General Specifications for Aeronautical Surveys

Volume I.
Establishment of Geodetic Control on Airports

First Edition, June 2000

http://www.ngs.noaa.gov/AERO/aero.html

Federal Aviation Administration

National Oceanic and Atmospheric Administration

National Geodetic Survey

TABLE OF CONTENTS

SUBJECT PAGE

1.0 INTRODUCTION 1

2.0 RECONNAISSANCE REQUIREMENTS 2
- 2.1 Station Descriptions in the NGS Data Base 2
- 2.2 Contact with Airport Authorities 2
- 2.3 Reconnaissance of Existing Marks 3
- 2.4 PACS and SACS Selection Guidelines 4
  - 2.4.1 Use of Existing Marks For PACS and SACS .. 4
  - 2.4.2 PACS and SACS Stability 5
  - 2.4.3 Proximity to Airport Features 5
  - 2.4.4 GPS Satellite Visibility 6
  - 2.4.5 Use of Marks Set by Other Agencies 6
  - 2.4.6 Marks on Private Property 6
  - 2.4.7 Damaged Survey Marks 6
  - 2.4.8 Approval of Proposed Sites for New Marks. 7
- 2.5 National Spatial Reference System (NSRS) Ties ... 7
- 2.6 Photographs 7
- 2.7 Station Location Sketch and Visibility Diagram .. 8
- 2.8 Station Descriptions 9
- 2.9 Reconnaissance Report and GPS Observation Plan .. 9

3.0 SETTING NEW MONUMENTS 11
- 3.1 Stamping 11
- 3.2 Bronze Disks 12
- 3.3 Stainless Steel Rod Marks 12
- 3.4 Concrete Marks 13
- 3.5 Mark Setting Materials 13
- 3.6 Witness Posts 13

4.0 GPS OBSERVATIONS 14
- 4.1 CORS Selection 14
- 4.2 CTCORS Selection 14
- 4.3 GPS Observation Requirements 15
  - 4.3.1 CTCORS 15
  - 4.3.2 PACS and HARN Tie 16
  - 4.3.3 SACS 17
  - 4.3.4 Bench Mark Ties 17
- 4.4 GPS Occupation at all survey stations 19
  - 4.4.1 Antenna Set-up 19
  - 4.4.2 Epoch Interval / Elevation Mask 19
  - 4.4.3 Station Rubbings 19
  - 4.4.4 Weather Data 19
  - 4.4.5 Observation Logs 20
- 4.5 Accuracy Standards 20
- 4.6 Recommended Equipment 20

5.0 VECTOR PROCESSING.....22
5.1 CORS to CORS Vectors.....23
5.2 CORS to CTCORS Vectors.....24
5.3 PACS, SACS, and NSRS Tie Vectors.....24

6.0 ADJUSTMENT PROCESSING.....27

7.0 FINAL PROJECT REPORT AND DIGITAL DATA SUBMISSION.....31

GLOSSARY 34

ATTACHMENTS

ATTACHMENT 1 – “Know These Markers” Pamplhet

ATTACHMENT 2 - *FBN Station Selection Guidelines*

ATTACHMENT 3 – Example Reconnaissance Photographs of Stations

ATTACHMENT 4 – Station Location Sketch and Visibility Diagram

ATTACHMENT 5 – Writing Station Descriptions with DDPROC

ATTACHMENT 6 – Example Airport Reconnaissance Station Table

ATTACHMENT 7 - Setting a Concrete Monument

ATTACHMENT 8 - Setting a Disk in Rock Outcrop or Structure

ATTACHMENT 9 - Setting a NGS 3-D Monument, List of Mark Setting Materials

ATTACHMENT 10 - Photographic Documentation of Setting a NGS 3-D Monument

ATTACHMENT 11 – Simplified Diagrams of GPS Positioning Requirements

ATTACHMENT 12 – Example GPS Observation Scheme

ATTACHMENT 13 – GPS Observation Log, Pencil Rubbing Form

ATTACHMENT 14 - GPS Antenna Height Measuring Instructions

ATTACHMENT 15 – Information, Data, and Software available on the World Wide Web

ATTACHMENT 16 – Outline for Processing Airport Geodetic Control Surveys with PAGE-NT

