Title

The PIN1 and PIN2 GPS Sites at Pinon Flat Observatory

Authors

Wyatt, Frank K
Agnew, Duncan Carr

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Frank. K. Wyatt

Duncan Carr Agnew

Institute of Geophysics and Planetary Physics
Scripps Institution of Oceanography
University of California, San Diego

1. Introduction

The continuous GPS sites at Piñon Flat Observatory (PFO) (which are called, naturally, PIN1 and PIN2) are two of the oldest continuous GPS sites in southern California and are also the originals of the drilled-braced monument design now in wide use. They are unique in providing a long-term record between two closely-spaced monuments. Unfortunately that record, particularly in its earlier phases, is somewhat complicated because of many changes made in the systems used. Some of these changes were done as part of tests; others were unavoidable consequences of attempting to make continuous GPS measurements at a period (the early 1990's) when the equipment available was much more cumbersome, and much more expensive, than later: the expense meant that a succession of equipment had to be borrowed from different sources in order to collect data continuously.

This document describes these changes in a form more complete than the usual standardized GPS site logs allow, partly as backup to a paper giving results from an analysis of the baseline between these monuments (Agnew *et al.* 2005), which used the L1 and L2 signals separately to get higher precision. We refer to this as the ''baseline'' analysis. These sites have also been analyzed as part of the network analysis done routinely by the Scripps Orbit and Permanent Array Center (SOPAC) and by the Jet Propulsion Laboratory (JPL). Section 6.2 describes how the corrections given here can be applied to the SOPAC time series, and compare these to the offsets determined by SOPAC. Note that the SOPAC analysis makes use of a site history log; since this is a dynamic document, when we refer to this site history we mean the version of June 2004.

Following our custom for most PFO projects, we maintained a detailed log of the construction of these monuments and, later, of various activities related to them. Appendix A has been compiled from these logs, omitting material about other sites and about issues, such as telemetry, that were important to keep track of at the time but which are unlikely to be of relevance in processing the data or understanding the results. In keeping these logs we preferred too much completeness rather than too little; but a consequence of this, and of the diary form used, is the difficulty of extracting an overview, so we provide that here.

2. Monument Designs

The two monuments at PFO aimed to meet slightly different goals. Both had the goal of being, to the greatest extent possible, anchored to depth and decoupled from the surface, as the NGS Class A rod-mark design does for the vertical (Floyd 1978). For PIN1 we had the additional goal, viewed as important at the time, of providing an actual ground mark (like the usual geodetic mark), with an antenna-mount that could be precisely positioned over it, and could be removed and precisely reset. For PIN2 we wanted to build a much simplified, more readily constructed GPS antenna mount, and still retaining stability.

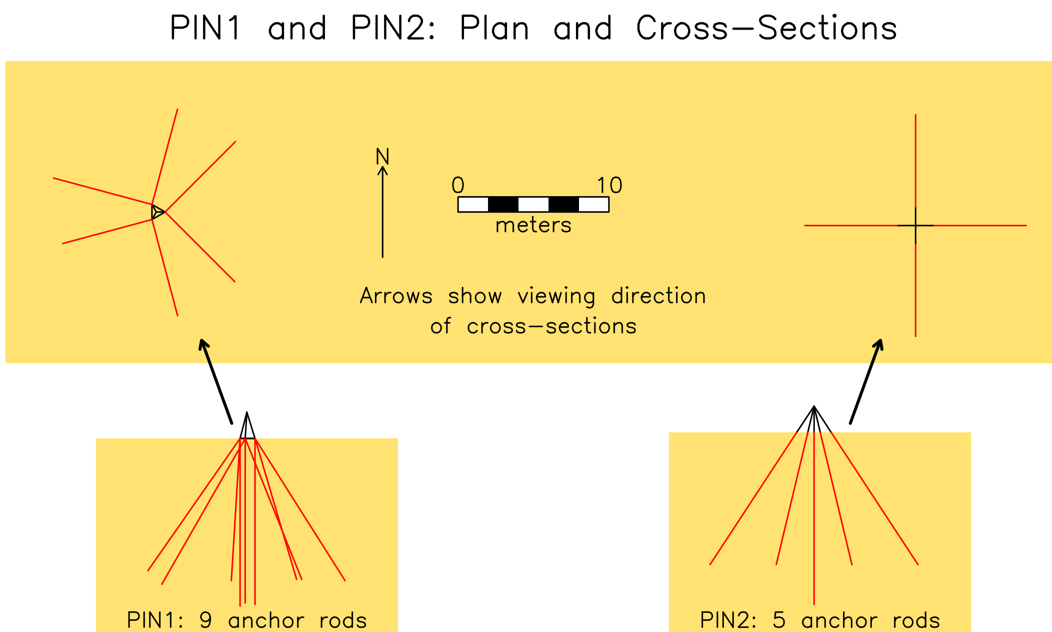

Figure 1

Figure 1 shows, schematically, the resulting monument designs, at the top in plan view (including the separation between them) and at the bottom in cross-section (to true scale). **Figure 2** shows the appearance of the monuments in February 2005, looking southeast. The PIN1 design incorporated a specially-built rigid tripod as the antenna mount, and a specially-anchored base. The feet of the tripod have V-grooves which sit on adjustable rounded-end bolts screwed into the base; this is a kinematic mount (Furze 1981), which allows the tripod to be removed and precisely reset, without subjecting it to any stress. The bolts are adjusted to make the head of the tripod (called the ‘‘hat’’) level; the hat can be adjusted to position its center hole vertically over the mark. The antenna is attached to the hat by a fixture that is a sliding fit to the center hole in the hat.

The PIN1 base is a stainless-steel triangle, with the mark welded at its center, and the receptacles for the tripod support bolts welded on the apices. From each apex of this triangular ground-level frame three pipes (set in place and then welded to the base) extend 11 m; these pipes are cemented-in below a depth of (about) 5 m to anchor the frame, and the top part of each pipe has compliant foam around it to provide decoupling.

Figure 2

The pipes are galvanized steel, Schedule 80. One of each triplet of pipes is vertical; the other two are angled at 35° from the vertical, and (in plan view) at right angles to each other.

