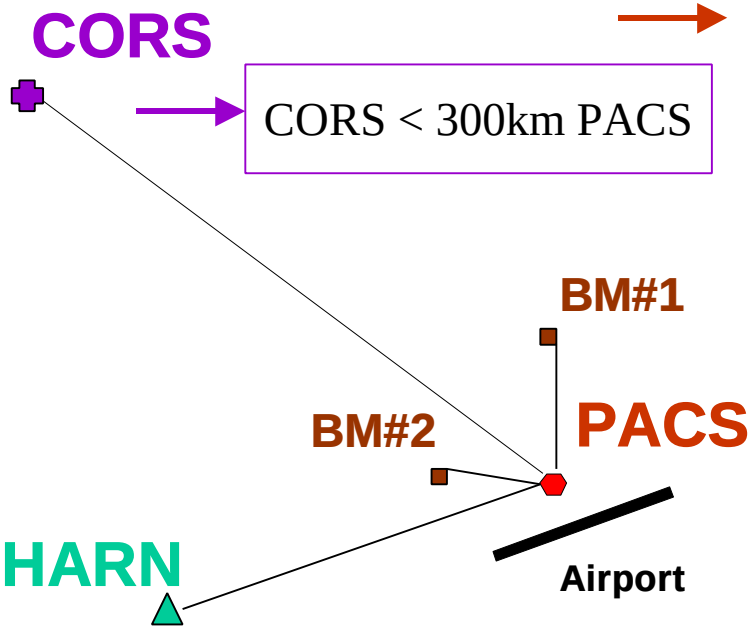
GPS Positioning Procedures

PACS Ties-

- **2, >4hr Sessions PACS - CORS**
- **1, >4hr Session PACS - HARN**
- **1, >4hr Session PACS - BM#1**
- **1, >4hr Session PACS - BM#2**



Bench Marks-
BM's > 1km Apart
BM's < 50km PACS

Co-observe BM's if < 20km Apart

HARN > 50km CORS
HARN < 100km PACS

NOTE: Final processed sessions must consist of at least 4 hours of continuous, simultaneous observations between points.

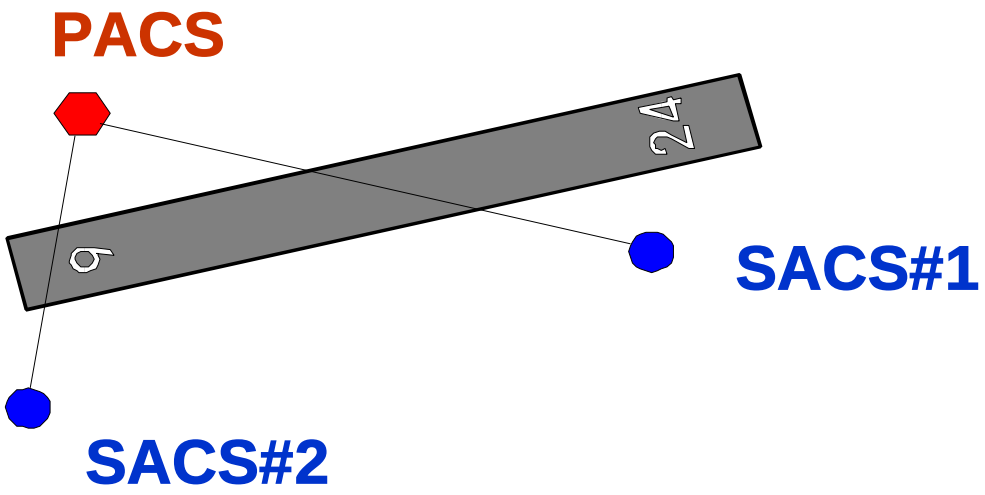
Simplified Schematic, See detailed requirements in the Supplemental Instructions for Airport ANA Surveys http://www.ngs.noaa.gov/AERO/aero.html