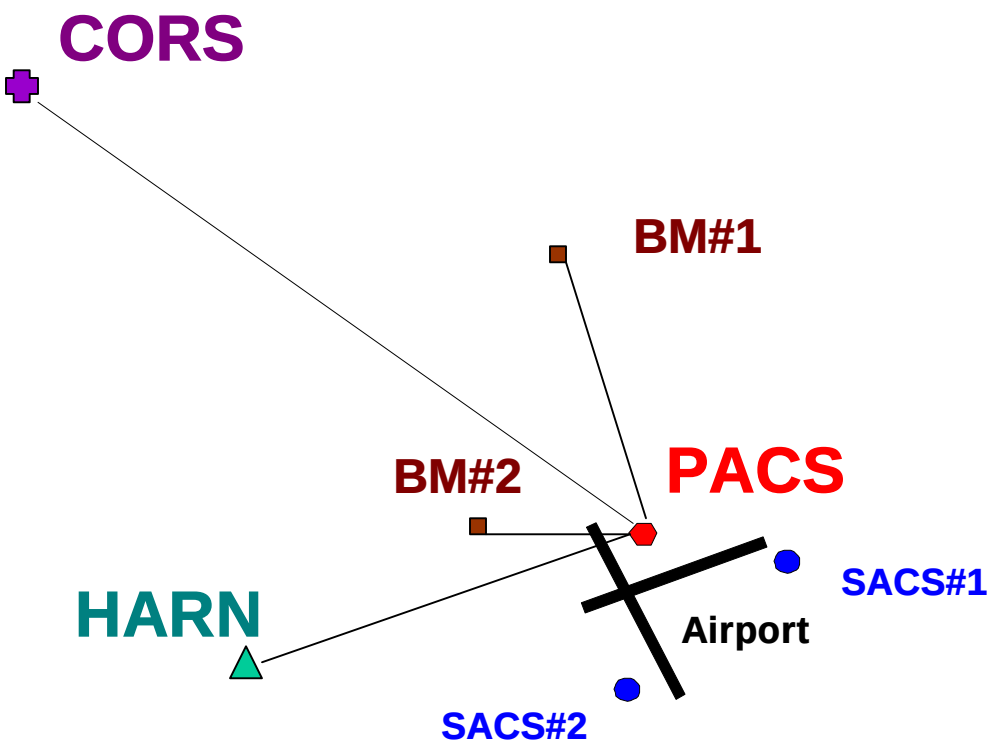
ATTACHMENT 17 – Outline for Adjusting GPS data for Airport Geodetic Control Surveys

ATTACHMENT 18 – Example Coordinate Comparison Spreadsheet

1.0 INTRODUCTION:

The National Geodetic Survey (NGS), in accordance with interagency agreements with the Federal Aviation Administration (FAA), provides geodetic control at airports selected throughout the United States for GPS Area Navigation Approach (ANA) procedure development. 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 National Spatial Reference System (NSRS) and will be used to support high accuracy surveys of airport features and obstructions. These General Specifications provide the requirements for performing the geodetic control phase for these surveys.

FAA No. 405, Fourth Edition, September 1996, Appendices 3 and 5 provides general guidance concerning PACS and SACS, including accuracy requirements, with more detailed information in this document. Any exception or deviation from these documents must be stated in writing in the Reconnaissance Report and/or Final Report, depending on timing. Recommendations to exceed or deviate will be considered if written justification is provided.



Airport Geodetic Control Network

2.0 RECONNAISSANCE REQUIREMENTS:

Reconnaissance activities for each survey will include the following: Review of station descriptions in the NGS Data Base; interviews with airport management; recovery of all survey monuments on the airport; selection of PACS, SACS, and NSRS ties; preparation of required descriptions, sketches, photographs, and other documentation; and compilation of a reconnaissance report.

2.1 STATION DESCRIPTIONS IN THE NGS DATABASE:

The contractor is responsible for reviewing NGS data sheets for existing control on and around the airport prior to performing the field reconnaissance. The review will be used to form a list of control to be recovered on the airport, and a priority list of High Accuracy Reference Network (HARN) stations and Bench Marks to be recovered as NSRS ties.

USC&GS (U.S. Coast & Geodetic Survey) and NGS monument descriptions are contained in the NGS data base, are published on CD-ROM, and are available via the NGS web site (http://www.ngs.noaa.gov) by selecting the red "Data Sheets" link. A database search of all marks within a short distance of the airport location will reveal USC&GS and NGS marks. This type of search can be performed via the "Data Sheet" web page or by using an NGS Data Sheet CD-ROM. Note, the CD-ROMs for each region are only updated once per year.

Some National Ocean Service (NOS) or Calibration Baseline (CBL) descriptions for stations on airports are classified in the NGS database as non-publishable until new positions are determined. When non-publishable, the descriptions will not be available through the NGS Home Page and will not be published on NGS CD-ROMs. NGS will supply these descriptions on floppy disk for each project.

2.2 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 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 reconnaissance report. Present the Aeronautical Survey Program Brochure and/or Letter to the Airport Manager, explain the survey work that will be performed, and describe the purpose of the PACS and SACS. Discuss optimal locations for the practical use and survivability of the monuments and finalize the PACS and SACS monument 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.

2.3 RECONNAISSANCE OF EXISTING MARKS:

All USC&GS (U.S. Coast & Geodetic Survey), NGS (National Geodetic Survey), and NOS (National Ocean Survey or National Ocean Service) monuments at the airport shall be recovered, including writing or updating descriptions as required. See ATTACHMENT 1, for diagrams of these survey disks. All required High Accuracy Reference Network (HARN) stations and Bench Marks (BM) will also be recovered.

Full, three paragraph, NGS-format station descriptions must be written or revised for stations recovered that are determined to be ANA suitable. ANA suitable stations are defined as a survey disk, rod, or similar type monument, meeting at least a stability code of “C”, considered suitable for GPS observations, and recovered in good condition. Photographs and station location sketches as described in this document are required for all ANA suitable stations recovered. Plot all ANA suitable stations on the airport layout diagram.

