is less than 25 KM away; Otherwise contact NGS.

- Differential geodetic (spirit) leveling (run in both directions) may be performed to satisfy the bench mark ties. These level ties shall be less than 3 km. Two bench marks are required for the beginning of a line of differential (spirit) leveling. Identify these two bench marks in the Project Survey Plan. If the PACS is tied to two bench marks by spirit leveling (within acceptable tolerances), then the two bench mark requirement has been met. Leveling shall meet third-order (or better) requirements listed in: *Interim FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems*, version 4.0, 15 JUL 94; *Standards and Specifications for Geodetic Control Networks*, FGCC, 1984; and NOAA Manual NOS NGS 3, *Geodetic Leveling*, 1981. Leveling data shall be submitted in "Blue Book" format on CD-ROM containing the final version of the following files: HGF, HGZ, and HA in direct access format and RPT and ABS in sequential format. Note, this case (third-order) is an exception to the NGS policy that second-order, class II is the lowest order leveling that will be accepted by NGS.



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- Third-order elevations determined by spirit leveling (run from various agencies' bench marks) already exist at airports that are in the Airport Obstruction Chart (AOC) Program. For the AOC airports that have been entered into the NGS database, the NGVD 29 elevations have been automatically converted to NAVD 88 elevations using program VERTCON and will be printed on the standard station data sheets, in meters, with a reference to VERTCON. Check these AOC third-order elevations against elevations determined in this survey and tabulate the result.

### **9.5.4 GPS OCCUPATION AT ALL SURVEY STATIONS**

GPS observations shall be performed using FGCS approved dual frequency GPS receivers. Fixed height tripods shall be used whenever practical. Fixed height tripods should be used. Tripods with multiple height settings should be set to the highest position. All tripods shall be tested for stability, plumb alignment (straightness of center pole), and height verification at the beginning and end of the project. All tripods shall be examined for stability with each use. Ensure that hinges, clamps, and feet are secure and in good repair. Also, check, and adjust if necessary, the position of the bubble in the circular vial. Separate tripod set ups are required for each occupation of a station and for each GPS observing session. General information on GPS equipment requirements and surveying can be found in the NGS GPS SURVEY MANUAL, available on line at (<http://www.ngs.noaa.gov/PROJECTS/GPSmanual/>).

Follow the additional guidance below:

#### **9.5.4.1 ANTENNA SET-UP**

GPS antenna setups shall be done independently for each session. The word "independent" means separate tripod setups, separate height determinations, and separate solutions. The height of instrument (HI) shall be measured in both meters and feet. See Attachment 14, "GPS Antenna Height Measuring Instructions." Minimize the mixing of GPS receiver and antenna types used for observations. Record the manufacturer, model number and, and serial number of the antenna on the field log.

#### **9.5.4.2 EPOCH INTERVAL / ELEVATION MASK**

GPS data shall be collected at 15 or 30-second epochs; and a 15 degree elevation mask. Data may be processed at a 15 second or 30 second interval. A NGS CORS station which collects at a 30 second interval may be used.

#### **9.5.4.3 STATION RUBBINGS**

A rubbing of the occupied mark shall be made at each occupation of a station. When not feasible to make the required rubbing, a plan sketch of the mark or a photograph shall be substituted, accurately and legibly recording all markings. This photograph, if used, is in addition to the photographs required in the Project Survey Plan, and the stamping shall be readable in this photograph. See Attachment 13 for a sample Pencil Rubbing Form.

#### **9.5.4.4 OBSERVATION LOGS**

- An observation log shall be filled out for each occupation of a station. See Attachment 13 for a sample GPS Station Observation Log. Data recorded on the observation log must include

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the following equipment information:

- (1) receiver manufacturer,
- (2) antenna manufacturer,
- (3) receiver model number (part number)
- (4) antenna model number (part number),
- (5) the complete serial number of the receiver,
- (6) the complete serial number of the antenna,
- (7) tripod model and serial number, and
- (8) tribrach model and serial number;

- Carefully monitor the receiver operation and antenna setup during each observing session. Note any unusual circumstances regarding satellite visibility, receiver operation, equipment malfunction, DOD adjustment of the satellite orbit, obstructions, weather events, tripod stability, etc., on the observation log.