GPS Positioning Procedures

SACS Ties-

→ **2 >1.5 hr Sessions SACS - PACS**

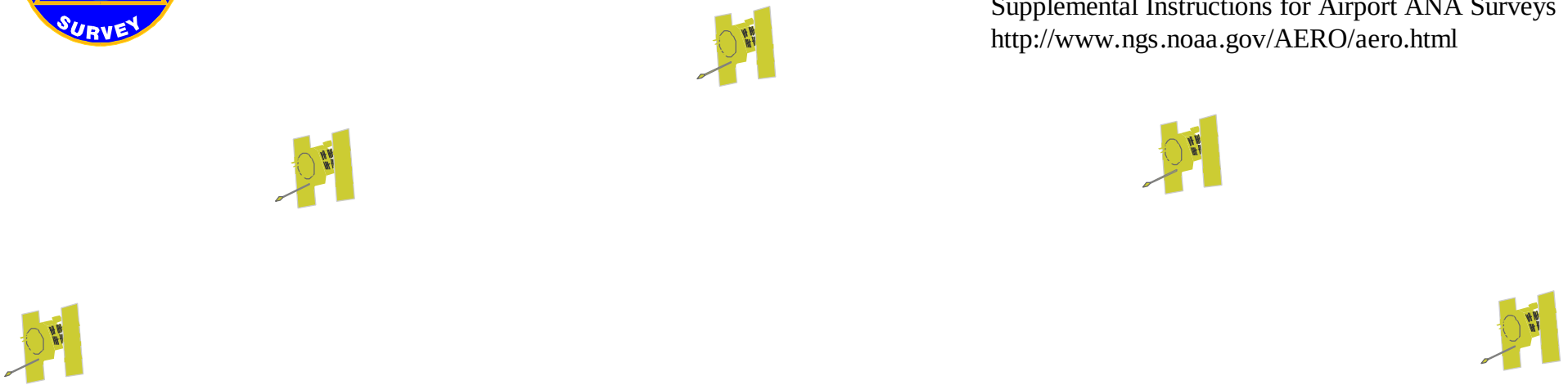
→ **Separate Sessions by 2.5 Hours**



Simplified Schematic, See detailed requirements in the Supplemental Instructions for Airport ANA Surveys
http://www.ngs.noaa.gov/AERO/aero.html

Protect the Airspace of ANA Geodetic Control Stations!

Supplemental Instructions for Airport ANA Surveys
http://www.ngs.noaa.gov/AERO/aero.html



➡ GPS Survey equipment requires a 15 degree minimally obstructed view of the horizon to collect signals from GPS satellites.

15 degree horizon

➡ Keep the area surrounding the survey mark free of large reflective items such as chain-link fences, structures, and buildings.

➡ Potential sources of electrical interference such as radio repeaters and high voltage power lines should not be placed near the survey marks.

GPS Equipment set up over Survey Mark

National Oceanic and Atmospheric Administration

ATTACHMENT 11

SAMPLE NGS DATASHEET DESCRIPTION FOR A PACS

```
**********************************************************************
  CBN         -  This is a Cooperative Base Network Control Station.
  PACS        -  This is a Primary Airport Control Station.
  DESIGNATION -  TWF A
  PID         -  AC5225
   STATE/COUNTY-  ID/TWIN FALLS
  USGS QUAD   -  HUB BUTTE (1980)

                        *CURRENT SURVEY CONTROL
______________________________________________________________________
* NAD 83(1992)-  42 28 48.51628(N)    114 28 33.16436(W)     ADJUSTED
* NAVD 88     -      1265.45   (meters)    4151.7    (feet)  GPS OBS
______________________________________________________________________
  X           -  -1,952,257.649 (meters)                    COMP
  Y           -  -4,288,622.063 (meters)                    COMP
  Z           -   4,285,932.614 (meters)                    COMP
  LAPLACE CORR-           2.53  (seconds)                   DEFLEC96
  ELLIP HEIGHT-        1250.30  (meters)                    GPS OBS
  GEOID HEIGHT-         -15.01  (meters)                    GEOID96

  HORZ ORDER  -  B
  ELLP ORDER  -  FOURTH    CLASS I

This mark is at Twin Falls-Sun Valley Reg Joslin Fld Airport (TWF)
The horizontal coordinates were established by GPS observations
and adjusted by the National Geodetic Survey in January 1997.
The orthometric height was determined by GPS observations.

GPS derived orthometric heights for airport stations designated as
PACS or SACS are published to 2 decimal places.  This maintains
centimeter relative accuracy between the PACS and SACS.  It does
not indicate centimeter accuracy relative to other marks which are
part of the NAVD 88 network.

The X, Y, and Z were computed from the position and the ellipsoidal ht.

The Laplace correction was computed from DEFLEC96 derived deflections.

The ellipsoidal height was determined by GPS observations
and is referenced to NAD 83.

The geoid height was determined by GEOID96.

                    North         East     Units   Scale      Converg.
SPC ID C     -    90,461.674   460,872.862   MT  0.99996620 -0 19 17.0
UTM  11      - 4,706,175.525   707,468.881   MT  1.00012961 +1 42 18.8


                          SUPERSEDED SURVEY CONTROL
No superseded survey control is available for this station.
```

