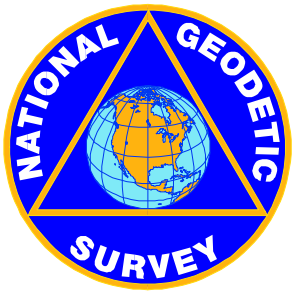
Version 2.1
February 1, 1999

Supplemental Instructions for Airport Area Navigation Approach (ANA) Surveys



Establishment of Geodetic Control on Airports

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

National
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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 Area Navigation Approaches (ANA) under the FAA's Wide Area Augmentation System (WAAS) program. 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 Supplemental Instructions provide the requirements for performing the Geodetic Control phase for the ANA survey.

FAA No. 405, Fourth Edition, September 1996, Appendices 3 and 5 provide general guidance concerning PACS and SACS, including accuracy requirements, with more detailed information in this document. Any exception or deviation from these "SUPPLEMENTAL INSTRUCTIONS" 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.

2.0 RECONNAISSANCE REQUIREMENTS:

Reconnaissance activities for each survey will include the following: Reconnaissance of station descriptions in the NGS Data Base, inquiries with airport management, reconnaissance of all marks at the airport, selection of control stations, writing of required descriptions and other documentation, and preparing a reconnaissance report.

The station name, exactly as listed in the NGS data base, must be used in all survey records.

2.1 STATION DESCRIPTIONS IN THE NGS DATABASE:

USC&GS (U.S. Coast & Geodetic Survey) and NGS mark descriptions are contained in the NGS data base, are published on CD-ROM, and are available via the NGS Aeronautical Survey Program Home Page at "http://www.ngs.noaa.gov/AERO/aero.html" under "NGS Hot Links" - "Data Sheets". 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 NOS 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.

Full digital recovery notes will be prepared for all NOS stations searched for or recovered that do not have complete digital descriptions in the NGS database.

2.2 CONTACT WITH AIRPORT AUTHORITIES:

Before performing any work at an airport, contact must be made with airport management to obtain permission and proper clearances to work in the aircraft operations areas. A security/ 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 escorted.

Inquire with Airport management about planned construction or changes in the airport layout. Present the Aeronautical Survey Program Brochure and/or Letter to Airport Manager, and explain the work that will be performed and describe what the PACS and SACS will be used for. Discuss optimal locations for the practical use and survivability of the 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 visibility to GPS satellites, or become a source of multipath.

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) marks at the airport shall be recovered, including writing or updating descriptions as required. See ATTACHMENT 7, "Know These Markers" for diagrams of these survey disks. Station descriptions for existing marks can be found via the NGS website (See section 2.1, “Station Descriptions in the NGS database”).

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. Factors to consider are mark stability, mark intervisibility requirements, visibility from the marks 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 marks. The marks must be accessible to survey crews, and allow for unattended, secure setup of GPS equipment for long

periods without hindering airport operations. If possible, SACS should be sited near the approach end of the Primary Runways so they can be better utilized for obstruction surveys.

Existing marks should be used if they meet requirements. If suitable marks cannot be found for use as PACS and SACS new marks should be set (See 3.0, ”Setting New Marks”)

Minimum requirements, as listed in FAA No. 405, Fourth Edition, must be met. Also, see ATTACHMENT 8, *Federal Base Network Station Selection Guidelines* for additional criteria. PACS and SACS must allow for setup of both conventional (optical) and satellite surveying equipment.

2.4.1 Use of Existing Marks for PACS and SACS:
An extensive effort should be made to recover existing NOAA survey marks. Existing USC&GS, NGS, & NOS marks should be used if they meet the PACS and SACS requirements. Using 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.

Note, B-order marks have been set at many airports by NGS. These marks should be used if they meet PACS requirements.

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 8, *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: triangulation mark, reference mark, azimuth mark, or bench mark; or a NGS mark; and it meets all siting, construction, and intervisibility requirements as listed in FAA No. 405, Fourth Edition, Appendix 3. (Note, the above paragraph is a clarification only, not changes to 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 requirements.

SACS - Other USC&GS, NGS, or NOS marks should be used as SACS if they meet all siting, construction, and intervisibility requirements as listed in FAA No. 405, Fourth Edition, Appendix 3 (stability quality codes of A, B, or C).

Concrete Marks- The DDPROC (description software) default code for a concrete mark set in an irregular mass of concrete is the stability code "D." If a mark, 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, source upon request) 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 rather their own CBL database.