### 9.5.5 ACCURACY STANDARDS

The required accuracy standards for PACS and SACS are provided in Attachment 2 *Selection Guidelines for Airport Geodetic Control Surveys*, or see FAA Number 405, “Standards for Aeronautical Surveys and Related Products”, Fourth Edition, Appendix 5.

### 9.5.6 RECOMMENDED EQUIPMENT

Dual-frequency GPS receivers that meet the following requirements:

- The receiver model has been evaluated against the Federal Geodetic Control Subcommittee (FGCS) test network.
- State-of-the-art dual frequency with high quality C/A code or P code pseudo-ranges.
- Capable of measuring full wavelength L2 carrier phase.
- Shall function acceptably in an Anti-Spoofing environment.

Any dual frequency receiver that is L2-squared capable may be used for SACS observations.

Use GPS antenna models that have been calibrated by NGS (See the NGS Antenna Calibration web page at <http://www.grdl.noaa.gov/GRD/GPS/Projects/ANTCAL/> )

Antennas equipped with a ground plane or choke ring are preferred for observations on the PACS and NSRS ties.



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## 9.6 VECTOR PROCESSING

Vector processing shall be performed using the latest version of the NGS software package PAGE-NT or equivalent. The 'equivalent' of PAGE-NT is subjective, based on the software's ability to correct for the same systematic errors that PAGE-NT corrects, apply the NGS required antenna offsets, and its ability to reproduce the same results as PAGE-NT. This determination will be made by NGS.

The NGS PAGE-NT software package and User's Manual are available via anonymous FTP from NGS (see Attachment 15). Follow the vector processing guidance below, The PAGE-NT User's Manual, and the Vector Processing Outline in Attachment 16.

- The grouping of vectors into processing sessions for each day of observations are determined by two factors: 1) The required reference station, and 2) The distance of each solve station from the reference station. This vector distance determines the final solution type to be run in PAGE-NT. Reference station requirements are detailed in the sections below. Use the following table for grouping vectors together into sessions according to vector length:

**PAGE-NT Final Solution Type Determination**

Vector Distance for Processing Session	Final Solution Type
Under 5km	L1 Fixed
5-100km	Ion-Free Fixed

- IGS precise orbit data and NGS National CORS data shall be used in data processing. For information on down loading CORS data and ephemeris data from NGS via the Internet see Attachment 15.
- **International Terrestrial Reference Frame (ITRF) station coordinates shall be used for all vector reductions.** Information about ITRF is available on the NGS WWW Home Page, under "PRODUCTS SERVICES". The current ITRF epoch shall be used in computations. The Antenna Height value entered into the PAGE-NT "Station Information" Menu, "Up" field, is the monument to the Antenna Reference Point (ARP). For example, 2.000 for a fixed height tripod. The monument for a CORS is generally coincident with the ARP, therefore, 0.000 is entered for a CORS station unless an offset is listed on the CORS coordinate sheet. PAGE-NT will automatically add a constant factor for the ARP to L1 phase center distance when it merges the data.
- Set the Tropospheric scale height in accordance with the following table:

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### Tropospheric Unknown Settings for PAGE-NT Sessions

Vector Length	Reference Station Setting	Solve Station Setting
Under 3km*	OFF/FIXED (Not Highlighted)	OFF/FIXED (Not Highlighted)
3-100km	OFF/FIXED (Not Highlighted)	ON/SOLVE (Highlighted)
100+km	ON/SOLVE (Highlighted)	ON/SOLVE (Highlighted)

\*If a station is within 3km of the reference station AND differs in height with the reference station by 5 meters or more, set the tropospheric scale height setting to SLV for that station.