_MARKER: I = METAL ROD
_SETTING: 49 = STAINLESS STEEL ROD IN SLEEVE
_STAMPING: TWF A 1996
_PROJECTION: FLUSH
_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
+SATELLITE: SATELLITE OBSERVATIONS - 1996
_ROD/PIPE-DEPTH: 4.8 meters
_SLEEVE-DEPTH : 0.9 meters

HISTORY	- Date	Condition	Recov. By
HISTORY	- 1996	MONUMENTED	NGS

STATION DESCRIPTION

DESCRIBED BY NATIONAL GEODETIC SURVEY 1996 (CSM)
THE STATION IS 5 MI (8.0 KM) SOUTHWEST OF TWIN FALLS AT THE TWIN FALLS-MAGIC VALLEY REGIONAL AIRPORT/JOSLIN FIELD, ON THE SOUTHEAST END OF RUNWAY 7-25. OWNERSHIP--CITY OF TWIN FALLS--P.O. BOX 1907, TWIN FALLS, IDAHO 83303. POINT OF CONTACT AT THE TIME OF ESTABLISHMENT WAS THE AIRPORT MANAGER--MR. RON MADSEN, PHONE 208-733-5215.
NOTE--PERMISSION MUST BE OBTAINED BEFORE ENTERING AIRPORT.

TO REACH THE STATION FROM THE JUNCTION OF INTERSTATE HIGHWAY 84 AND STATE HIGHWAY 93 IN TWIN FALLS, GO SOUTH ON STATE HIGHWAY 93 FOR 5.65 MI (9.09 KM) TO THE JUNCTION OF STATE HIGHWAY 74 (SHOSHONE STREET). TURN RIGHT ON STATE HIGHWAY 74 AND GO SOUTHWESTERLY FOR 3.3 MI (5.3 KM) TO WHERE STATE HIGHWAY 74 TURNS SOUTH. CONTINUE STRAIGHT AHEAD ON WASHINGTON STREET SOUTH (2900 E) FOR 2.55 MI (4.10 KM) TO A FORK IN THE ROAD. BEAR LEFT AT THE FORK AND GO SOUTHEAST FOR 0.05 MI (0.08 KM) TO THE FIRE STATION/MAINTENANCE BUILDING ON THE LEFT. TURN LEFT AND GO EAST FOR 0.05 MI (0.08 KM) TO AN ELECTRONIC GATE. PASS THROUGH THE GATE, TURN RIGHT AND PROCEED SOUTH FOR 0.1 MI (0.2 KM) ACROSS APRON TO TAXIWAY A. TURN LEFT ON TAXIWAY A AND PROCEED EAST FOR 0.35 MI (0.56 KM) TO TAXIWAY B ON THE RIGHT. TURN RIGHT AND GO SOUTHEAST FOR 0.05 MI (0.08 KM) TO RUNWAY 7-25. BEAR RIGHT CROSSING THE RUNWAY TO THE STATION AHEAD.