PIN2 turned out to be the prototype for the SCIGN (and PBO) drilled-braced monument. This design uses pipes intersecting at a single point above the ground surface, with the antenna mounted as close as possible to this intersection point. For redundancy, there are five pipes, one vertical, and four at 35° from the vertical, (and in plan 90° apart, and running NS and EW). These five pipes thus intersect the ground in a quincunx (Browne 1658/1964). The intersection point is at a height of ~1.75 m, to agree with the height of the tripod at PIN1 (see the log entry for 2004:334). The anchor-pipe lengths are, again, about 11 m: a depth of 9 m for the angled pipes.

3. Adaptor and Antenna History

Much of the complication of the history of these sites comes from the different ways in which the antennas have been attached to the monument. The details are given in the log; here we outline the terminology used, and provide summary results.

3.1. PIN1

Prior to 2001:059, none of the antennas used for the permanent systems at PIN1 could be set directly on the tripod hat because of physical interference from the cable connectors or some other part of the antenna. Therefore, different standoffs were used between the hat and the antenna base. All of these had close to the same height, but not exactly so. The various standoffs used were:

Trimble Standoff. This is an black, anodized aluminum cylinder, Trimble P/N 14791, which has a nominal length of 3.89″ (0.0988 m) according to a label etched on it, but measures 3.90″ (0.0991 m)

UCSD Standoff. An imitation of the Trimble standoff, but with height 3.875″ (3 7/8″, or 0.0984 m).

UCSD Choke-Ring Standoff. A standoff for the Allan Osborne choke ring (IGS type AOAD/M_B), which did not have the standard 5/8″×11 threads. Since the cable connectors are on the bottom of the antenna near the center, a standoff was needed that would keep these above the hat. This standoff has an upper adaptor ring to fit the bolt circle of the choke ring (8 3/8″); this ring is attached to an aluminum cylinder of 8 ¼″ OD. Our aim was to match the adaptor height to the Trimble standoff (3.890″) but the actual height (measured July 2004) is 3.4″ for the cylinder plus 0.45″ for the ring, or 3.85″ total (0.0978 m). This adaptor attaches to the bottom of the choke ring, but for this type of antenna this point, not the preamp, is the antenna reference point.

JPL Choke-Ring Standoff. A standoff for the JPL choke ring (IGS type JPLD/M_R); according to notes from Steve DiNardo, the height of this was measured as 3 7/8″ (0.0984 m) in July 1990.

The history of these standoffs, reconstructed from the log, is given in Table 1, first for the continuous site and then for a one-day occupation done in 1993 to tie sites together. (A second one-day occupation, on 1997:023, involved removing the standard tripod). After 2001:059 no standoff was used. Note that the full antenna height is the height given here, plus 1.745 m as the height of the top of the tripod hat: this value is (somewhat) nominal, but confirmed by the measurements on 1990:040 and 2004:175—14 years apart.

Table 1

From	To	Standoff Type	Height (m)
1990:040	1990:073	Trimble	0.0991
1990:074	1990:156	UCSD Choke-ring	0.0978
1990:169	1990:217	JPL Choke-ring	0.0984
1990:218	1991:044	UCSD Choke-ring	0.0978
1991:045	1991:180	UCSD	0.0984
1991:181	1991:276	JPL Choke-ring	0.0984
1991:297	1992:268	UCSD Choke-ring	0.0978
1992:269	1993:173	UCSD	0.0984
1993:174	1993:308	UCSD Choke-ring	0.0978
1993:309	1995:214	UCSD	0.0984
1995:214	2001:058	UCSD Choke-ring	0.0978
2001:059	present	none	0.0000
1993:230	1993:231	UCSD	0.0984

3.2. PIN2

The uppermost permanent part of the PIN2 monument is the end of the vertical anchoring pipe, which is threaded with a pipe thread (1.25″ NPT), onto which different adaptors could be screwed. As a permanent reference mark for the vertical, a divot about 1 mm in diameter was punched in the N side of this pipe when the monument was built; the top of this divot (TOD in the log) is the vertical reference. There is no physical point as horizontal reference (nor any ground mark), but the center of the pipe at the TOD level can be taken as a notional one. As described in several points in the log this pipe is not, however, exactly vertical; the best estimate, derived from the measurements between the lower and upper plate of the SCIGN adaptor (1998:295) is that it is tilted −1.0° to the

East and 0.5° to the North.

Two adaptors have been used to go from this pipe to the 5/8″×11 thread that is standard for GPS antennas.