2.4.3 PACS and SACS Proximity to Airport Features:
PACS and SACS should not be set close to runways (see FAA No. 405 for distances), nor on the imaginary runway extension, nor within the FAA No. 405 distances of the imaginary runway edge extensions. Also, marks must not be set within 305 meters (1000 ft) of the front 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, completely around the horizon. Minor obstructions are acceptable, but should be depicted on the Visibility Obstruction Diagram. Visibility Obstruction Diagrams are required at all stations with obstructions above 20 degrees. See sample in ATTACHMENT 5. 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.

Any marks used in this survey which were set by other agencies, that do not have complete digital descriptions in the NGS database, will have full digital descriptions written. See section 2.6, “Station Descriptions”.

2.4.6 Marks on Private Property:
Before using a mark on private property, owners should be contacted to request permission. Take care to return landscape to the original condition. The name and phone number of the property owner shall be included in the description. In addition, the address is required if the owner lives in another town.

2.4.7 Damaged Survey Marks:
Metal disks which have been moved or defaced so that they no longer can 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: exposed edge of disk, missing logo cap, missing log cap lid, and exposed edge of concrete.

2.4.8 Approval of Proposed Sites for New Marks:
Proposed sites for new PACS and SACS should be approved by NGS prior to setting the marks. New PACS and SACS should only be set if no existing mark can meet the requirements. See section 3.0, “Setting New Marks”, for mark setting guidelines.

2.5 PHOTOGRAPHS - Two photographs shall be taken of each mark used in the survey, including PACS, SACS, HARN, bench marks, and CTCORS. One photo will show the mark from directly above and cover an area about 1 meter in diameter. If it is a rod mark,

the logo cap should be open. The second photo 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 designator) of the airport and the station name. Include a brief description with each photo, including the compass orientation of the camera. Also submit photographs of proposed locations for new marks. Photographs shall be included in the Reconnaissance Report.

2.6 STATION DESCRIPTIONS:

NGS style Station Descriptions must be written for all marks set, searched for, recovered, or occupied during the survey. The descriptions will be submitted in digital format in accordance with chapter 3, vol. I, of "Input Formats and Specifications for the NGS Data Base" (Blue Book). The Blue Book, and recent changes to the Blue Book are available on line at "http://sinbad.ngs.noaa.gov/FGCS/tech_pub.html" Hard Copy of the Blue Book can be obtained from NGS Information Services Branch (301) 713-3242. NGS program DESC.EXE should be used to write the descriptions in the proper format. Standard NGS format will be used for all descriptions. See ATTACHMENT 11 for a sample datasheet with a description for a PACS.

Descriptions are one of the end products of surveying, along with the positions and the survey marks themselves. All three must be of highest quality. The descriptions must be complete, accurate, and in standardized format if the station is to be reliably recovered for use in the future. Descriptions will be in the standard NGS format of three paragraphs as described below under "Description Format." A "description" details the location of a new survey mark, or one not previously in the NGS digital database. A "recovery note" is an update and/or refinement to a description already in the NGS digital database, written upon a return visit to a survey mark. Descriptions and recovery notes must be written by one person and checked by another. For example, a mark setter can draft a description immediately after setting the mark, and an observer can check a description during observations. Descriptions should be written immediately after visiting a station so that all details are fresh. Descriptions (or recovery notes) must be written for all marks set, searched for, recovered, or occupied during the survey. Note, separate descriptions (recovery notes) are not required for reference marks nor azimuth marks unless they were occupied for this survey. Also, reference and azimuth marks need not be mentioned in station descriptions (or recovery notes) except for the third paragraph reference measurements. In the Project Report, include a printout of file *.SST and an additional list showing the stations recovered but not used. Use program DDPROC to enter station description and recovery information.

If an existing NGS horizontal or USC&GS triangulation station digital description is complete, accurate, and meets Blue Book requirements, the station may be recovered with a brief recovery note, such as "Recovered as Described." If minor changes or additions to the description are required, they may be added after the above phrase, such as "Recovered as described, except a new wooden fence is now 3 meters north of the station."

A complete, new, three-paragraph description is required for all stations where:

- there is no NSRS digital description (not in NGS database)
- for all vertical stations (bench marks) unless a complete (usually three paragraph), accurate, up-to-date digital description exists in the NGS database
- where major changes have occurred or major inaccuracies are found
- where required information is missing
- generally for stations other than NGS horizontal or USC&GS triangulation stations.

2.6.1 Description Format:

"A description must be clear, concise, and complete. It should enable one to go with certainty to the immediate vicinity of the mark, and by the measured distances to reference points and the description of the character of the mark, it should inform the searcher of the exact location of the mark and make its identification certain. It should include only essential details of a permanent character," USC&GS Special Publication No. 247, MANUAL OF GEODETIC TRIANGULATION, page 116.