- Review the PAGE-NT generated plots and text outputs to analyze each processing session. PAGE-NT's overall RMS-of-fit of the post-fit double-difference residuals should not exceed 2.0 cm. Investigate individual satellites with a relatively high RMS or where integers could not be fixed. Also review the files for input errors such as improper reference station coordinates, antennae height errors, or improper station names.
- Compare the ITRF coordinates of all repeat baselines and for NSRS ties that were occupied more than once. Investigate any station coordinate comparisons that do not agree within 3 cm.
- Submit all files and printouts as required in Attachment 16.

#### 9.6.1 CORS VECTORS

At least one national CORS shall be used for determining a PACS position. However, for several airports observed simultaneously, utilize data from as many National CORS in the project area as feasible. CORS to CORS vectors strengthen the GPS network and allow for easier error detection. Discuss with NGS the CORS to CORS vectors to be processed. Generally, two 24 hour vectors shall be processed between the CORS stations to form an interconnecting network. See section 9.5.1 for more information on CORS data.

#### 9.6.2 CORS TO CTCORS VECTORS

Three independent sessions between the CORS and CTCORS are required at the beginning of the project and one session, as a check, at the very end of the project. Process these three sessions using the most recent ITRF coordinates published by NGS for the CORS. If the new computed ITRF coordinates of the CTCORS differ from the NGS ITRF coordinates by more than 3 cm in horizontal or 10 cm in vertical (ellipsoidal or orthometric), call NGS immediately for further instructions. These instructions may include processing additional CORS to CTCORS sessions. Any discrepancy, even if resolved, shall be described in the project report. Note, the PACS accuracy requirement is relative to a CORS, not a CTCORS, so any discrepancy in the CTCORS position shall be included in the error budget for the PACS. The last session at the CTCORS

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shall be used to again check the position of the CTCORS relative to the CORS.

### 9.6.3 PACS, SACS, AND NSRS TIE VECTORS

The sequential order of vector processing is listed below. The selection of either L1 or Ion-Free fixed for the final solution type is based on vector lengths. See the Solution Type Determination Table (Section 9.6) for guidance when grouping vectors together for a processing session.

Discuss the plan for processing any “shared” HARN and bench mark ties with NGS if more than one airport is observed for the project. Generally, each HARN or BM observation should be included in only one processing session. Use the following guidance for preparing the processing plan:

- If a HARN station tie is NOT also a PACS, SACS, or BM tie for an airport, and it is greater than 50km from a PACS, it may be processed in the CORS to PACS session. In the case of multiple airports using the same HARN, the PACS observed simultaneously with the HARN to “share” the tie shall be tied to it indirectly in the group adjustment. Separate processing sessions from each PACS to the HARN are not required.
- If a HARN station tie is NOT also a PACS, SACS, or BM tie for an airport, and it is within 50km of a PACS, it should be processed directly from the closest PACS. In the case of multiple airports using the same HARN, a second nearby PACS that was observed simultaneously to “share” the HARN tie shall be tied to it indirectly in the group adjustment. A separate processing session from the second PACS to the HARN is not required.
- Bench mark ties should be processed to their PACS. In the case of multiple airports, the second, simultaneously observed, PACS shall be tied to the bench mark indirectly in the adjustment. Again, a processing session from the second PACS to the BM is not required.

Substitute CTCORS for CORS in the steps below if applicable: To check the position of the PACS, the sequential order of vector processing is:

Step 1 - Process first CORS-to-PACS vector, with CORS as reference, using the latest ITRF coordinates. Note, if more than one PACS was observed simultaneously, include these PACS in the session if they conform to the vector distance limitations for the session (See Solution Type Determination table above). Also include any appropriate HARN and Bench mark stations in the session.