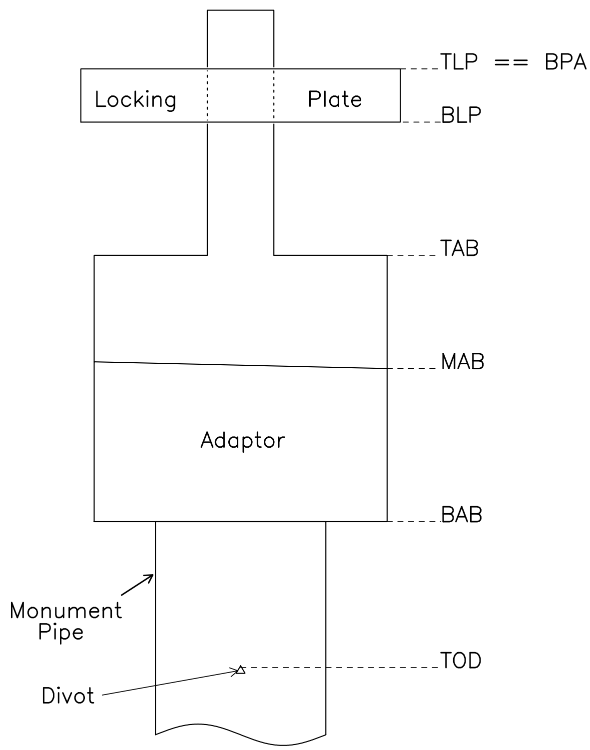

Figure 3

3.2.1. D1 Adaptor

From **1990:060 through 1998:295**, the adaptor was a "Type D1": a unique type, sketched in **Figure 3**. This consisted of two pieces, a lower one with a female pipe thread, and an upper one with a male 5/8″×11 thread. The top part of the adaptor was machined so that its axis was tilted by 1.3° relative to the axis of the bottom piece, to try to make it vertical when attached to the monument. The antenna was screwed onto the top thread until seated, backed off to be properly aligned to North, and then held in place by a locking plate 0.505″ (0.0128 m) thick screwed up to the bottom of the antenna with a nut. This usually meant that the antenna would be on by about 5.75 to 6 turns. Possible reference levels for this adaptor were the bottom of the adaptor (BAB), the join between the two pieces (MAB) and the top (TAB). The easiest measurement to make of antenna height was from TAB to the bottom of the preamp antenna (BPA)—which is equivalent to the top of the locking plate (TLP). (The bottom of the locking plate (BLP) was sometimes used). Because of the way in which the adaptor was machined, measurements from the BAB point were not the same on all sides.

The shop drawing for this adaptor indicates that the distance MAB-TAB should be 1.00″ (0.0254 m), and the distance BAB-MAB should be a maximum of 1.5″ (0.0381 m) and a minimum of 1 7/16″ (1.4375″, or 0.0365 m), making the distance BAB to TAB 0.0636 to 0.0619 m. The diameter of the adaptor is 2.75″ (0.0699 m). Actual measurements in 2004 make the distance from BAB to TAB somewhat shorter than the drawing, from 0.0618 to 0.0604 m, perhaps because the distance MAB-TAB seems to be less than 1″. Another in-lab test was to put a nut on the top thread and turn it 6 turns, then put the locking plate on it and measure the distance TAB to BLP (and hence BAB to TLP): this gives a distance TAB-TLP of 0.0439 m, with a scatter of less than .0001 m. For 5 7/8 turns the distance would then be 0.0442 m, and for 5.75 turns 0.0445 m.

Measurements in the field were made from a variety of points. Obviously, the most variable might be TAB-TLP (equivalent to TAB-BPA), since the antenna might have been put on differently at different times, and because different antennas would end up at slightly different heights when backed off to be oriented North. The relevant measurements are given in Table 2.

Table 2

Date	Based on	Value (m)
1991:066	TAB-BPA	0.0453
1993:105	TAB-BPA (N)	0.0442
"	TAB-BPA (S)	0.0440
1993:229	MAB-BLP	0.0448
1993:244	TAB-BPA	0.0445
1993:244	MAB-BLP	0.0446
1993:252	TAB-BPA	0.0442
Trimble antenna replaced by choke ring on 1997:023		
1997:023	TAB-BPA	0.0452
1997:264	TAB-BPA[1]	0.0445
1997:264	TAB-BPA[1]	0.0440
1998:295	TAB-BPA (N)	0.0437[2]
1998:295	TAB-BPA (S)	0.0434
1998:295	TAB-BPA (E)	0.0434
1998:295	TAB-BPA (W)	0.0442

1. Two measurements, one for the milled antenna (in place from 1997:023), the second for the cast antenna (from 1997:264 until the adaptor was changed on 1998:295).

2. The antenna was found twisted 15° W of N on 1998:295; this would change the elevation by only 0.0001 m.

Another field measurement needed is from the top of the divot to the bottom of the adaptor (TOD to BAB). This was measured directly on 1993:244 as 0.0360 m, on 1993:252 as 0.0365 m, on 1997:023 as 0.0357 m, and on 1997:295 as 0.0363 m. An indirect measurement of the total height (TOD to BPA) on 1991:066 was 0.1435 m, which after subtracting 0.0453 (TAB to BPA) and 0.0618 (BAB to TAB) gives 0.0364 m.

The least certain measurements are of the tilt of the upper part of the adaptor as actually installed on the monument. The lower part of the adaptor has letters written on it; from measurements in the lab in 2004, the tilt is 0.3° towards the "A" mark (along the "A-C" axis), and −1.1° towards the "B" mark (along the "B-D" axis). Unfortunately the azimuth of these letters was not recorded after the adaptor was put on. Measurements on 1998:295 suggest that ''B'' was North, and ''A'' East. This, with the pipe tilt given above, makes the net East tilt −0.7°, and the net North tilt −0.6°. Actual measurements of the tilt of the Trimble antenna ground plane on 1993:174 give a tilt of −0.9° E and −1.1° N. For the calculations below, we adopt −0.7° for both E and N tilt; assuming an uncertainty for the tilt of 0.3° each for the pipe and the top of the adaptor gives a horizontal uncertainty of 0.6 mm.

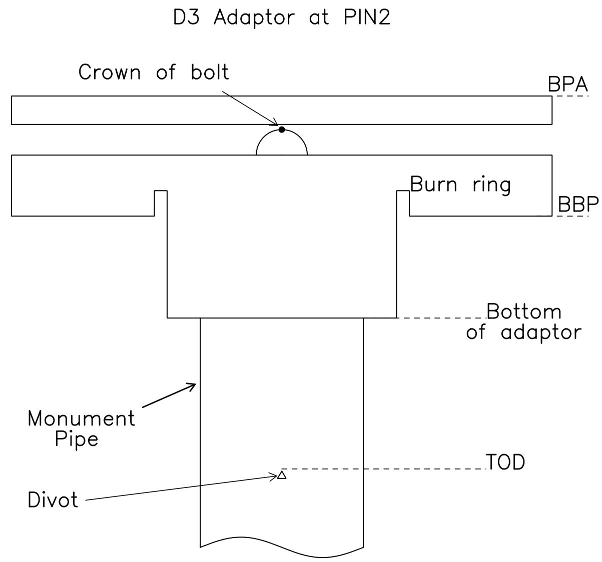

Figure 4

3.2.2. D3 Adaptor

From **1998:295 onward**, a standard SCIGN D3 adaptor (**Figure 4**) was installed, though it was removed and replaced on 1998:344 (to install a tall dome with unsplit baseplate) and again on 1999:110 to replace the unsplit with a split baseplate. However, measurements on 1998:295 and 2004:175 give the height from the TOD to the bottom of the adaptor as 0.0394 m and 0.0396 m, so this adaptor can be taken as fixed.