The **first paragraph** is the "Description of Locality." This part of the description begins by referring to the distance and direction (cardinal or inter-cardinal point of the compass) from the nearest well-known mapped geographic feature(s), usually the nearest city or town. Always progress from the farthest to the nearest reference point. State the name of the airport the mark is on or near, and include station location relative to runways and other airport features. Distances in this part of the description should be in kilometers (miles) or meters (feet). Detailed measurements which appear elsewhere in the description should not be repeated in this paragraph. Points of the compass should be fully spelled out. State the name, address, and phone number of the airport manager or property owner. State any advance notice and security access requirements for reaching the station.

The **second paragraph** is the "Directions To Reach the Station." This section is one of the most useful parts of a description. It usually enables a stranger to go directly to a station without the delay due to a detailed study of maps or of making local inquiries. It is a route description which should start from a

definite point, such as (a) the post office of the nearest town, (b) the nearest intersection of named or numbered main highways (which are shown on commonly used road maps), or (c) some definite and well-known geographical feature. Odometer distances should be given to tenths of kilometers (tenths of miles). The general direction of travel should be given. Turns from one road to another road should be indicated by the kind of turn (right or left) followed by a point of the compass and the name or number of the road. The final statement should end with "to station on right (or left)." For example, "TO REACH THE STATION FROM THE POST OFFICE ON MAIN STREET IN JONESVILLE, GO EASTERLY ON STATE HIGHWAY 101 FOR X KM (2.3 MILES) TO AN INTERSECTION. TURN RIGHT AND GO SOUTH ON MILLER ROAD FOR X KM (3.2 MILES) TO A T-ROAD RIGHT. CONTINUE SOUTH ON MILLER ROAD FOR X KM (4.1 MILES) TO AN INTERSECTION. TURN LEFT AND GO EAST ON SMITH ROAD FOR X KM (1.5 MILES) TO STATION ON THE LEFT IN THE FENCE LINE." Use the word "EAST" if the road goes due east and "EASTERLY" if the road wanders in an generally easterly direction. Use intermediate references, as above, if the distance becomes longer than about 5 miles.

The **third paragraph** provides details of the mark and reference measurements. This section should give a short description of the station mark, such as: "THE STATION IS THE TOP CENTER OF A STAINLESS STEEL ROD DRIVEN TO A(refusal or slow driving rate) DEPTH OF XX M. THE ROD IS RECESSED YY CM BELOW GROUND LEVEL IN A 90 CM GREASE FILLED FLUTED PLASTIC SLEEVE, AND ENCASED IN A ZZ CM DIA. PVC PIPE WITH NGS LOGO CAP SURROUNDED BY CONCRETE. THE LOGO CAP AND CONCRETE ARE SET (flush or recessed x cm) WITH THE GROUND." The detailed location of each mark must include distances and directions from three or more definite objects in the mark's immediate vicinity such as existing reference marks, witness posts, centerlines of roads, edges of runways, ditches, power or telephone poles, or buildings. If steep slope distances were measured, that should be stated in the paragraph. The distances should be in meters (followed by English units in parentheses) and the directions should be cardinal and inter-cardinal directions, fully spelled out, for example "NORTH," "NORTHEAST," or "NORTH-NORTHEAST." Magnetic bearings from the reference objects are recommended to assist in future recoveries.

If the station is a PACS or SACS the sentence "THIS STATION IS DESIGNATED AS THE PRIMARY AIRPORT CONTROL STATION" or "THIS STATION IS DESIGNATED AS A SECONDARY AIRPORT CONTROL STATION."

General description requirements are given in Chapter 3 of the Blue Book, page 3-1 (sample descriptions, page 3-13); and in the instructions in S.P. 247, Pages 119-120.

Note, the Blue Book does not require separate paragraphs in the "30 Records," but having separate paragraphs makes the

description much easier to read. So, to increase clarity, separate each paragraph with a blank line by inserting two carriage returns at the end of the paragraph.

Note, the policy stated in the first three sentences of the last paragraph of page 3-1 in the Blue Book, regarding full descriptions for recovery notes, has been canceled.

2.6.2 Important points regarding descriptions:

1. Use the station name and PID, exactly as listed in the NGS data base, in all survey records. Do not add dates, agency acronyms, or other information to the name, nor the stamping. Note, frequently the stamping and the official station name are not the same.

2. Correct NGS survey terminology shall be used in all station descriptions and reports, see Glossary to this document and GEODETIC GLOSSARY, NGS, 1986.