Step 2 - Process the second CORS-to-PACS vector, with CORS as reference, as above. Again, include appropriate PACS or HARN stations that were observed simultaneously into this session.

Step 3 – Compare the resulting ITRF coordinates of the PACS and NSRS ties that were used more than once. Use a spreadsheet to show the differences between the sessions and the calculation of the mean (See Attachment 18 for an example). The two PACS coordinates should compare within 3 cm. If they do, mean the positions and go on to Step 4. If not, contact NGS.

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The PACS may need to be reprocessed or reobserved.

Note, Steps 4-6 shall be completed individually for each airport (Each PACS shall be the reference station for its respective SACS).

Step 4 - Process the first PACS to SACS session using the PACS as the reference station and using the mean ITRF position calculated in step 3. Process these short lines using the L1 frequency only.

Step 5 - Process the second session SACS data as above.

Step 6 – Compare the ITRF coordinates of the SACS. Include this comparison on the same spreadsheet used for the PACS comparison. Investigate any SACS coordinate comparisons that do not agree within 3 cm.

Discuss with NGS procedures for processing if a HARN station or Bench Mark tie also serves as a PACS or SACS.

**NOTE that the PACS to SACS ties will form a separate B-file and G-file.**

### **9.7 PACS ADJUSTMENT PROCESSING**

All airports in a project area may be adjusted together if airports which are located close together share tie stations (CORS, BM, HARN). Airports can be adjusted individually.

The adjust software package can be downloaded from the NGS home page (<http://www.ngs.noaa.gov>) by accessing the “PC Programs” link. Attachment 17 contains a detailed outline of the adjustment process for airport geodetic control projects. Follow the attached outline, the guidelines found below, and the written Adjust documentation when performing the adjustment.

Five adjustments are required: (1) free, (2) constrained with CORS or CTCORS and HARN stations held, (3) a final free with accuracies, (4) a free vertical holding one bench mark in the center of the project, and (5) a fully constrained vertical (with all approved bench marks held).

- ADJUST's 'Mean Absolute Residual' statistics (from Adjustment #1) shall not exceed 2.0 cm in NORTH or in EAST, and shall not exceed 5.0 cm in UP.
- ADJUST's maximum residual (from Adjustment #1) should not exceed 3.0 cm and shall not exceed 5.0 cm on the horizontal components. The estimates could be twice as large for the vertical component.
- Vectors may be rejected if the residual exceeds 4.0 cm in any horizontal component, but may not be rejected if it supplies the only redundancy for a station. A written justification for

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rejecting the vector should be included in the Final Report.

- HARN ties should check within 5 cm horizontal and 10 cm ellipsoidal height compared to their published positions. Notify NGS immediately if checks exceed these tolerances. Show the coordinate comparisons on a spreadsheet (See Attachment 18).
- Bench mark orthometric heights should agree within 15 cm of published elevations. Notify NGS immediately if checks exceed these tolerances. Show the height comparisons on a spreadsheet (See Attachment 18).

Section 7 of the Bluebook, Annex L, are superseded by the following guidelines for adjustment processing and submittal. Use these guidelines along with the step by step Outline of the Adjust Procedure in Attachment 17.

All adjustments shall be run in three dimensions. Do NOT scale the gfile for the PACS adjustments. Ensure all input files are complete and free of format errors by utilizing the checking programs (ignoring errors relating to missing codes at this time). \*86\* records should be in the bfile before beginning the adjustment. Do not insert GEOID heights until the horizontal adjustments are complete.

Ensure the proper code was inserted into the solution coordinate system code (cc 52-53) of the G-file created by PAGE-NT. Adjust will use this code to internally transform the ITRF vector components to the NAD 83 reference system.

**ADJUSTMENT ONE-** A free adjustment to determine the strength of the GPS network. Hold the NAD 83 position and ellipsoid height of one CORS station fixed. For multiple airports, constrain the CORS that was used for the majority of the vector reductions or that is located near the center of the project area.