Because the bottommost part of the adaptor is not precisely machined, the measurement needed is to the bottom of the bottom plate (BBP). The measurements on 2004:174 give this as 0.0640 m (measured directly) and 0.0642 m (measured to the bottom of the burn ring, corrected by the nominal depth of 0.25″ for that ring). (Using the nominal dimensions from the bottom of the adaptor to the BBP point gives 0.0640 m.) As is conventional with this type of adaptor, the antenna height is referred to the center (crown) of the rounded bolt in the lower plate of the adaptor—not to the divot on the monument pipe. This point is 0.900″ (0.0229 m) above the bottom of the lower plate, making it 0.0869 m above the TOD. The antenna height (BPA) is 0.0083 m above the crown of the bolt, fixed by the dimensions of the adaptor.

3.2.3. Combined Estimates of Antenna Offsets

Putting all this information together, we can get the antenna offsets relative to the permanent point represented by the center of the monument pipe at the level of the top of the divot. For both types of adaptors, the offset is a slightly ‘‘dogleg’’ path, first along the pipe to a point within the adaptor, then along another direction from that point to the antenna reference point.

For the D1 adaptor, the first leg has the pipe tilt, and runs from the TOD to the MAB; this is 0.0363 m (adopted for TOD to BAB) plus 0.0373 m (mean value of BAB to MAB, from drawing), for a total of 0.0736 m. The second leg has the adaptor tilt, and is 0.0254 m MAB to TAB, plus (for the Trimble antenna) 0.0442 m, for a total of 0.0696 m. This makes the total vertical 0.1432 m, very close to the measured 0.1435 m adopted by SOPAC. The horizontal offsets are, from TOD to MAB, −0.0013 m E and 0.0006 m N, and from MAB to BPA, −0.0009 m E and N, for a total of −0.0023 m E and −0.0003 m N. However, because the antenna is tilted, we need to add an additional offset that is the amount of tilt times the elevation from the BPA to the phase center, which we can take to be 0.070 m: an adequate approximation for the L1 and L2 phase centers for this antenna. We thus need to add −0.0008 m E and N to get the offset of the phase center, making the total offset −0.0030 m E and −0.0010 m N.

The Ashtech choke ring installed on 1997:023 seems to have been at the same height as the Trimble antenna (from the measurements in Table 2, and the analyzed data). It appears that after 1997:265 the height should be lowered to 0.1424 m. This changes the horizontal offset of the BPA by a negligible amount. However, the elevation from BPA to phase center changes to 0.116 m (a roughly weighted mean of the L1 center elevation of 0.110 m and the L2 elevation of 0.128 m), so the tilt of the antenna means that we need to add −0.0014 m (E and N) to the horizontal offset of the BPA, making the total offset of the phase center −0.0036 m E and −0.0016 m N.

For the D3 adaptor, the two legs of the dogleg are along the pipe to the reference point in the crown of the support bolt, and vertically from that point to the base of the antenna. The first leg is thus 0.0869 m along the pipe, and the second leg is 0.0083 m vertical from the bolt crown to the preamp base. This gives a total vertical offset of 0.0952 m, and horizontal offsets of −0.0016 m E and 0.0008 m N, both for the reference point and for the antenna phase center, relative to the pipe center at the level of the divot.

We expect the physical offset in the vertical from the change of adaptors to be 0.0952−0.1424 or −0.0472 m: that is, the antenna moved down by this much. We can check this by using the measurements against another reference, namely the level-rod scale that is clamped to the monument. On 1998:295 the distance from the 4.3′ mark on this scale to the bottom of the preamp was 0.0871 m (allowing 0.0348 m from the bottom of the preamp to the bottom of the choke ring). On 2004:175 the distance from the 4.2′ mark (the 4.3′ mark having been removed) to the bottom of the dome baseplate (0.316″ thick) was 0.0305 m, which makes the distance from the 4.3′ mark to the bottom of the preamp 0.0392 m. This is a change of −0.0479 m, which agrees with −0.0472 m at the millimeter level.

The horizontal offsets for the change in adaptor are, in going from the Trimble to the choke ring on the D1 adaptor, −0.00056 m in E and N. In going to from the D1 to the D3 adaptor, the offset is 0.0020 m E and 0.0024 m N. If we take the horizontal reference point to be vertically below the bolt crown in the D3 adaptor, but at the level of the pipe divot, we have an offset for the choke ring on the D1 adaptor of −0.0020 m E and −0.0024 m N; for the Trimble on the D1 adaptor, we add 0.00056 m to get a total offset of −0.0015 m E and −0.0018 m N. These numbers need to be subtracted from the measured distances to convert them all to distances for a common reference point (Section 5).

4. Tests and Disturbances

A variety of tests and changes were made at one or another of these marks. This section summarizes these events; details are given in the log.

4.1. Site Ties and Local Surveys

Because of the shortness of the PIN1-PIN2 baseline, it could also be measured with conventional survey methods, in particular by using a high-precision EDM to measure between these points (and other marks). These surveys did involve disturbing the GPS antennas, at PIN1 usually by removing the tripod with the antenna left on it; and at PIN2 by unscrewing the antenna from the thread atop the adaptor. Table 3 shows the dates of these surveys and which sites were disturbed, along with the ‘‘survey number’’ (which is nonconsecutive because not all surveys included these points). It also includes occasions on which the antennas for the permanent sites were removed so that local site ties could be done with the same antennas at all sites; these ties are numbered with Roman numerals (again, not including surveys that did not involve disturbances of these marks).