3. Correct aviation terminology (e.g., runways, taxiways, etc.) shall be used in all station descriptions. See FAA No. 405, Fourth Edition, Glossary, and FAA Documents: STANDARDS FOR AIRPORT MARKINGS, A GUIDE TO GROUND VEHICLE OPERATIONS ON THE AIRPORT, and STANDARDS FOR AIRPORT SIGN SYSTEMS.

4. A mark should not be described as destroyed unless the disk is found and returned to NGS. If there is strong evidence that the mark has been destroyed, state "PRESUMED DESTROYED" and the evidence in the recovery note. State the number of person-hours spent searching for a mark that is reported as "NOT FOUND."

5. Any work done to repair a disk should be described completely in the updated description.

6. Record the length of rod driven (and the length of the grease-filled sleeve) or the depth of the concrete monument in the station description.

7. Run all draft descriptions through program CHKDESC.

8. Note, reference marks are abbreviated RM x in descriptions, but on pre-stamped "Reference Mark" disks they are stamped "NO. x".

9. When a description is being written for an existing point that has never been in the NGS description data base, use "R" in cc 15 of the *10* record, see page 3-3 of the Blue Book. In cc 16 of the *10* record use "F". These letters indicate that this is the first digital description for an existing station. In the *20* record, cc 33-36, enter the year the mark was established, and in

cc 64-71 enter the date recovered.

10. The Blue Book abbreviation for U.S. Coast and Geodetic Survey is CGS. Note, USC&GS is used in this document.

11. The Blue Book abbreviation for U.S. Army Corps of Engineers or U.S. Engineers Department is "USE". Note, USACE is used in this document.

12. For all stations, including those recovered but not used, indicate if the station is occupiable with GPS by entering a "P" in cc 69-72 of the *10* record.

The terms "flush" or "recessed" in the "29 Record" should be used to refer to the logo cap, not to the mark inside the logo cap. Both the logo cap recess amount and the amount the top of the rod is recessed below the logo cap must be included in the station description.

2.6.3 Mark Default Codes for DDPROC

The DDPROC default code for a concrete mark set in accordance with the requirements of ATTACHMENTS 1 and 1A is the stability code "C". The default code for a concrete mark set in an irregular mass of concrete is the stability code "D".

The setting code for the stainless steel rod will be "I 59". This “59" code describes a stainless steel rod with a greater than 10 foot greased sleeve. The “59" code will default to an "A" stability code in the DDPROC software. Since only a one meter long greased sleeve is used for the rod marks, the stability code must be changed to "B".

2.7 RECONNAISSANCE REPORT:

A reconnaissance report and survey 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.

The reconnaissance report will include the following information:

Station Table - For each airport submit a table which lists Station Name, PID Number, Establishing Agency, Order, Stability, Condition at Recovery, and Comments (Station is PACS, BM Tie, etc.) for each station. Give status of marks not used and reason. See ATTACHMENT 12 for an example.

Airport Summary Report - A separate paragraph for each airport to include:
whether airport is controlled; whether escort is required;

whether radio is required; intervisibility of the PACS and SACS; comments on unusual circumstances; comments on any exceptions, including justification; any other miscellaneous information.

Project Sketch - Depict entire survey area (state) with all occupied stations, except SACS (because of scale). Include 300 km dashed circles around CORS and CTCORS, and 50 km circles around PACS. Include independent GPS vectors. Recommend one sheet of large size and additional smaller sheets depicting individual airports or airports grouped together for GPS observations. Note distances from the PACS to the CORS, HARN, and Bench Mark Ties.

Airport Sketches - Plot all PACS, SACS, and BM's that are on or near each airport on an airport map. Hand plotting is acceptable. Size 8.5 x 11 inches is acceptable.

Visibility diagrams - Fill out completely for stations that will be occupied by GPS and have obstructions over 20 degrees above horizon. Note "No Obstructions" if applicable for a station.

Photographs - Two of each existing station, one of proposed locations, see Section 2.5.

Monumentation - Proposed new and/or existing monumentation to be used as control. Note type of mark (i.e. SS Rod, Disk in Rock Outcrop, etc.) for proposed new monumentation.

Proposed instrumentation - Brand and model.

Proposed vector reduction software - Name and version. Ensure that the current version of all software is used by checking the NGS WWW Home Page, under PRODUCTS SERVICES, CATALOG OF PRODUCTS AND SERVICES, and then SOFTWARE PRODUCTS.

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, part 2, for an example.

Station Descriptions - Submit draft recovery notes or draft 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 2.6 for details on writing station descriptions.

3.0 SETTING NEW MARKS:

The importance of setting quality marks cannot be over emphasized. Marks that are properly located and set can provide years 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 mark. The only physical evidence left after a survey has been completed are the marks; therefore, permanency and neatness of the mark 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 these services must be contacted if required by state or local regulation.