Stations recovered that are determined NOT to be ANA suitable will be noted as such in the digital recovery note for that station. A full, three paragraph description is NOT required for these stations. A recovery note which states the reason why the station is NOT ANA suitable, the condition of the mark, and providing any updates to the “to reach” description IS required. Photographs and station location sketches are NOT required for these stations.

See section 2.8 and ATTACHMENT 5 for detailed information on writing digital station descriptions and recovery notes. A complete, correctly formatted, digital D-FILE from NGS DDPROC software shall be submitted with the final report. This D-FILE shall include updated descriptions or recovery notes for all stations recovered during the project, and shall correlate with the adjustment B-FILE and G-FILE. The contractor shall provide

draft station descriptions as requested by NGS for quality control purposes.

2.4 PACS and SACS SELECTION GUIDELINES:
Proper monument site selection for PACS and SACS is a primary goal for these surveys and must be carefully considered. FAA No. 405, Appendix 3, provides control station siting guidelines. NGS shall review all contractor recommended PACS, SACS, and NSRS tie station selections for approval.

Factors to consider are monument stability, intervisibility requirements, visibility from the monuments to airport features such as runways, navigation aids, and airport obstructions off the end of runways, any previous high accuracy connection to the National Spatial Reference System (NSRS), accessibility, and survivability of the monuments. The monuments must be accessible to survey crews, and allow for unattended, secure setup of GPS equipment for long periods without hindering airport operations. PACS and SACS must allow for setup of both conventional (optical) and satellite surveying equipment. If possible, SACS should be sited on high ground near the approach end of the primary runways so they can be better utilized for obstruction surveys. Monuments must be established in areas clear of future construction, and should be slightly recessed to protect them from snow removal and mowing equipment.

Minimum requirements, as listed in FAA No. 405, Fourth Edition, must be met. Also, see ATTACHMENT 2, *Federal Base Network Station Selection Guidelines* for additional guidelines.

2.4.1 Use of Existing Marks for PACS and SACS:
An extensive effort should be made to recover existing survey marks. 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 must be thoroughly checked to confirm the station's identity, stability, and location, and to provide input for an updated description. Stamping will 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 Reconnaissance Report.

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 Reconnaissance Report.

2.4.2 PACS and SACS Stability:

PACS - An existing mark may be used as a PACS if the mark meets the stability quality codes of A or B in that order of preference, as defined in ATTACHMENT 2, *Federal Base Network Station Selection Guidelines*.

In addition, an existing concrete mark with stability code C (and 4+ feet deep, belled bottom) may be used for a PACS if the disk is a pre-stamped USC&GS or NGS mark and it meets all siting, construction, and intervisibility requirements.

Note, an existing HARN station ("A" or "B" order station) does not necessarily qualify to be a PACS, it must still meet PACS stability and siting requirements.

SACS - Other USC&GS, NGS, or NOS marks should be used as SACS if they meet all siting, construction, and intervisibility requirements.

Concrete Monuments- The DDPROC (description software) default code for a concrete monument set in an irregular mass of concrete is the stability code "D." If a monument, such as a NGS calibration base line (CBL) monument (normally "C" stability), is classified as a code "D" and appears to be better than a "D," contact NGS with a recommendation. Note, a "tile probe" (long steel rod) may be used to help determine the underground extent of a concrete monument. CBL locations and data are available on the NGS WWW Home Page, under "PRODUCTS & SERVICES". Note, most CBL descriptions are not in the NGS database, but can be provided by NGS.

2.4.3 PACS and SACS Proximity to Airport Features:

PACS and SACS siting requirements are listed in FAA No. 405, Appendix 3. PACS and SACS should be established in a secure area on airport property. If establishing the PACS and SACS requires new monumentation, the new monuments should be set no closer than 60 meters from a runway edge, or 60 meters from the imaginary runway extension. If an existing control station is used, the station should be at least 15 meters from a runway edge. PACS

and/or SACS should be at least 400 meters apart, and in locations that will not interfere with airport operations, including propeller and jet blast. The monuments must not be within 305 meters (1000 ft) of the critical side of an:

Instrument Landing System (ILS) Glideslope Antenna,
Instrument Landing System (ILS) Localizer,
Microwave Landing System Elevation Station,
Microwave Landing System Azimuth Station.

2.4.4 GPS Satellite Visibility:
The GPS satellite visibility should be minimally restricted from 20 degrees above the horizon to the zenith, in all directions. Minor obstructions are acceptable, but must be depicted on the Visibility Obstruction Diagram. 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, but set a mark at least 2 meters from the pole, to the south if possible. Likewise, 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.

2.4.5 Use of Marks Set by Other Agencies:
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.

2.4.6 Marks on Private Property:
Before using a mark on private property, owners must be contacted to request permission. Take care to return 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 agrees to have the information included in the description.

2.4.7 Damaged Survey Marks:
Metal disks which have been moved or defaced so that they can no longer serve as survey marks are to be removed, have updated descriptions written describing the mark as destroyed, and the disk sent to NGS. A mark will not be described as destroyed unless the disk is found and returned to NGS. State the number of person-hours spent searching for a mark that is reported as "not found."

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 should be described completely in the updated recovery description. Care must 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 a vandal from prying the disk from its location.

For all marks used in this survey, perform mark maintenance as required, 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 log cap lid, and exposed edge of concrete monument.