Table 3

Number	Date	Disturbance at		Comments
		PIN1	PIN2	
	1991:179		•	UCLA removed until 1991:205
1	1991:183	•		EDM survey
2	1992:319		•	EDM survey
6	1993:058	•	•	EDM survey
7	1993:188	•		EDM survey
9	1993:222	•	•	EDM survey
10	1993:229	•	•	EDM survey
VII	1993:230	•		site ties
11	1993:237		•	EDM survey
12	1993:251	•	•	EDM survey
15	1993:310		•	EDM survey
16	1993:351		•	EDM survey
20	1994:281	•	•	EDM survey
23	1995:235		•	EDM survey
VIII	1997:023	•	•	site ties
25	1997:023	•	•	EDM survey

4.2. Environmental Tests (PIN2 only)

Because the PIN2 site could be regarded as ‘‘redundant,’’ it was an attractive place to try various tests on the effect of different environments close to the antenna, such as (artificial) trees and fences, and different domes. The details of these tests are all given in the log, which includes for each change the days it affects; note that in most cases whatever change was made was done for a day (a UTC day, approximately), undone for the next day, redone, and so on. Table 4 gives the days on which the test caused a noticeable change in the PIN1-PIN2 baseline—this is in general on alternate days only, as described in the log.

Table 4

Span	What	Days Affected
1998:162—188	Fence test #1	
1998:198—204	Tree test #1	198 200 202 204
1998:211—218	Tree test #2	211 212 214 216 218
1998:240—246	Tree test #3	240 242 244 246
1998:260—265	Fence test #2	260 262 265
1998:267—288	Fence test #3	267 269 271 282 284 286 288
[1998:344]	Dome added	all days (new reference level)
1998:357—365	Dome tests: dome off and on	357 362 364 001
1999:002—008	Dome tests: baseplate wet and dry	
1999:010—017	Dome tests: dome up and down by 0.014m	010 012 014 017
1999:020—031	Dome tests: dome tipped N and S	020 021 022 023 024 025 027 029 031
1999:032—040	Dome tests: dome tipped E and W	033 035 037 039 040
1999:057—063	Short Dome tests: dome shifted N and S	All days
1999:065—072	Short Dome tests: dome shifted E and W	All days
1999:073—096	Short Dome tests: dome off and on	All days
1999:118—143	Fence test #4	
1999:154—159	Different antennas swapped in and out	All days
1999:181—187	Different antennas swapped in and out	All days
1999:209—215	Fence test #5 (fence in and out)	
1999:243—334	Fence test #6 (fence up and down)	259 260 261 262 263 264 265 273 274 275 276 277 278 279

Note that one ‘‘permanent’’ change that took place in the course of these tests was the addition of a SCIGN dome to the PIN2 antenna, on 1998:344; after this, the removal of the dome counts as a disturbance.

5. A-Priori Corrections to GPS Time Series

From the material given above we can work out corrections to the time series for the PIN1 to PIN2 baseline. Of course, these corrections will depend on the antenna heights used in the processing that produced this series; as noted in the introduction, these are the heights in the SOPAC database as of June 2004, with two corrections: the time of the antenna changeover at PIN1 in late 1995 was changed to 1995:214, and the PIN1 current height (since the end of 2001) was taken to be 1.7450 m. Table 5 gives the offsets, along with the correct offsets from the summary above. (Section 6.2 discusses the corrections appropriate to the SOPAC series).

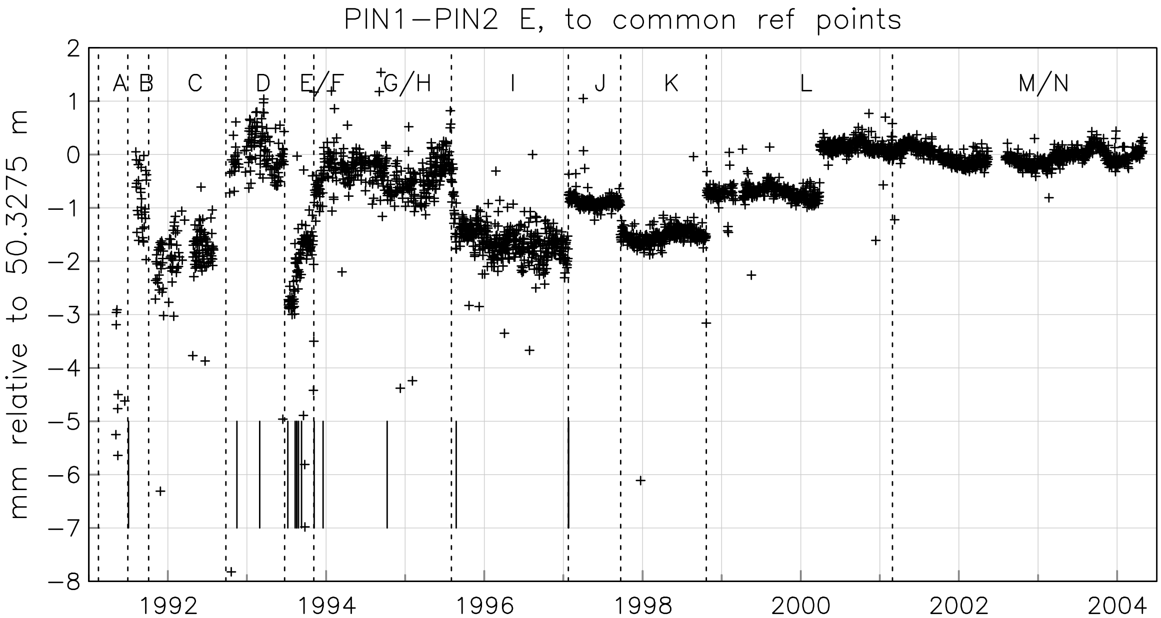

Figure 5

For PIN1 the reference point is taken to be 1.7450 m below the hat on the top of the tripod; this is within 0.0005 m vertically of the disk in the base. For PIN2 the reference point is taken to be 0.0869 m below the ''usual'' reference point on the SCIGN D3 adaptor (the center of the bolt crown): this reference is at the vertical elevation of the top of the divot on the vertical pipe of the monument. (Note that this PIN2 reference point is slightly different from the reference point used in Section 3.2.3)