PACS - New PACS must meet stability code A or B requirements as defined in ATTACHMENT 8, *FBN Station Selection Guidelines*. New rod marks must meet the "Quality Code B" requirements found in ATTACHMENT 3 and *Geodetic Bench Marks.*

SACS - New SACS must meet stability code A, B, or C requirements as defined in ATTACHMENT 8, *FBN Station Selection Guidelines*. Bronze disks set in rock outcrops, massive structures, or as concrete monuments will be used for new SACS.

3.1 Stamping - New PACS and SACS will have a unique stamping. Marks set at a site with an official FAA site 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, 3.6 inch diameter, 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 bronze disks with pre-stamped NGS logo. For detailed instructions on setting a disk in bedrock or a structure, see ATTACHMENT 2, “SETTING A DISK IN ROCK OUTCROP OR STRUCTURE.”

3.3 Stainless Steel Rod Marks - An 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 3, “SETTING A NGS 3-D MONUMENT.” See also, ATTACHMENT 4, "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 set 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. 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 1.

3.4 Concrete Marks - New concrete marks, with standard NGS 3.6 inch bronze disks, may be used for SACS only. Construction requirements are in ATTACHMENT 1, “SETTING A CONCRETE MONUMENT.” Note, new concrete marks should be set flush or slightly recessed with the ground and should set 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 3 and 3A. 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 - Witness posts shall not be set on airport property, unless requested by airport management, but must be set at marks used in this survey which are not on airport property, if practical. 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 POSITIONING PROCEDURES:

GPS observations will be performed using dual frequency GPS receivers. PACS should be positioned directly from the nearest Continuously Operating Reference Station (CORS). If the nearest CORS is more than 300 km from the PACS, a Central Temporary Continuously Operating Reference Station (CTCORS) must be established by setting up a GPS receiver on a suitable existing horizontal NSRS station. The SACS, Bench Marks, and HARN stations should be positioned directly to their respective PACS.

4.1 CORS SITES:

The CORS site selected must be included in the NGS CORS system. CORS maps, data, and information are available on the NGS CORS Data web page (See ATTACHMENT 16 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 USCG and USACE CORS site has two antennas. WAAS sites will have up to four antennas. To determine which CORS antenna was in use during observations, read the weekly NGS "CORS ELECTRONIC NEWSLETTER" which is published and distributed electronically each Sunday by NGS. The "CORS NEWSLETTER" is available through the NGS CORS Data web page described above. Users may subscribe to the newsletter at this site. 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.

4.2 CTCORS SELECTION CRITERIA:

A CTCORS station will only be used when an airport is not within 300 KM of a CORS station. In this case, the CTCORS will provide the CORS function in the positioning of the PACS. The position of the CTCORS will be checked 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. NGS sets and positions marks at current and future WAAS and USCG CORS sites.

These marks are positioned to A-order and B-order specifications, and most have first- or second-order elevations. The marks make excellent candidates for a CTCORS.

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, for practical considerations, observation of sessions longer than 4 hours is highly recommended. Likewise for 1.5 hour sessions.

If a CTCORS is not required and a CORS is used for connections, substitute CORS for CTCORS in the following paragraphs.

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 in length 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.

- 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 NAVD 88 BENCH MARKS section of this document, below.

4.3.2 PACS:

- Each PACS shall be positioned from the CTCORS in two or more independent, continuous, simultaneous observation sessions of at least 4 hours in length. The observations to position the PACS must be performed simultaneously with the CORS or CTCORS observations. If feasible, the start time of one PACS observing sessions should be at least 2 hours different than the second PACS session to incorporate different satellite geometries.

- All PACS must have a separate positional check by observing at least one session of 4 hours or more in length to a "A" or "B" order (HARN) check station. The check station should be within 100 km of the PACS and should be at least 50 km from the CTCORS. Tie to as many "A" order stations as possible during the project. HARN ties to "A" or "B" order stations should be within 5 cm in horizontal and 10 cm in ellipsoidal height compared to the published positions. If not, notify NGS ASAP.

- If there is an existing "A" or "B" order station on an airport, it should be used as the PACS if it meets all siting, construction, and intervisibility requirements. It must be checked with at least one 4 hour session to a CORS or CTCORS. A tie to an additional "A" or "B" order station is not required.

- 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.

4.3.3 SACS:

- Each SACS shall be observed in two or more independent, continuous sessions of at least 1.5 hours. The session beginning 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, the two or more 1.5 hour sessions are adequate for the bench mark tie, rather than the normal 4 hour bench mark tie requirement. This is due to the short distance from the PACS to the SACS.