2.4.8 Approval of Proposed Sites for New Marks:
Proposed sites for new PACS and SACS must be approved by NGS prior to setting the marks. NGS may approve station selections based on preliminary reconnaissance reports to facilitate efficient field operations. New PACS and SACS should only be set if no existing mark can meet the requirements. See section 3.0, ASetting New Marks@, for mark setting guidelines.

2.5 NATIONAL SPATIAL REFERENCE SYSTEM (NSRS) TIES:

Each PACS must be tied to at least one “A” or “B” order High Accuracy Reference Network (HARN) station and two First or Second order North American Vertical Datum (NAVD) bench mark stations. The stations selected for these ties must be recovered during the field reconnaissance. Details for selecting and positioning the PACS (and CTCORS) ties are listed in section 4.3 “GPS OBSERVATION REQUIREMENTS.” All reconnaissance deliverables required for “ANA Suitable” stations are also required for the NSRS ties.

2.6 PHOTOGRAPHS:

Existing Monuments- Two photographs shall be taken of all ANA suitable monuments recovered during the survey. To show the condition of the monument, clear the brush, grass, and dirt from the concrete or rock surface area of the monument and clean the disk or logo cap with a whisk broom or wire brush before taking the photographs.

The first photograph will show the monument from directly above and cover an area about 1 meter in diameter. If it is a rod mark, the logo cap should be open. Include a small sign in this photograph with the station designation written so it is clearly visible in the photograph.

The second photograph will show the mark in the foreground, and its identifying surroundings and any unusual obstructions in the background. Place a sign in each photograph with the name (or identifier) of the airport, the station designation and PID, compass orientation, station type (i.e. PACS, SACS, etc.), and date. See ATTACHMENT 3 for examples of the required photographs.

Submit both a color paper copy and digital copy of each photograph to NGS. The project instructions will specify the format and file naming convention to be used for the digital photographs. The photographs shall be included in the Reconnaissance Report and may be published on the NGS web site as a link for each station's data sheet.

New Monuments- Submit the second photograph as described above for proposed monument locations. Mark the monument location with a tool or lath if possible and include the sign as described above. When the monument is being set, take an additional photograph of the empty hole before pouring the concrete. Place a rod staff or other rigid measuring device in the hole to indicate the depth of the hole. Take the picture from near directly above the hole to show as much of the shape of the hole and the soil structure that will be surrounding the monument as possible. Label each photograph with the station name and submit in digital form (no paper copy required). When the monument is complete, take and submit a overhead view photograph as described for Existing Monuments above.

2.7 STATION LOCATION SKETCH AND VISIBILITY DIAGRAM:

Submit a station location sketch and visibility diagram for all ANA suitable stations recovered during the survey, and for all new monuments that will be set (See ATTACHMENT 4). The location sketch should show the monument in 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 must be neatly and accurately completed. Submit both the paper copy and a scanned digital copy to NGS. The project instructions will specify the format and file naming convention to be used for the digital graphic files. Graphic files must be reduced to a size that will print clearly and completely on one page when viewed and printed from a standard web browser. The digital graphic of the completed form will be published in the NGS data base as a data sheet link for each station.

2.8 STATION DESCRIPTIONS:

NGS-style station descriptions or recovery notes shall be written for all marks set, searched for, recovered, or occupied during the survey. The descriptions and recovery notes will be submitted in digital (D-file) format in accordance with chapter 3, vol. I, of AInput Formats and Specifications for the NGS Data Base@ (Blue book). (The Blue Book is available on the NGS web site http://www.ngs.noaa.gov/FGCS/BlueBook/) Hard Copy of the Blue Book can be obtained from NGS Information Services Branch (301) 713-3242. The latest version of NGS DDPROC software should be used to write the descriptions in the proper D-file format. Standard NGS format will be used for all descriptions. See ATTACHMENT 5 for detailed information on writing station descriptions and examples of descriptions in D-file format.

2.9 RECONNAISSANCE REPORT and GPS OBSERVATION PLAN:

A reconnaissance report and GPS observation plan shall be submitted to NGS for review prior to field observations. This report(s) may be submitted at intervals during the reconnaissance. NGS will respond with an approval or comment letter as soon as possible, normally within 5 working days. GPS observation requirements are detailed in Section 4.

The station designation (name) and PID (Permanent Identifier), exactly as listed in the NGS data base, must be used in all survey records.

The reconnaissance report will include the following information:

- 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 on deviations from these General Specifications. The Airport Summary Report can be combined with the Station Table described below.

- Station Table - For each airport submit a table which lists Station Name, PID Number, Establishing Agency, Order, Stability, Condition at Recovery, and Comments for each station. List proposed name and monument type of any new stations to be set. 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.

- Airport Control Plot - Plot all “ANA suitable” control that is on or near each airport on an airport map. Label each station with it’s 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.

- Photographs – Submit photographs in accordance with section 2.6 for all ANA suitable stations recovered during the survey, and for all new monuments that will be set.

- Station Location Sketch and Visibility Diagrams - Submit for all ANA suitable stations recovered during the survey, and for all new monuments that will be set (See section 2.7).