Table 5

Code	From		To		PIN1 Vert		PIN2 Vert		PIN2 E	PIN2 N
					As-anal	Actual	As Anal	Actual		
A	1991	045	1991	180	1.8435	1.8434	0.1435	0.1432	-0.0015	-0.0018
B	1991	181	1991	276	1.8435	1.8434	0.1435	0.1432	-0.0015	-0.0018
C	1991	277	1992	268	1.8435	1.8428	0.1435	0.1432	-0.0015	-0.0018
D	1992	269	1993	173	1.8435	1.8434	0.1435	0.1432	-0.0015	-0.0018
E	1993	174	1993	229	1.8435	1.8428	0.1435	0.1432	-0.0015	-0.0018
F	1993	231	1993	308	1.8435	1.8428	0.1430	0.1432	-0.0015	-0.0018
G	1993	309	1993	359	1.8435	1.8434	0.1430	0.1432	-0.0015	-0.0018
H	1994	001	1995	213	1.8435	1.8434	0.1435	0.1432	-0.0015	-0.0018
I	1995	214	1997	022	1.8450	1.8434	0.1435	0.1432	-0.0015	-0.0018
J	1997	023	1997	264	1.8450	1.8434	0.1430	0.1432	-0.0020	-0.0024
K	1997	265	1998	294	1.8450	1.8434	0.1430	0.1424	-0.0020	-0.0024
L	1998	295	2001	058	1.8450	1.8434	0.0083	0.0952	0.	0.
M	2001	059	2001	365	1.7900	1.7450	0.0083	0.0952	0.	0.
N	2002	001	2004	365	1.7450	1.7450	0.0083	0.0952	0.	0.

Notes:

F and G are separate because of an error in the analysis, propagating a value for one day into later ones (station.info error)

M and N are separate because of the partial correction to the SOPAC values.

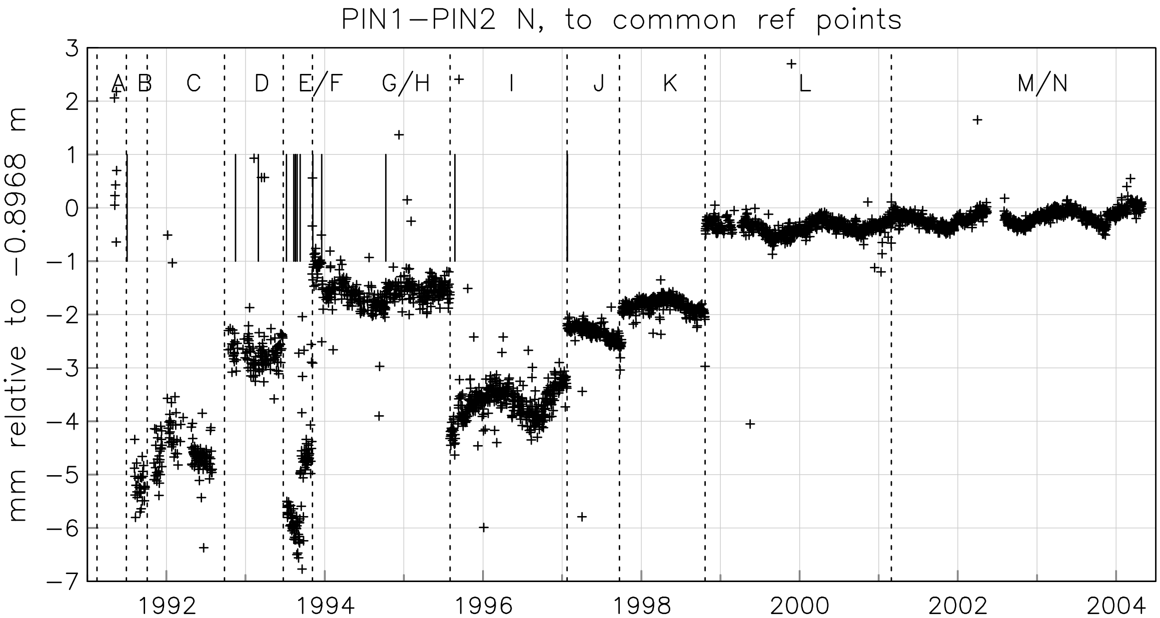

Figure 6

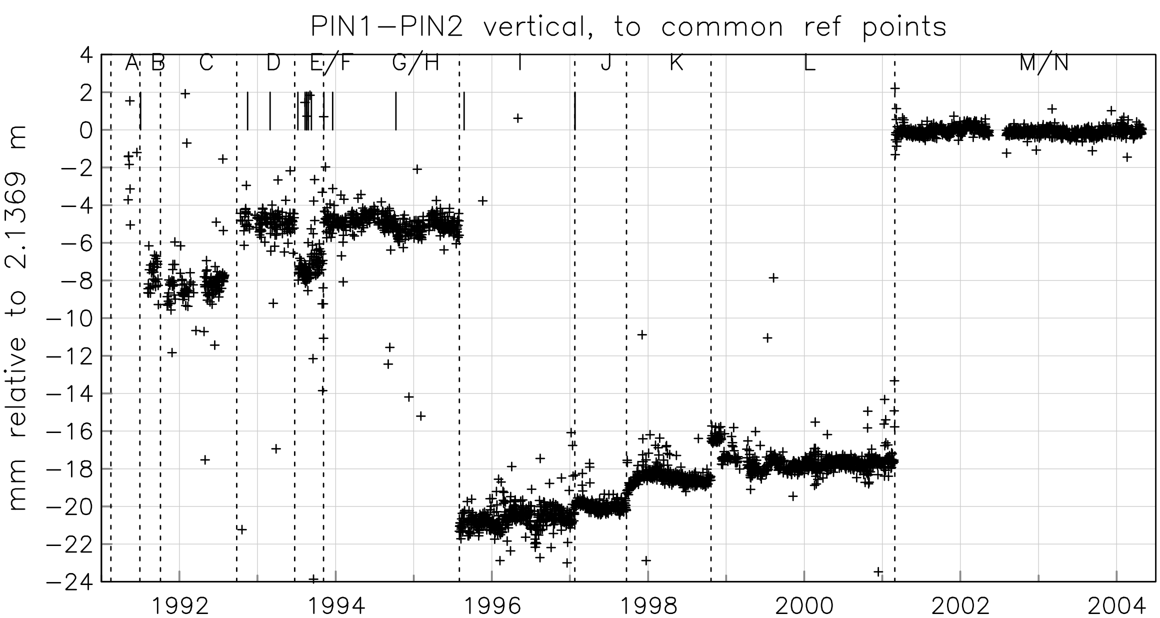

Figure 7

6. Comparison with Analyses of GPS Data

To this point we have been concerned with describing the changes in the two systems at PFO in terms of physical measurements at the site, without regard to what the GPS data show. We conclude by comparing our conclusions about site changes with those deduced from two analyses of GPS data: first, the analysis of the PIN1-PIN2 baseline described in Agnew *et al.* (2005); we call this the ''baseline analysis''. We also consider the analysis of the individual sites (as part of an analysis of a much larger number) by Nikolaidis (2002), which we term the ‘‘SOPAC analysis’’, since the results are distributed by that organization.