- SACS at an airport will be positioned directly from the PACS for that airport.

4.3.4 Bench Mark Ties:

All bench mark elevations used in this survey must be published NSRS NAVD 88 bench mark elevations. All final elevations determined in this survey will be NAVD 88 elevations, in meters. 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 distance between two bench marks being tied is less than 20 km, the two bench marks must be observed simultaneously. Bench mark ellipsoidal heights should agree within 10 cm and bench mark orthometric heights within 15 cm. If checks exceed these tolerances, notify NGS ASAP.

- **CTCORS** - A first-order, class II, or better, NAVD 88 bench mark is recommended for bench mark ties. CTCORS will be tied to two bench marks by one continuous observation session at least 4 hours in length. These bench marks should be as close as possible and must be within 50 km of the CTCORS, see BM PRIORITY TABLE below. If the CTCORS has a published bench mark elevation, the second bench mark tie is not required. These bench marks will be positioned relative to the CTCORS. (Note, this is not a change in the required number of bench marks, just a clarification.)

- **PACS** - A first-order, class II, or better, NAVD 88 bench mark is recommended for a bench mark tie. PACS will be tied to two bench marks by one continuous observation session at least 4 hours in length. These bench marks should be as close as possible and must be within 50 km of the PACS, see BM PRIORITY TABLE below. If the PACS has a published bench mark elevation, the second bench mark tie is not required. These bench marks will be positioned relative to the PACS. (Note, this is not a change in the required number of bench marks, just a clarification.)

- The same bench marks may be used for the CTCORS ties and for PACS ties if distance and check requirements are met.

- Bench mark (BM) selection must be based on the following **BM PRIORITY TABLE**:

DISTANCE TO CLOSEST	SELECTION

PRIORITY	FIRST-ORDER BM	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 1/2 the distance to the first-order BM.
3	> 50 km	Use a second-order BM if less than 25 km. Otherwise contact NGS.

! Differential geodetic (spirit) leveling (run in both directions) may be performed to satisfy the connections listed above. 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:

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 (clarification only) in both meters and feet, unless a fixed-height tripod is used. See ATTACHMENT 13, "GPS Antenna Height Measuring Instructions." Minimize the mixing of GPS receiver and antennae types used for observations.

- Proper antenna set-up is critical. Fixed-height tripods should be used at CTCORS and PACS, and are highly recommended for all sites. The plumbing bubbles on the antenna pole of the fixed-height tripod should be shaded from direct sunlight when plumbing is performed. They should be shaded for 3 minutes before checking and/or re-plumbing. Perpendicularity of the poles should be checked at the beginning and end of each project. Antennas will be aligned to north.

- If a set-up does not permit a fixed-height tripod, the height of the antenna must be carefully measured to prevent station set-up blunders from occurring. Tribrachs used for these set-ups should be checked and adjusted at least at the beginning of each project area, and at other times when necessary. Totally independent measurements of the antenna height above the mark in both metric units and English units must be made before and after each session. Someone other than the observer should check the measurement comparison computations and enter their initials on the log. The type of antenna (name and part number) must be recorded on the field log.

- Sandbags are recommended to stabilize all tripods and frequent checks should be made of the antenna's centering and height.

4.4.2 Epoch Interval / Elevation Mask:

GPS data will be collected at 15 or 30-second epochs; and with a 15 degree elevation mask. Data may be processed at a 15 second or 30 second interval. An 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 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 6 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:

GPS RECEIVERS

Dual-frequency 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.

5.0 DATA PROCESSING AND VERIFICATION:

For information on Format, Accuracy, Monumentation, Field Records, Project Report, Review, Returned Submissions, Submitted Projects, Cost, and Publications, see *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 in ATTACHMENT 9. Any exceptions to the specifications and unusual circumstances must be reported in the Project Report along with explanations and recommendations. See ATTACHMENT 17, for a Project Submission Checklist and a listing of processing and adjustment files to be submitted to NGS. See also, ATTACHMENT 16, for a listing and summary of NGS Processing Programs available on the NGS web site.