- Station Descriptions - Submit Recovery Notes or Descriptions for existing marks. Encode the descriptions using DDPROC software. Note, these descriptions should be reviewed and corrected by GPS observers when they travel to marks. See section 2.8 and ATTACHMENT 5 for details on writing station descriptions.

- GPS observing scheme - 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.

- Project Vector Diagram - Depict entire project area (state) with 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.

- Proposed instrumentation list – Tabulate the brand and model numbers of GPS equipment.

- Data Processing Software – Specify software name and version for the software used. Ensure that the current version of all software is used.

3.0 SETTING NEW MONUMENTS:

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 must 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 will be monumented in accordance with the following criteria: in paragraphs below, in attachments to this document, and in 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 must meet stability code A or B requirements as defined in ATTACHMENT 2, *FBN Station Selection Guidelines*. New rod marks must meet the "Quality Code B" requirements found in ATTACHMENT 9 and *Geodetic Bench Marks.*

SACS - New SACS must meet stability code A, B, or C requirements as defined in ATTACHMENT 2, *FBN Station Selection Guidelines*. Bronze disks set in rock outcrops, massive structures, or as concrete monuments will be used for new SACS.

Submit updated photographs, descriptions, and sketches of the new stations to update the Reconnaissance Report.

3.1 STAMPING:

New PACS and SACS will have a unique stamping. Marks set at a site 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" should be stamped before they are set in place.

3.2 BRONZE DISKS:

Standard NGS bronze, horizontal disks will be used for rock outcrop, massive structure, and concrete marks. A rock outcrop in which a disk is set must be hard and a part of the main ledge and NOT a detached fragment. A disk set in a drill hole must be well counter-sunk and adequately fixed in place using highway epoxy or equivalent. The disks must be fastened so that they will effectively resist: extraction, change of elevation, or rotation. Disks must 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 scrap 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. NGS will supply the standard (3.6 inch diameter) bronze disks with pre-stamped NGS logo. For detailed instructions on setting bronze disks, see Section 3.4, ATTACHMENT 7 and ATTACHMENT 8.

3.3 STAINLESS STEEL ROD MARKS:

A NGS 3-D rod mark meeting quality code "B" for stability, may be set for PACS. A 1 meter long, grease filled, finned sleeve will be used with this mark. Instructions are in ATTACHMENT 9, ASETTING A NGS 3-D MONUMENT.@ See also, ATTACHMENT 10, "PHOTOGRAPHIC DOCUMENTATION OF SETTING A NGS 3-D GEODETIC CONTROL MONUMENT." Standard NGS aluminum protective covers ("logo caps") will be used over rod marks. NGS will supply stainless steel rod sections, including studs and driving points. Pre-manufactured datum points will not be used. Survey disks will not be affixed to stainless steel rods.

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.

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 must be brushed or washed off thoroughly. Install a standard concrete

monument with brass disk. See ATTACHMENT 7.

3.4 CONCRETE MARKS:

New concrete marks, with standard NGS bronze disks, may be used for SACS only. Construction requirements are in ATTACHMENT 7, ASETTING A CONCRETE MONUMENT.@ 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 will be centered in the top of the concrete surface, will be flush or slightly recessed with the surface of the concrete, and the top of the disk will be free of concrete. A round form will be used for the top of all concrete marks and 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) can be used to easily construct a form. All loose concrete and other debris around the construction site must be removed and the site left in excellent condition.

3.5 MARK SETTING MATERIALS:

A listing of mark setting materials can be found in ATTACHMENT 9. All NGS supplied materials will be specified in the project instructions. NGS will generally provide the stainless steel rod, threaded studs, logo caps, brass disks, and witness posts. NGS inscribed materials, including: disks, protective covers (logo caps), and witness posts, etc. shall not be used outside the scope of this project.

3.6 WITNESS POSTS:

Placement of witness posts on airport property must 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. All witness posts set must contain the standard NGS witness post logo.

4.0 GPS OBSERVATIONS:

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

4.1 CORS SELECTION:

The CORS sites selected must 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. If a PACS is not within 300km of a CORS, a CTCORS must 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 must 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. The disk names and positions must not be confused with the antenna names and positions.

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

4.2 CTCORS SELECTION:

A Central Temporary Continuously Operating Reference Station (CTCORS) must be used if the nearest CORS is more than 300 km from the PACS. The CTCORS will be established by setting up a GPS receiver on a suitable existing horizontal NSRS station, and will provide the CORS function in the positioning of the PACS. The position of the CTCORS will be verified by using the GPS observation requirements in section 4.3.1. 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 must be approved by NGS prior to commencing field observations.

PRIORITY	TYPE OF STATION	STATION IS BENCH MARK	STATION IS AT AIRPORT
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)

4.3 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. Likewise for 1.5 hour sessions. Separate tripod set-ups are required for each session.

4.3.1 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 will be used as a check at the end of the project. If the distance between the CORS and CTCORS is greater than 300 km,

contact NGS for guidance on increasing the length of observation sessions. All CTCORS will 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.

4.3.2 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 must be performed simultaneously with the CORS observations. The start time of one PACS observing session should be at least 2.5 hours different than the second PACS session to incorporate different satellite geometry.