Residuals on any vector component should not exceed 3 cm and must not exceed 5 cm. Outliers remaining after a review of the vector reductions may be rejected if sufficient redundancy exists or upon approval from NGS headquarters.

A comparison shall be made between the coordinates determined in this adjustment and those currently published by NGS. Use a spreadsheet to calculate the differences in the X, Y, and Z components (See example in ATTACHMENT 18). Program INVERSE3D should be used to determine the exact Delta Height and Ellipsoidal Distance for comparisons that do not fall well within tolerance. As noted previously, differences of 5 cm horizontally and/or 10 cm in ellipsoidal height with published positions should be immediately brought to the attention of NGS for investigation. Consult NGS for guidance on controls for this adjustment if any differences are outside these tolerances. Submit all comparisons with the final report.

**ADJUSTMENT TWO-** A fully constrained horizontal adjustment. Constrain the NAD 83 coordinates (latitude, longitude, ellipsoid height) of all CORS or CTCORS stations and HARN tie stations used in processing.

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**ADJUSTMENT THREE-** A minimally constrained free adjustment to determine the length of the relative accuracies of the adjustment. Run program QQRECORD to add QQ records to the afile. Hold the NAD 83 position and ellipsoid height of one CORS station fixed. Use the output bfile from adjustment 2 as the input bluebook.

Use program BBACCUR to derive a listing of the accuracies. Examine the accuracies to determine that all lines meet the requirements for the order the stations will be published, e.g., CTCORS to PACS should be 1:1,000,000; PACS to SACS should be 1:100,000. PACS shall be published as B-order; SACS and bench marks as first-order. Discuss any problems with NGS and detail them in the report. NOTE: The final PACS and SACS coordinates shall meet FAA document No 405, Fourth Edition, accuracy requirements. The computed accuracies will help in the analysis of meeting those requirements.

Use program ELLAC to derive the order/type of the ellipsoid heights. This value shall be edited into the \*86\* records of the final B-file. The value chosen should be that of the majority of the lines and shall be used for all stations.

**ADJUSTMENT FOUR-** A free vertical adjustment to determine the strength of the vertical network. Insert geoid heights into the output bfile from adjustment 2 and use it as the input bfile. Use the latest version of NGS geoid software to derive the geoid heights. Hold the NAD 83 latitude and longitude of one CORS station and the NAVD 88 orthometric height of one bench mark (center of project area) fixed. Compare the published bench mark elevations with those obtained in this adjustment and notify NGS of any exceeding 15 cm. Consult NGS for guidance on Bench Mark controls to use if any checks exceed 15 cm.

**ADJUSTMENT FIVE-** A constrained vertical adjustment to determine the new GPS derived elevations for the project. This adjustment may need to be run several times to determine the optimal selection of bench marks to use as vertical constraints. In consultation with NGS, constrain the NAVD 88 elevations of bench marks that checked the best with their published positions based on the free vertical adjustment. Run the adjustment and review the results. Continue to add constraints until any “poor fitting” bench marks are determined. Allow poor fitting bench marks to float in the final vertical adjustment. Use the orthometric heights from this adjustment for the final B-file.

Submit a spreadsheet which shows the height difference between the published NAD 83 bench marks and their final adjusted elevations. Discuss any outliers in the project report. Also document any actions taken as the result of poor bench mark checks.

The **final B-file** submitted shall contain the positions and ellipsoidal heights derived from the final constrained adjustment (ADJUSTMENT TWO) and the orthometric elevations from the final vertical adjustment (ADJUSTMENT FIVE). Program ELEVUP can be used to easily combine the files. The B-file shall satisfactorily run through the required checking programs. No errors are allowed in the final B-file submitted for data base entry.

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### **9.71 SACS ADJUSTMENT PROCESSING:**

The final B-file from the PACS adjustment shall be used to obtain the positions and heights of the PACS which are constrained in the SACS adjustment. Only PACS positions shall be held fixed. All procedures and analysis of these adjustments shall be the same as for the PACS except the PACS serves as the control rather than the CORS and the G-file should be scaled.