THE STATION IS, 73.6 M (241.5 FT) WEST-SOUTHWEST OF AN ACCESS ROAD, 72.8 M (238.8 FT) SOUTH-SOUTHEAST OF THE CENTERLINE OF THE RUNWAY, 40.6 M (133.2 FT) SOUTHEAST OF THE 1000/7000 FOOT RUNWAY DISTANCE INDICATOR SIGN, AND 1.1 M (3.6 FT) NORTH-NORTHWEST OF A FIBERGLASS WITNESS POST. THE STATION IS A PUNCH HOLE IN THE TOP OF A 9/16 INCH STAINLESS STEEL ROD DRIVEN TO THE REFUSAL DEPTH OF 14 METERS. THE ROD IS RECESSED 5 CM BELOW THE SURFACE OF THE GROUND IN A 1 METER GREASE FILLED SLEEVE, AND ENCASED IN A 5-INCH PVC PIPE WITH LOGO CAP. NOTE--ACCESS TO DATUM POINT IS THRU A 5-INCH NGS LOGO CAP. THIS IS THE PRIMARY AIRPORT CONTROL STATION. DESCRIBED BY J.E. DUNFORD III.

Station Recovery Data Tables
Maine ANA Survey, 1998

(LEW) Auburn-Lewiston Municipal Airport; Lewiston, ME

Station Name	PID	Estab. Agency	Order	Stability	Recovery Condition	Comments
LEW A	n/a					Proposed PACS, SS rod mark
ARP 1964	PF0086	CGS	H 4S, V1	C	Good	SACS#2
LEW AP STA B	PF0085	CGS	H 2, V 1	C	Good	SACS#1
A 196	PF0720	CGS	BA, 1	B	Good	HARN Tie
E 171	PF0723	NOS	V 1	B	Good	BM Tie
G 171	PF0724	NOS	V 1	A	Good	BM Tie
M 164	PF0080	NOS	V 1	B	Not Found	Searched 20 min, 2 people
ARP RM1	PF1079	CGS	H 26	C	Good	Not suitable for GPS Obs
ARP RESET	PF1080	CGS	H 24, V 3	C	Good	Too close to Rwy
LEW AP STA C	PF0083	CGS	H 24, V 3	C	Good	Intervisibility problem w/ SAC and PAC
TARMAC	PF0087	MEDOT	H 2, V 3	C	Good	Could be destroyed in planned future construction

Airport is uncontrolled with restricted access (gate with lock) and no escort required. Radio communications is through VHF UNICOM 122.8. Contact the airport manager, Joe Manager (207) 287-1234 prior to entry. Intervisibility between the PACS and SACS is good. Construction of a new hangar is planned by the SE side of the main tarmac.

ANA Multi-Airport GPS Observation Scheme

Maine ANA Survey, 1998

AIRPORT(s)-Auburn-Lewiston Municipal Airport (LEW)
and Augusta State Airport (AFN)

Observation Day- Day 1, (045)
#Receivers Used- 9
CORS Tie- BRU1
A Order Tie- n/a
Observers- Contractor, Inc. (6); Subcontractor, Inc. (3)

(LEW)	**(AFN)**
PACS- LEW A	**PACS**- AUG AP STA C
Session 1- 8:00-13:00 (5hr)	Session 1- 8:00-13:00 (5hr)
Session 2- 14:00-19:00 (5hr)	Session 2- 14:00-19:00 (5hr)
SACS#1- LEW AP STA B	**SACS#1**- AUG AP STA B
Session 1- 8:00-10:30 (2.5hr)	Session 1- 8:00-10:30 (2.5hr)
Session 2- 14:00 -16:30 (2.5hr)	Session 2- 14:00-16:30 (2.5hr)
SACS#2- ARP 1964	**SACS#2**- AUG A
Session 1- 8:00-10:30 (2.5hr)	Session 1- 8:00-10:30 (2.5hr)
Session 2- 14:00 -16:30 (2.5hr)	Session 2- 14:00-16:30 (2.5hr)
BM#1- E 171	**BM#1**- G 31
14:00-19:00 (5hr)	14:00-19:00 (5hr)
BM#2- G171	
8:00-13:00 (5hr)	
HARN- A 196	
14:00-19:00 (5hr)	

Remarks:
Session duration is fixed, start and end times are approximate depending on travel times, date of survey, satellite status, weather conditions, airport logistics etc. Stations used for multiple airports are listed on the center of the page.