- All PACS must have a separate positional check by simultaneously observing at least one session of 4 hours or more in length with a "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 must 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 must check within 3cm. The final adjusted positions of the HARN ties should check within 5 cm horizontal and 10 cm ellipsoidal height with their published positions.

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

- These observations will 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 3cm.

4.3.4 Bench Mark Ties:

- Ties to two separate NSRS NAVD 88 bench marks are required for each PACS and CTCORS station. The ties will 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.

- Bench mark ties will 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 must 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 must 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 reconnaissance report. 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 must 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 will be submitted in "Blue Book" format on floppy disks 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.

- 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. These elevations (National Geodetic Vertical Datum of 1929 (NGVD 29)) are listed on the NOS paper description form as a Mean Sea Level (MSL) elevation, in feet. For the AOC airports that have been entered into the NGS database by headquarters, 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.

4.4 GPS OCCUPATION AT ALL SURVEY STATIONS:
GPS observations will be performed using FGCS approved dual frequency GPS receivers. Fixed height tripods will be used whenever practical. Separate tripod set ups are required for each occupation of a station. 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/ADVISORS/FBN/GPSmanual/).

Follow the additional guidance below:

4.4.1 Antenna Set-up:
GPS antenna setups must be done independently for each session. The word "independent" means separate tripod setups, separate height determinations, and separate solutions. The HI must be measured in both meters and feet, unless a fixed-height tripod is used. See ATTACHMENT 14, "GPS Antenna Height Measuring Instructions." Minimize the mixing of GPS receiver and antenna types used for observations. Record the manufacturer, model name, and part number of the antenna on the field log.

4.4.2 Epoch Interval / Elevation Mask:
GPS data will 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.

4.4.3 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 must be substituted, accurately and legibly recording all markings. This photograph, if used, is in addition to the photographs required in the Reconnaissance Report, and the stamping must be readable in this photograph.

4.4.4 Weather Data:
Before taking weather observations, the meteorological instruments should be allowed ample time (approximately 10 minutes) to stabilize to ambient conditions. Observations of wet-bulb and dry-bulb temperatures must be observed and recorded to the nearest 1 degree Celsius. Barometric readings must be observed and recorded to the nearest millibar (or English equivalent). Meteorological data should be collected at each station at the beginning, middle, and end of each session. Meteorological data should also be collected to delineate unusual weather events, such as sudden changes in temperature or pressure, and immediately after an obvious weather front passes during a session and immediately before it passes, if possible. Perform temperature, relative humidity, and pressure measurements near and about the same height as the antenna phase center. All

antenna height and weather measurements are to be recorded in raw form, and all field calculations should be independently checked. Unusual weather conditions, such as passing fronts and storms, are to be noted on the observation log. Meteorological instruments must be compared against a known standard before and after each project. Note, severe weather may degrade GPS data.

4.4.5 Observation Logs:

- An observation log must 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 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.

4.5 ACCURACY STANDARDS:
See FAA No. 405, Fourth Edition, Appendix 5.

4.6 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.

- Must 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.

5.0 VECTOR PROCESSING:

Vector processing will 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
5-15km	Better of L1 Fixed and Ion-Free Fixed
15-100km	Ion-Free Fixed
100+km	Ion-Free Fixed or Partially Fixed

- IGS precise orbit data and NGS National CORS data must 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 will be used for all vector reductions.** Information about ITRF is available on the NGS WWW Home Page, under "PRODUCTS SERVICES". The current ITRF epoch must 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:

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 3cm.

- Submit all files and printouts as required in ATTACHMENT 16.

5.1 CORS to CORS VECTORS:
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 will be processed between the CORS stations to form an interconnecting network. See section 4.1 for more information on CORS data.

5.2 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, must 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 will need to be included in the error budget for the PACS. The last session at the CTCORS will be used to again check the position of the CTCORS relative to the CORS.

5.3 PACS, SACS, and NSRS TIE VECTORS:

The sequential order of vector processing is listed below. The selection of either L1 or Ion-Free for the final solution type is based on vector lengths. See the Solution Type Determination Table (Section 5.0) for guidance when grouping vectors together for a processing session.

Discuss the plan for processing any “shared” HARN and bench mark ties with NGS. 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. The PACS observed simultaneously with the HARN to “share” the tie will be tied to it indirectly in the group adjustment. Separate processing sessions from the 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. A second nearby PACS that was observed simultaneously to “share” the HARN tie will be tied to it indirectly in the group adjustment. A separate processing session from the second PACS to the HARN is not required.

- Shared bench mark ties should be processed to their closest PACS. The second, simultaneously observed, PACS will 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:. 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 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 sessions. 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. The PACS may need to be reprocessed or reobserved.

Note, Steps 4-7 must be completed individually for each airport (Each PACS must be the reference station for its respective SACS, etc.).

Step 4 - Process the first PACS to (HARN and/or BM) session using the PACS as the reference station and using the mean ITRF position calculated in step 3. Include stations for this airport that are over about 5km from the PACS. BM or HARN stations that are less than 5km from the PACS will be processed in a separate L1 session. The frequency of the final solutions is based on the length of the vectors. Use the Final Solution Type Determination Table for guidance on grouping vectors together for processing.

Step 5 - Process the second PACS session, as above.