5.1 VECTOR PROCESSING:

The processing software must be OMNI or equivalent. The 'equivalent' of OMNI is subjective, based on the software's ability to correct for the same systematic errors that OMNI corrects, and its ability to reproduce the same results as OMNI. This determination will be made by NGS. Note, CORS sites may have antennas produced by manufacturers different from the receivers used during the survey. OMNI software is able to apply correctors for different antenna brands and is able to apply the standard set of antenna constants (e.g., L1-L2 phase center offsets), and is able to process multiple vectors simultaneously. Therefore, 'equivalent' software must also be able to do these things. See: OMNI USER'S GUIDE, Version 3.42, 1994; Practical Hints to Process GPS Vectors USING OMNI, Soler, Hall, and Foote; see ATTACHMENT 15, "DIRECTIONS FOR ACCESSING OMNI VIA THE INTERNET." The following additional requirements and guidance are provided:

- NGS precise GPS orbit data (see ATTACHMENT 14) and NGS CORS data must be used in data processing. For information on down loading CORS data from NGS via the Internet see ATTACHMENT 16. **International Terrestrial Reference Frame (ITRF) station coordinates will be used for all vector reductions using (OMNI).** Information about ITRF is available on the NGS WWW Home Page, under "PRODUCTS SERVICES". Note, the current ITRF epoch must be used in computations. NGS can supply ITRF coordinates of "A" order stations from an adjustment and "B" order stations from a transformation.

- The Antenna Height value entered into OMNI’s MERGE setup is the monument to Top of Groundplane (TGP) distance. OMNI will automatically add a constant factor for the TGP to L1 phase center distance when it merges the data. The “monument” for a CORS station is the L1 phase center of its respective antenna. Therefore, when entering the antennae

height for a CORS station during OMNI's MERGE setup, the reciprocal of the antenna constant in OMNI may need to be entered as the antennae height. This reciprocal value will offset the constant added by OMNI to give a net "up" correction of 0.00m for processing.

- OMNI'S overall RMS-of-fit of the post-fit double-difference residuals should not exceed 2.0 cm. Review OMNI generated plots for data processing problems and outliers.

- To help ensure that SACS names are correct, and not reversed, compare "Bluebook" and "Savit" files. Also review the SAVIT files to double check: Reference Station Coordinates, Antennae Heights, and RMS values.

- Submit all files and printouts as required in ATTACHMENT 17.

- Partially fixed integer solutions are acceptable for base lines over 150 km in length. For base lines less than 150 km, fix integers whenever possible.

5.1.1 CORS/CTCORS Vectors:

Data processing will involve some of the following CORS/CTCORS vectors:
(1) CORS to CTCORS, (2)CTCORS to PACS, or (3)Direct CORS to PACS. In all three cases ITRF coordinates of the reference station must be used and NGS precise orbits will be used.

(1) CORS to CTCORS - The session length depends on the length of the vector. If the vector is under 300 km, observe at least 4 hours for each session as stated elsewhere in this document. If the distance is over 300 km, contact NGS for advice on a case by case basis.

Three 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. Request the ITRF coordinates of the CTCORS from NGS for comparison purposes. Use precise orbits from NGS and use OMNI processing software. 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 may 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.

(2) CTCORS to PACS - use the newly computed ITRF coordinates for the CTCORS if a satisfactory check was obtained. The distance limit is 300 km. Two 4 hour sessions are required.

(3) CORS to PACS - use the most recent NGS ITRF coordinates for the CORS. The distance limit is 300 km. Two 4 hour sessions are required.

5.1.2 OMNI Processing Procedure:
The following steps are designed to maximize the quality of the height determination between the bench marks and the PACS. L1 verse Ion-Free final solutions are based on vector lengths. See the table under Step 4 for guidance when grouping vectors together for a processing session. The sequential order of OMNI processing is:

Step 1 - Process first CORS-to-PACS vector, with CORS as reference, using 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 table in Step 4).

Step 2 - Process second CORS-to-PACS vector, with CORS as reference, as above. Again, if more than one PACS was observed simultaneously, include appropriate PACS in this OMNI session.

Step 3 - The horizontal positions of the PACS, based on the vectors above, should compare within 3 cm. If they do, mean the positions and go on to Step 4. If not, reprocess and/or reobserve.

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

Step 4 - Process the first PACS to (BM, HARN) session using the PACS as the reference station and using its' ITRF position calculated in step 3. Include stations for this airport that are over about 5km from the PACS (except the CORS). BM or HARN stations that are less than 5km from the PACS will be processed in a separate session. The frequency of the final OMNI solutions is based on the length of the vectors. Use the following table for guidance on grouping vectors together for processing:

OMNI Final Solution Type Determination

Vector Lengths 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

Set the Tropospheric scale height in accordance with the following table:

Tropospheric Scale Height Settings for OMNI Sessions

Vector Length	Reference Station Setting	Solve Station Setting
0-5km*	FIX	FIX
5-100km	FIX	SLV
100+km	SLV	SLV

*If a station is within 5km 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.

In cases where a single vector satisfies all BM and HARN tie requirements for an airport, it is advisable to include a vector to a nearby airports' PACS, BM, or HARN station in the solution to aid the strength of the solution and the network adjustment.