Detailed station information is listed in the Station Table.

ATTACHMENT 13
GPS ANTENNA HEIGHT MEASURING INSTRUCTIONS

MEMORANDUM FOR DISTRIBUTION

FROM: **Tomás Soler**
Chief, Global Positioning System Branch
Spatial Reference System Division

SUBJECT: **GPS Antenna Height Measuring Instructions**

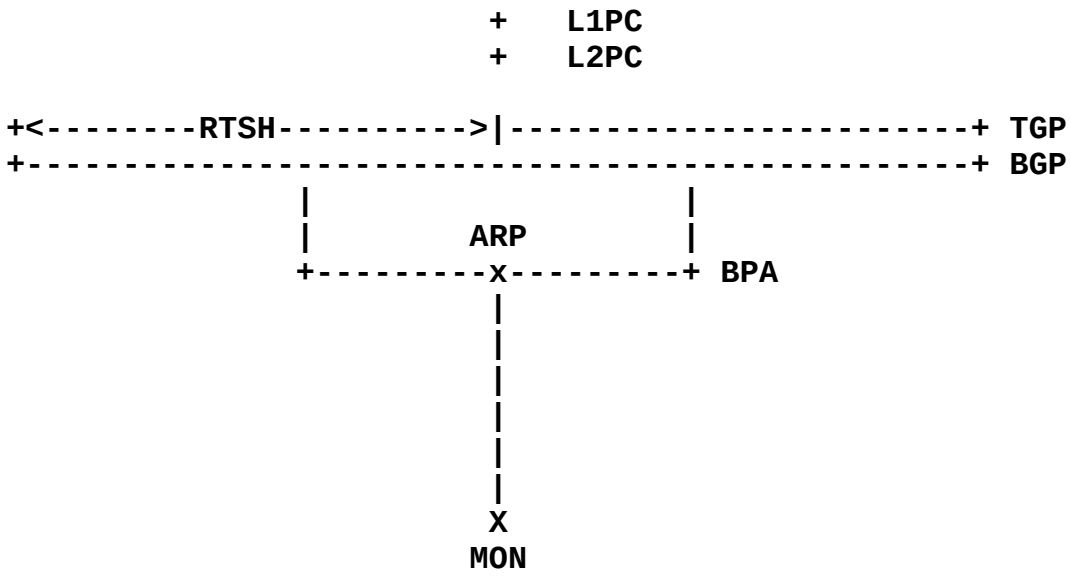
One of the most important operations performed in the field during GPS surveys relates to determining the exact relationship between the antenna phase center and ground reference mark. Proper time and concentration should be devoted to achieve this task. The situation is even more serious when crustal motions are investigated and unknown systematic errors, introduced by careless setting of the antenna (centering and height measurement errors) could be incorrectly interpreted as possible displacements caused by nonexistent geophysical phenomena.

It is imperative that all antenna height measurements made in the field be properly described in the station log sheet. "Antenna height," as used inside GPS software, is usually defined as the vertical distance between the assumed reference ground mark of the station and the L1 phase center of the antenna collecting GPS data at a certain epoch.

Whenever recording the antenna characteristics in the field logs, the antenna type, part number (P/N), and serial number (S/N) should be clearly stated. These numbers should be explicitly recorded in the log sheet. Station logs without this information would be considered incomplete and will be returned to the observers for appropriate corrections.

Schematic diagram of GPS antennas

To properly characterize the major reference components of all GPS antennas, the most important basic definitions generically applying to various GPS antennas are schematically described in the sketch that follows:



where:

MON = Reference Ground Mark of the station (e.g., monument).
ARP = Antenna Reference Point (can be anywhere on the antenna depending on manufacturer).
BPA = Bottom of PreAmplifier (usually: ARP=BPA).
BGP = Bottom of Ground Plane.
TGP = Top of Ground Plane.
TGP - BGP = Ground Plane Thickness.
RTSH = Radius of TGP to slant height reference notch.
L1PC = L1 Phase Center.
L2PC = L2 Phase Center.