6.1. PIN1-PIN2 Baseline Series

To examine the consistency of the baseline series with our conclusions in Section 5, we apply the corrections deduced there to the baseline time series, to produce a time series that is nominally referenced to fixed locations on the monuments, though imperfectly so both because of errors in the measurements detailed above, and because of errors in the models used in the GPS analysis: notably the antenna phase corrections. Figures 5 through 8 show the complete time series, and Figures A-1 through A-6 (in Appendix A) detailed views of particular parts.

The overall plots show large offsets from two causes. In the vertical (**Figure 7**), the largest offset is a step down of about 14 mm on 1995:214 (the H/L boundary), when the PIN1 antenna was changed from an Ashtech model ASH700228D to an Allan Osborne antenna, Dorne-Margolin B, serial number 101. This step was recovered on 2001:059 (the L/M boundary), when this antenna was replaced by the standard SCIGN antenna. The antenna in use at PIN1 between 1995 and 2001 had also been used there from 1993:174 through 1993:308 (E/F); this period shows an offset of only 2-3 mm relative to the data before and after (collected with the ASH700228D antenna). A possibility is that the offset is caused by an improperly designated antenna type, since the processing assumed this antenna to actually be a JPL ‘‘Type R’’ choke ring, rather than the Osborne ‘‘Type B’’. However, the phase center is the same distance above the antenna reference point for both types.

It is also worth pointing out that the change of antenna on 1995:214 is followed by a very rapid drift in the E component, of 1.5 mm in 20 days (**Figure A-3**). Nothing equivalent is seen elsewhere in the series.

In the horizontal (**Figure 5** and **Figure 6**), there may be offsets at the 1-2 mm level associated with some of the EDM surveys, though in many cases there are none obvious at the few tenths of a millimeter level.

A particularly interesting offset (1 mm E, 2 mm N) is associated with the change from the D1 to the D3 adaptor (K/L). The vertical offset (best seen in **Figure A-5**) is only 2 mm, indicating that the various measurements used to estimate the relative locations of these adaptors are valid at this level—this error is too small to account for an horizontal offset this large. A possible cause (unlikely) would be an unintentional bending of the monument pipe in the course of removing the D1 monument and putting the D3 on. However, as described in Section 3.2.1, there is good agreement between the measured antenna tilt in 1993 and that deduced from the D1 adaptor dimensions and the pipe tilt measured after the D3 adaptor was put on. This would appear to rule out any bending of the pipe. Since there was no change in the antenna at this boundary, any change in the phase pattern would have to come from the varying electromagnetic effects of the different adaptors, or because the change in antenna height (lowering it by 0.0472 m), by moving it closer to the legs of the monument, changed the local phase pattern.

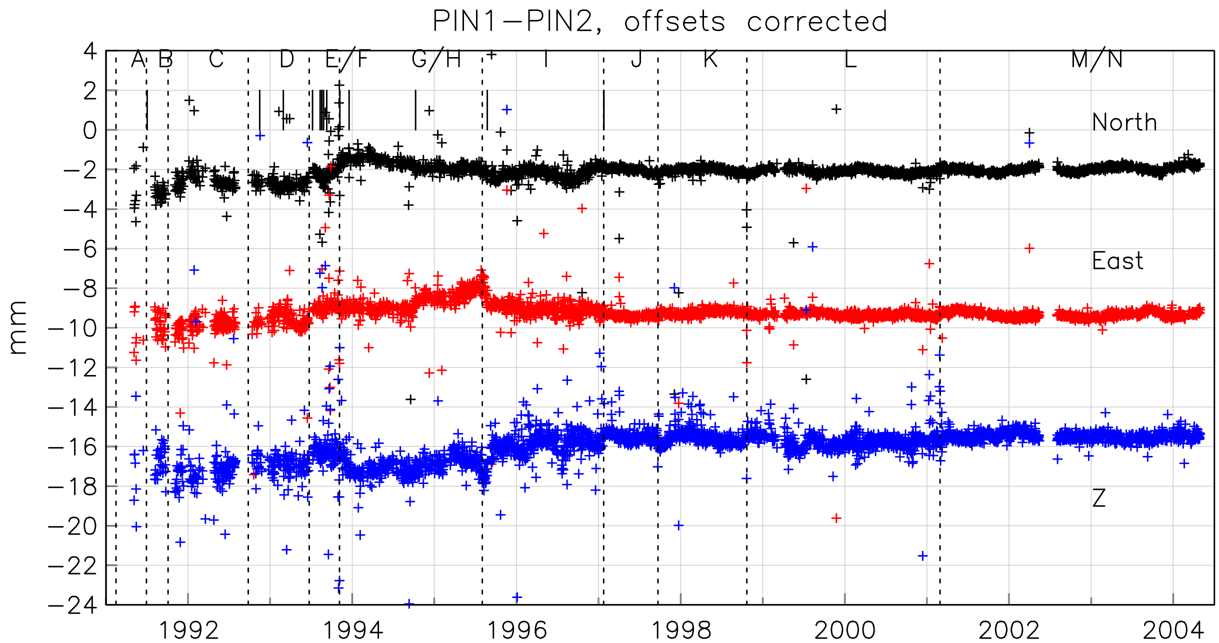

Figure 8

Table 6 lists the offsets that are obvious in the series before 1993:310, and after that date all times when there might have been an offset (the earlier period has too many possible times of offsets from the EDM surveys). The date is the day after the offset; the bullets show which ends were modified or disturbed. The offsets were first estimated by fitting (robustly) a trend to the data before and after each offset, and choosing the offset to match these; this was corrected for the early values to make the series line up "by eye". Judging by its performance over data with no offsets, the error in the trend-fitting procedure for the post-1997 data is about 0.1 mm (1-sigma). **Figure 8** shows the series after these offsets have been applied.