If a HARN station tie is not also a PACS, SACS, or BM tie for that airport, it may be processed in the CORS to PACS session (Step 1), if the vector length constraints listed above would have required it to be processed in a single vector (PACS to HARN) session.

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 its' ITRF position calculated in step 3. BM's and HARN stations that are within 5km of the PACS may be included in these sessions, but must have at least four hours of continuous data in the solution. Process these short lines using the L1 frequency only.

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

Step 8 - Run the required ADJUST runs (constraining stations to

the NAD 83 datum) for each airport OR as one set for all airports.

(Substitute CTCORS for CORS in the above steps as appropriate.)

5.2 ADJUSTMENT PROCESSING:
The project adjustment can be performed as a whole, or can be performed by adjusting separate groupings of airports that are located close together and that share tie stations (BM, HARN). Discuss an adjustment plan with NGS prior to running 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). NOTE: ITRF vector components in the G-file will be internally transformed to the NAD 83 reference system by ADJUST using the code inserted in cc 52-53 of the B record of the G-file created by OMNI.

- 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.

Sections 7.2 and 7.3 of 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. ATTACHMENT 17 also contains a listing of data processing and adjust files to be submitted to NGS.

7.2 **(ADJUSTMENT ONE)** A free adjustment. Hold the NAD 83 coordinates of one CORS station fixed. This adjustment will be run using program ADJUST, in 3 dimensions, without using geoid heights.

The A-file should have parameters set to show the entire input

B-file and G-file and to run in mode 3.

Residuals on any vector component 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.

7.3 **(ADJUSTMENT TWO)** A fully constrained adjustment holding the NAD 83 coordinates (latitude, longitude, ellipsoid height) of all CORS or CTCORS stations used in processing will be submitted. 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 should be made between the coordinates determined in this adjustment and those currently published by NGS. As noted previously, differences of 5 cm horizontally and/or 10 cm in ellipsoidal height should be immediately brought to the attention of NGS for investigation. Also tabulate all the differences in the final report.

(ADJUSTMENT THREE) In addition, run an 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 (see 7.4).

7.4 **(ADJUSTMENT FOUR)** A minimally constrained free adjustment, holding NAD 83 coordinates for one CORS station fixed, and showing accuracies over all observed lines, will be run using the output of the constrained horizontal adjustment.

Program BBACCUR can be used to give a formatted, sorted listing of these accuracies. Examine these 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 comment 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.

Program ELLAC may be used to determine the order/type of the ellipsoid heights. This value will be added to the *86*

records in the final B-file. The value chosen should be that of the majority of the lines and will be used for all stations.

7.5 **(ADJUSTMENT 5)** A free vertical adjustment holding the NAD 83 position of one CORS or CTCORS station fixed, one bench mark (center of project area) NAVD 88 height fixed, and including geoid heights in the bluebook *86* records. Geoid heights are obtained by running program GEOID 96. Compare the values obtained for the published bench marks with those obtained in this adjustment and notify NGS of any exceeding 15 cm.

(ADJUSTMENT 6) If all comparisons meet the above criteria (<15 cm) or upon advice from NGS, run a constrained vertical adjustment holding all approved bench marks. Use the orthometric heights from this adjustment for the final B-file.

In the report, tabulate the free minus published differences for all bench marks and discuss any residuals over 15 cm. Also document any actions taken as the result of poor bench mark checks.

7.6 The **final B-file** submitted should contain the positions and ellipsoidal heights derived from the final constrained adjustment (ADJUSTMENT 2) and the orthometric elevations from the final vertical adjustment (ADJUSTMENT 6). Program ELEVUP can be used to easily combine the files. The B-file must satisfactorily run through the required checking programs.

7.7 The **project report** should discuss each of these adjustments separately, including points held and the source of the position or elevation used. Results and any analysis done should also be discussed. ATTACHMENT 17 provides additional guidance for the report.

7.8 ATTACHMENT 17 contains a listing of all **files and program outputs**, relating to processing and adjustment, to submit in the final package. Keep backups of all files until notified that the NGS data base has been loaded.

Data may be submitted on the following media, listed by NGS preference:

IOMEGA Zip (100 MB) disks
BERNOULLI (230 MB) disks
Floppy disks

Data should be archived in the following form:

*Project Name/Day of Observations/Raw Data/
Project Name/Day and Session/Formated Data/
Project name/Day and Session/OMNI Results/
Project Name/Adjust Results
*(Project Name is State two-letter ID, plus ANA)

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 7.

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. See ATTACHMENT 2 and 7.

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 Spacial 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 7.

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.