Note:

All NGS CORS (Continuously Operating Reference Stations) use L1PC as the station reference mark. Most IGS (International GPS Service for Geodynamics) fiducial stations use the ARP as the station reference ground mark (individual station logs should be consulted for details).

The L1PC is not always above the L2PC (e.g., Dorne Margolin antennas). Sometimes L1PC • L2PC (e.g., Ashtech Geodetic L1/L2 L antennas).

<u>Recording antenna heights in the field</u>

First of all, a distinction must be made on the methodology employed to measure antenna heights. There are three possibilities:

a) Direct vertical height measurement.

b) Slant height measurement.

c) Special cases such as Leica/Wild SR-299

a) This procedure is less accurate and should be restricted to fixed poles. Nevertheless, in such cases, a clear reference should be made in the log stating "from where" and "to where" the vertical height was calibrated and/or measured. Generally, this information comes from calibrations previously performed at the laboratory before the antenna is used in the field. It is important to specify if the known calibrated values refer to the TGP, BGP, or L1PC.

When using a fixed pole, make sure the bubble is leveled and shaded from the direct rays of the sun when plumbing is performed. Plumbing bubbles must be shaded for at least 2 minutes before checking and/or re-plumbing. The perpendicularity of the poles must be checked at the beginning of the project and any other time when suspicion of a problem arises.

b) When slant heights are measured, it is critical to record if the readings made with the "measurement height stick" refer to the TGP or to the BGP. This information should always be explicitly written in the station logs. Because they are easier to read, it is recommended that, whenever possible, measurements to the TGP be made. This assumption will be used for the remaining discussion. A minimum of 1 millimeter reading precision is expected for each slant height reading.

Every individual slant measurement (a minimum of three) and the "mean slant height" should be clearly shown in the logs.

Once the mean slant height (MSH) with respect to the TGP is known, the following equation should be used to determine the height of L1PC with respect to the MON.

Height of L1PC above mark = SQRT(MSH^2 - $RTSH^2$) + (TGP to L1PC)

The final antenna height determined in the field is the distance between the station reference point (generally the MON) and the L1PC. This final value and all intermediate steps used to compute it should be clearly stated in the log sheet. This implies that constants such as "TGP to L1PC" used in the computations should be explicitly given, indicating the reference source.

c) The Leica/Wild SR-299 antenna has a special mount design deserving some comment. In the tripod set-up option, the vertical height is measured from the bottom of the "hook" (e.g., ARP). From that point to the top of the GRT44 carrier, a constant of 0.350 m should be added. Finally, the distance from this point to the currently calibrated NGS L1PC is 0.116 m. Consequently, the total vertical height from the assumed ARP to the L1PC is 0.4660 m (which is the number to be used in PAGE4).

<u>Antenna specifications in NGS' GPS software</u>

Several values related to the station antenna height appear as input on different files required by NGS' GPS software. Depending on the type of software used, the following possibilities arise. Besides precise height information, consideration of antenna/elevation-dependence phase corrections is a must when different antenna types are combined. The antenna phase center corrections are dependent on the elevation of the incoming signal. The two GPS reduction programs currently used at NGS, OMNI and PAGE4, apply these corrections when using mixed antennas.

TO: NGS Field Parties

FROM: Stephen Hilla
Systems Development Division

SUBJECT: New versions of MERSET and MERGE
(MERSET.IAF and ANT_INFO.001)

DATE: 29 October 1997

The MERSET and MERGE programs have been updated to add a new antenna: the Ashtech Choke Ring antenna (with radome), Part No. 700936C. They have also been modified to run now using input files that list different types of antenna information. In the future, when new antennas are added, only these antenna files will change and not the MERSET and MERGE programs themselves.