Step 6 - Process the first PACS to SACS session using the PACS as the reference station and using the mean ITRF position calculated in step 3. BM=s and HARN stations that are within 5km of the PACS may be included in these sessions. Process these short lines using the L1 frequency only.

Step 7 - Process the second session SACS data as above.

Step 8 – Compare the ITRF coordinates of all repeat baselines and NSRS ties that were occupied more than once. Include this comparison on the same spreadsheet used for the PACS comparison. Investigate any station coordinate comparisons that do not agree within 3cm (if vectors are from the same reference station) or 5cm (if vectors are from different reference stations).

6.0 ADJUSTMENT PROCESSING:

All airports in a project area should be adjusted together, or the area can be subdivided into groups of airports which are located close together and share tie stations (CORS, BM, HARN). Airports can be adjusted individually only if approved by NGS. Discuss an adjustment plan with NGS prior to running the adjustment.

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.

Six adjustments are required: (1) free, (2) constrained with only CORS or CTCORS held, (3) constrained with CORS or CTCORS and HARN stations held, (4) a final free with accuracies, (5) a free vertical holding one bench mark in the center of the project, and (6) a fully constrained vertical (with all approved bench marks held).

- ADJUST's 'Mean Absolute Residual' statistics (from Adjustment #1) must not exceed 2.0 cm in NORTH or in EAST, and must not exceed 5.0 cm in UP.

- ADJUST's maximum residual (from Adjustment #1) should not exceed 3.0 cm and must 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 rejecting the vector should be included in the Final Report.

- HARN ties to "A" or "B" order stations 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 ellipsoidal heights should agree within 10 cm and bench mark orthometric heights 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 will be run in three dimensions. Do NOT scale the gfile for ANA geodetic control projects. Ensure all input files are complete and free of format errors by utilizing the checking programs. *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. 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 3cm 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.

ADJUSTMENT TWO- A fully constrained horizontal adjustment to determine new NAD 83 coordinates. Constrain the NAD 83 coordinates (latitude, longitude, ellipsoid height) of all CORS or CTCORS stations used in processing. This adjustment would be run in a similar fashion to the free, except for holding any additional CORS or CTCORS stations fixed which might have been used in the project.

NGS will determine if all the PACS are to be positioned relative to the published or newly computed coordinates of the CTCORS, on a project-by-project basis.

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. Submit all comparisons with the final report.

ADJUSTMENT THREE- A supplemental, horizontally constrained adjustment holding all CORS and HARN stations fixed for NGS use in deciding on the final constraints. Submit the results of this adjustment, but use the results of the previous adjustment (holding all CORS stations only) for the final files and for computing accuracies.

ADJUSTMENT FOUR- A minimally constrained free adjustment to determine the length 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 l:100,000. PACS will 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 must 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 must be edited into the *86* records of the final B-file. The value chosen should be that of the majority of the lines and will be used for all stations.

ADJUSTMENT FIVE- 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.

ADJUSTMENT SIX- 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. 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 must contain the positions and ellipsoidal heights derived from the final constrained adjustment (ADJUSTMENT TWO) and the orthometric elevations from the final vertical adjustment (ADJUSTMENT SIX). Program ELEVUP can be used to easily combine the files. The B-file must satisfactorily run through the required checking programs.

7.0 FINAL PROJECT REPORT and DIGITAL DATA SUBMISSION:

A final project report detailing the GPS observations, vector processing, and adjustment shall be submitted to NGS. This report is in addition to the Reconnaissance Report that is described in Section 2.9. Photographs, updated sketches, descriptions, and other information concerning mark setting performed for the project must be submitted separately as a supplement to the Reconnaissance Report.

General guidance for project reports and 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).

The **Project Report** shall contain at least the following:

- An overview discussion of the field work, data processing, and adjustment performed. This discussion should include a summary of the results, problems encountered, and any unusual circumstances or deviations from the requirements in the Project Instructions or these General Specifications. Include comments on any deviations from the Reconnaissance Report.

- A listing of personnel who worked in the field or were involved with the data processing for this project.

- A listing of the brand, model number, and serial number for all the GPS receivers and antennas used in the project. List the quantity, brand, and type of tripods used. Include any instrumentation used for differential leveling.

- A listing of all software, including version, used during the project for RINEX conversion, vector processing, adjustment, and verification (all checking programs).

- 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.

- A final Project Vector Diagram. Update the vector diagram submitted with the Reconnaissance Report (see Section 2.9). Submit only the large size plot. Discuss the final layout with NGS. Include processing session designations on the vectors if feasible. Show indirect ties to “shared” HARN stations and bench marks.

- Submit the original copy of all field logs (Observation logs, Pencil Rubbing forms, updated Station Location Sketch and Visibility Diagrams).

- A 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. 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.

- 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.

- Submit paper copies of the COMBINED.SUM files for any processing sessions that were difficult to process or produced questionable results. Submit paper copies of any other files requested by NGS for quality control.

- Submit paper copies of the coordinate sheet for all CORS and CTCORS stations used during vector processing.

- Submit a detailed description of the project adjustment. Discuss each of the adjustments separately, including points held and the source of the position or 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 6).