**9.8 DATA SUBMITTAL** - Final project data shall be submitted in Blue Book format. The Project Sketch, descriptions, photos, project adjustments, reports, etc., shall be both paper and digital, if possible. Submit all original data records, see Sections 2.7, 6.1, 9.3, and 11. General guidance for data submitted to NGS can be found in Annex L of the NGS Bluebook, and in *Policy of the National Ocean Service Regarding the Incorporation of Geodetic Data of Other Organizations into the National Geodetic Survey Data Base*, dated September 1994 (available on line at [http://www.ngs.noaa.gov/INFO/incorp\\_data.html](http://www.ngs.noaa.gov/INFO/incorp_data.html)).

### **10. FINAL PROJECT REPORT**

A final project report detailing the GPS observations, vector processing, and adjustment shall be submitted to NGS. This report is in addition to the Project Survey Plan that is described in Section 9.3. Photographs, updated sketches, descriptions, and other information concerning mark setting performed for the project shall be submitted separately as a supplement to the Project Survey Plan.

10.1 The Final Project Report shall contain at least the following sections:

- a. An overview discussion of the planning, field work, data collection, data processing, adjustment, and data error analysis. This discussion should include a summary of the results, problems encountered, conditions affecting progress, and any unusual circumstances. Include comments on any deviations from the Project Survey Plan, or these General Specifications (include comments from weekly Status Reports).
- b. A written description and analysis of the quality control performed; tables showing check positions; a listing and analysis of all unusual circumstances, discrepancies, and deviations.
- c. A listing of personnel who worked in the field and/or were involved with the data processing for this project.
- d. A listing of the brand, model number, and serial number of all survey equipment (GPS receivers, antennas, levels, etc.) used in the project. List the quantity, brand, type, and height of fixed height tripods used. Include any instrumentation used for differential leveling if done.
- e. A listing of all software, including version, used during the project for RINEX



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conversion, vector processing, adjustment, and verification (all checking programs).

f. A final station list: use a table format to list each station, the station type (PACS, SACS, etc.), and each observation session for the station.

g. A final Project Vector Diagram: update the vector diagram submitted with the Project Survey Plan (see Section 9.3). Submit only a large size, readable plot (approximately 24 x 32 inches). Include processing session designations on the vectors if feasible. Show indirect ties to “shared” HARN stations and bench marks.

h. The vector processing scheme tabulated by airport and session, which lists: reference station and solve stations with their station type; observation time for the vector, solution type (L3 fixed, etc.), and final RMS for the session. Provide any comments on problems encountered or anomalies with the processing session. Note the tropospheric unknown settings for each session. Provide any comments on problems encountered or anomalies with the processing session. This table can be incorporated into the spreadsheet described below.

i. A spreadsheet showing the comparison of the ITRF coordinates (X, Y, and Z) of all repeat baselines and for NSRS ties that were occupied more than once. Show the solution type, final RMS, and distance for each vector. Show the calculation of the mean PACS coordinate. See Attachment 18 for an example spreadsheet.

j. A detailed description of the project adjustment. Discuss each of the adjustments separately, including fixed control and the source of the coordinates, ellipsoid heights, and NAVD 88 elevation used. Explain unresolved error messages from the checking programs. Discuss the analysis performed and the results of the adjustments. Submit the spreadsheets or tables used to compare the adjusted coordinates with their published coordinates (see Section 9.7).

k. A completed Project Submission Checklist, see Attachment 19. Also available on-line at: <http://www.ngs.noaa.gov/FGCS/BlueBook/> (Click on “Annex L” and scroll down to page 9).

l. Recommendations for future projects.