The MERSET 4.00 program now reads a file called MERSET.AIF. This file lists the different antennas and their TGP->phase center offsets. MERSET now creates a merge.inp file that shows antenna "names" for each station rather than integer antenna codes. The new MERGE program will use these antenna "names" to apply the correct antenna phase pattern. The MERGE 4.00 program reads MERSET.AIF and also a file called ANT_INFO.001. The latter file contains the antenna phase patterns. Both antenna files should be stored with the *.exe files in the OMNI directory.

There are now six antennas (out of 12) listed in MERGE that do not have a groundplane. For the Dorne-Margolin T antenna, the distance from the bottom of the preamp to the top of the circular plate (beneath the choke rings), is 0.0382 meters. For MERGE, we will consider this circular plate to be the groundplane. This same measurement (0.0382) is also used for the Trimble Choke Ring Antenna. The offset (0.0379) is used for the Ashtech Choke Ring.

The Leica SR299 and SR399 receivers have antennas that are built-in. They use the same antenna pattern exactly (i.e., if you have Leica SR399 data, you can use the SR299 antenna in the MERGE menu). For these two receivers, the antenna height to be entered into MERGE is the vertical height from the monument to the manufacturer's L1 phase center.

Leica also has two receivers named the SR299E and SR399E. The "E" stands for EXTERNAL antenna. The antenna used with the SR299E has the lettering AT202 on the outside. The antenna used with the SR399E has the lettering AT302 on the outside. These two antennas are identical -- use the SR299E antenna in the MERGE

menu. The antenna height is from the monument to the manufacturer's L1 phase center. The antenna height for the Topcon Turbo-SII antenna is handled the same as the Leicas -- the antenna height entered into MERGE is the height from the monument to the manufacturer's L1 phase center.

The following is a list of the offsets used in the MERSET/MERGE programs. These offsets in MERSET/MERGE match the latest values derived by Gerry Mader. If you have any questions you can call me at (301)713-3202, Ext. 162 or e-mail me at steveh@ngs.noaa.gov .

ANTENNA CONSTANTS FOR MERGE VERSION 4.00
(all dimensions are in meters)

Antenna Manufacturer and Part Number	TGP to L1PC	TGP to L2PC	BPA to TGP	Thickness of Ground Plane
Trimble P/N:14532-00	0.0151	0.0115	0.0629	0.0032
Trimble P/N:22020-00	0.0160	0.0101	0.0591	0.0035
Ashtech L1-L2 (Z-12) P/N:700829, U.S.C.G.	0.0272	-.0047	0.0648	0.0032
Ashtech P/N:700228D	0.0173	0.0143	0.0635	0.0035
Trimble P/N:23903-00	0.0199	0.0133	0.0631	0.0035
Ashtech P/N:700718	0.0225	-.0014	0.0648	0.0032
Dorne-Margolin T	0.0718	0.0898	0.0382	0.0034
Trimble P/N:29659-00	0.0713	0.0895	0.0382	0.0034
Ashtech P/N:700936C	0.0701	0.0903	0.0379	0.0031

Antenna Manufacturer and Part Number	MANL1 to L1PC	MANL1 to L2PC	ARP to MANL1
Leica SR299/SR399	0.0221	0.0262	0.0910
Leica SR299E/SR399E	0.0295	0.0131	0.0390
Topcon P/N:72110	0.0524	0.0331	0.0947

(L1PC = the NGS L1 Phase Center, L2PC = the NGS L2 Phase Center,
TGP = Top of Ground Plane, BPA = Bottom of PreAmplifier,
P/N = Part Number, MANL1 = Manufacturer's L1 Phase Center,
ARP = Antenna Reference Point (top of bayonet for the Leicas,
BPA for the Topcon antenna))

Attachment 14
Where to Find NGS Orbits

NOAA post-fit ("precise") GPS orbit data, computed by the National Geodetic Survey, are available on the WWW at: http://www.navcen.uscg.mil/gps/precise/default.htm

To access from the NGS Home Page at http://www.ngs.noaa.gov/ Click on "PRODUCTS SERVICES", "GPS Orbital Data", "USCG NAVCEN", then select "(NGS) Precise Ephemeris Data" from the drop down menu.

This page gives access to the ephemeris files in various formats and provides utility programs that can be used to decimate and concatenate the files to cover a desired time range.