- Submit a paper copy of the output for programs COMPGB, NEWCHKOB, OBSCHK, OBSDES, CHKDESC, BBACCUR and ELLACC. Submit any other paper copies of adjust files requested by NGS for quality control.

- 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.

- If the RAW and RINEX data files are not named by their occupied station 4 character ID, submit an index of station name to RAW and RINEX file name.

- Submit a transmittal letter listing all items submitted to NGS with the project report.

Digital data should be submitted on CD-ROM or IOMEGA ZIP disks. The following digital files shall be submitted:

PAGE-NT files-

- Submit all the raw data, RINEX data, precise ephemeris, and PAGE-NT files in accordance with ATTACHMENT 16. Include the CORS RINEX data files used for processing.
- Submit the spreadsheets used for comparing the vector processing results (see Section 5).

ADJUST files-

- Submit all ADJUST and checking programs input and output files in accordance with ATTACHMENT 17.
- Submit the spreadsheets used and/or INVERSE3D program output files used for comparing published coordinates with their adjusted coordinates.
- 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.).

Other Digital Files-

- Submit the finalized description file (D-file and .ha format) from the NGS DDPROC software.
- Submit any other digital files required by the Project Instructions, these General Specifications, or requested by NGS that were not submitted previous to this report.

GLOSSARY

(For an additional glossary of terms, see FAA No. 405, Fourth Edition.)

ANA - Area Navigation Approach

ASAP - As Soon As Possible

AZ MK - Azimuth Mark: A marked point established in connection with a triangulation (or traverse) station to provide a starting azimuth for dependent surveys. Note, some azimuth marks also were positioned and some have an underground disk. The azimuth mark is usually a pre-stamped survey disk, generally 1/4 to 2 miles from the horizontal station. The next consecutive azimuth mark number was used if an earlier number was destroyed. See ATTACHMENT 1.

BM - Bench Mark

CD-ROM - Compact Disc - Read Only Memory

CBN - Cooperative Base Network (NGS)

CTCORS - Central Temporary Continuously Operating Reference Station. A permanently monumented control station established near the center of a 300 km (radius) survey area (as defined elsewhere in this document) and which functions as a temporary Continuously Operating Reference Station (CORS).

CORS - Continuously Operating Reference Station, See FAA No. 405, Fourth Edition, Glossary.

DISK - A thin metal plate about 9 cm in diameter, with a stem attached to the center of the bottom. The plate is slightly convex (in vertical), usually round (in horizontal) and contains the mark for which survey information is known, or to be determined. The plate usually also contains a designation, year, and the name of the agency setting the plate. It is usually made of bronze, brass, or aluminum and may be set in a drill hole or embedded in concrete.

DOD - Department of Defense

FAA - Federal Aviation Administration

FBN - Federal Base Network (NGS)

FGCC - Federal Geodetic Control Committee (Changed to FGCS in October 1990)

FGCS - Federal Geodetic Control Subcommittee

GPS - Global Positioning System

HARN - High Accuracy Reference Network

ITRF - International Terrestrial Reference Frame

MARK - (1) A dot, the intersection of a pair of crossed lines, or any other physical point corresponding to a point in a survey; (2) The object, such as a disk, on which the mark (1) is placed; (3) The entire monument, consisting of the mark (1), the object on which it occurs (2) and the structure to which the object is fastened.

MONUMENT - A structure that marks the location of a point determined by surveying. In the case of a disk in concrete, the monument would be the entire structure. Mark, monument, and station can mean the same thing.

NAD 27 - North American Datum of 1927

NAD 83 - North American Datum of 1983

NAVD 88 - North American Vertical Datum of 1988

NGS - National Geodetic Survey, NOAA. Disks inscribed with this name have been set from 1970 to the present.

NGVD 29 - National Geodetic Vertical Datum of 1929

NOAA - National Oceanic and Atmospheric Administration. No survey disks have been set with this name.

NOS - National Ocean Survey, NOAA. Disks inscribed with this NOS name were set from about 1970 to December, 1982.

NOS - National Ocean Service. Disks inscribed with this NOS name were set from about 1983 to the present.

NSRS - National Spatial Reference System

PACS - Primary Airport Control Station

RM - Reference Mark: A survey mark of permanent character close to a survey station, to which it is related by an accurately measured distance and azimuth. For a

triangulation station, reference marks are pre-stamped survey disks, usually within 30 meters (one tape length) of the triangulation station. Standard procedure was to set two reference marks, numbered clockwise from north, with the next consecutive reference number used if an earlier number was destroyed. See ATTACHMENT 1.

SACS - Secondary Airport Control Station

STATION - A physical location or site at which, from which, or to which survey observations have been made. See also mark and monument.

USACE - U.S. Army Corps of Engineers (Blue Book abbreviation is USE)

USCG - U.S. Coast Guard

USC&GS - U.S. Coast and Geodetic Survey. Disks inscribed with USC&GS were set from about 1900 to 1970. Over 10 different pre-stampings were used. (Bluebook abbreviation is CGS)

USE - U.S. Army Corps of Engineers or U.S. Engineers Department (old acronym; present Blue Book abbreviation)

WAAS - Wide Area Augmentation System (FAA)

WGS 84 - World Geodetic System 1984

National Agency abbreviations are listed in Bluebook, Appendix C.