### **11. DELIVERABLES TO NGS**

**11.1 LABOR, EQUIPMENT, ETC.** - The contractor shall provide all labor, equipment, supplies, materials, and transportation to produce and deliver the products as required

**11.2 QUALITY CONTROL PLAN** - Before any field work begins, the Contractor shall submit to NGS a Quality Control Plan covering all work (see Section 5). NGS will review this plan and respond with an approval or comment letter (or email) as soon as possible, normally within five



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working days. Submit paper and digital copies.

**11.3 SURVEY PLAN** - Before any mark setting or GPS observations begin, the Contractor shall submit a Project Survey Plan (see Sections 9.3) to NGS. NGS will review this plan and respond with an approval or comment letter (or email) as soon as possible, normally within five working days. Field work may commence after the Contractor receives the approval letter (or email) and the Task Order, if required.

**11.4 PROJECT STATUS REPORTS** – See section 2.6

**11.5 PROJECT SKETCH (VECTOR DIAGRAM)** - Submit a vector diagram showing all computed vectors. Submit only a large size, readable plot (approximately 24 x 32 inches). Include processing session designations on the vectors if feasible. Submit a paper version and a digital version, if possible.

**11.6 FIELD LOGS** - Submit the original version of all the observation logs, pencil rubbing forms, hand-written station descriptions/recovery notes, Station Location Sketch and Visibility Diagrams, digital photographs, etc.

**11.7 VECTOR PROCESSING OUTPUT** - Submit paper copies of the COMBINED.SUM files for any processing sessions that were difficult to process or produced questionable results. Submit the spreadsheets used for comparing the vector processing results (see Attachment 18). Submit paper copies of any other files requested by NGS for quality control.

**11.8 FINAL PROJECT REPORT** - Submit a Final Project Report covering Airport Geodetic Control Station surveys; see Section 10.1.

**11.9 ADJUSTMENT AND CHECKING PROGRAMS** - Submit all ADJUST and checking programs input and output files in accordance with Attachment 17 (a paper copy of COMPGB, NEWCHKOB, OBSCHK, OBSDES, CHKDESC, BBACCUR, ELLACC and all ADJUST files). Also, submit the digital data sheet or coordinate file for stations used for fixed control during the adjustment (CORS log/coordinate sheets, NGS data sheet for HARN and bench mark coordinates, etc.). Submit paper copies of the coordinate sheet for all CORS and CTCORS stations used during vector processing. Submit the spreadsheets used and/or INVERSE3D program output files used for comparing published coordinates with their adjusted coordinates.

**11.10 ORIGINAL DATA** - Submit all the original, raw data, RINEX data, precise ephemeris, and PAGE-NT files in accordance with Attachment 16. Include the CORS RINEX data files used for processing. For all RAW and RINEX data files not named by their occupied station four character ID, submit an index of station names to RAW and RINEX file. Submit a detailed directory tree listing, on paper, to be used as an index for locating all processing, adjustment, and supporting files that are submitted in digital format. Do not list the individual files within the PAGE-NT vector processing directory for each session or the files in the RAW and RINEX data directories; Just provide a summary explanation of the files to be found in these type directories. Submit any other digital files required by these General Specifications, or requested by NGS that

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were not submitted.

**11.11 DESCRIPTIONS** - Submit the finalized description file from the NGS WDDPROC software. Submit both paper and digital formats. This includes the recovery notes submitted with the Survey Plan and the final version of the descriptions of new marks, written after the marks are set. Note, descriptions and recovery notes should be written by one person and checked, in the field, by another.

**11.12 TRANSMITTAL LETTER** - For all hardcopy data being sent via express mail, regular mail, etc., prepare a transmittal letter listing all items being sent. Include a copy of the transmittal letter within the data package and send a second copy to the receiving office via FAX or email. The receiving office will check the data package against the letter, sign and date it, and FAX it back to the sender. Be sure to include the prime contractor=s firm name on all transmittals and communications. See sample Transmittal Letters in Attachment 23.