Table 6

Date	PIN1	PIN2	Offset N	Offset E	Offset Z	Comments
1991:181	•		−6.	3.	−6.	A/B: Change from UCSD Ashtech (and antenna) to JPL Rogue (and antenna).
1991:276	•		0.	−1.	0.	B/C: Change from JPL Rogue (and antenna) to Osborne Rogue (and antenna).
1992:286	•		2.	1.6	3.	C/D: Change from Rogue to Ashtech antenna/receiver.
1993:174	•		−3.6	−3.3	−3.3	D/E: Change from Ashtech to Rogue antenna/receiver.
1993:222	•	•	0.	0.7	0.	EDM survey number 9; see Figure A-1.
1993:251	•	•	1.0	0.2	0.6	EDM survey number 12; see Figure A-1.
1993:310	•	•	3.0	1.1	2.4	EDM survey number 15, and (at PIN1), change from Rogue to Ashtech antenna/receiver (F/G). See Figure A-2.
1993:351		•	−0.5	0.5	0.7	EDM survey number 16; see Figure A-2.
1994:281		•	0.5	−0.9	−0.8	EDM survey number 20.
1995:214	•		−2.5	−0.7	−15.1	H/I: change Ashtech antenna/receiver, to Rogue antenna. See Figure A-3, and the discussion above.
1995:235		•				EDM survey number 23; see Figure A-3.

1995:252		•	0.7	0.2	−1.3	EDM survey number 24; see Figure A-3. Offset is for 23 and 24 combined.
1997:024	•	•	0.	0.	0.3	EDM survey number 25, and site ties. At PIN2, Trimble antenna changed to Ashtech. See Figure A-4.
1997:264		•	0.	−0.5	1.3	J/K: change from milled to cast choke ring. See Figure A-5.
1997:276		•	0.5	−0.3	0.3	Change from one cast choke ring to another. See Figure A-5.
1998:295		•	1.75	0.9	1.9	Change from D1 to D3 adaptor; see Figure A-6, and the discussion above.
1998:344		•	−0.3	0.	−0.95	Dome put on PIN2 antenna; see Figure A-6.
2000:089		•	0.15	0.9	0.	Change from ASH700936E_C to ASH701945B_M.
2001:059	•		0.	−0.2	17.35	Change of antenna from AOA choke ring, to ASH701945C_M (SCIGN standard).

6.2. PIN1 and PIN2 Individual Series

Because of the errors in the SOPAC site history log when the SOPAC time series was computed, a correction of the series to a common reference point will not address all of the changes correctly. We therefore instead compare the offsets computed in three ways: first, from the individual time series by Nikolaidis (2002); second, from the same fitting procedure as used in the previous section, but applied to the difference of the individual site series; and third, from the baseline time series (uncorrected). Table 7 gives the results.

Table 7

Date	PIN	SOPAC			PIN2-PIN1			Baseline		
		N	E	U	N	E	U	N	E	U
1991:181.5	1	0.	-17.8±0.9	-47.8±2.8				-6.	3.	6.
1991:297.5	1	0.	-0.6±0.8	0.				1.	0.	0.
1992:269.5	1	0.	0.	-18.2±2.9				-2.6	-1.6	-1.3
1993:175.5	1	0.	0.	19.2±2.5				3.2	3.6	2.7
1993:310.5	1	-4.3±0.9	0.	0.				-1.1	-3.0	-1.8
1995:214.5	1	0.	5.4±0.9	-32.4±2.6						
1995:245.5	1	2.5±0.9	-7.0±0.9	49.8±2.6						
1997:023.5	1	0.	0.	-1.9±2.4						
1997:026.5	2	4.0±0.8	0.	-9.5±2.1	4.7	2.5	-9.1	0.6	0.5	0.8
1997:264.5	2	-2.0±0.8	-1.5±1.2	0.	-2.9	-1.2	5.3	-0.5	0.	0.5
1998:295.5	2	4.2±0.8	0.	93.3±2.0	4.1	1.2	95.5	4.1	2.9	89.4
2000:088.5	2	-2.5±0.9	5.9±1.4	0.	-2.6	6.2	0.	0.1	0.9	0.
2001:060.5	1	0.	0.	-38.8±2.4	2.1	0.	-41.8	-0.1	0.2	-60.8
2001:234.5	1	0.	0.	-43.8±2.5	0.	0.	-43.0			

The offsets deduced from differencing the two site time series (the middle set), generally confirm the offsets deduced from each time series after 1997 (earlier results were inconclusive because of much higher scatter in the data). These are often at odds with the offsets from the baseline series, by amounts beyond the errors in the estimates—though the horizontal offset from the PIN2 adaptor change matches well. The differences in the vertical are most likely because of the different phase centers involved for the different kinds of phase processing, given any incorrectness in modeling the local phase pattern of the antenna and its surroundings.

7. Conclusions

Since this document is meant mostly as reference and description, we leave interpretation to another paper. One conclusion that can be drawn is that in this case (admittedly, a complicated one), it is not possible to keep track of antenna displacements at the level of 1-2 mm purely by non-GPS measurements of the antenna position. Figures 5 through 7 show the result of doing so, and clearly have a large number of offsets unaccounted for. Given the limitations of estimating offsets from the usual GPS time series (Williams 2003), there is a clear benefit in being able to make high-precision measurements over a short baseline. This suggests that ‘‘duplicate’’ measurements of the type done at PIN1 and PIN2 would be a valuable addition to stations at which small signals are to be detected, and even more important at sites which are designed to maintain the global reference frame over long times, since over wuch times there are bound to be equipment changes of the type experienced at PIN1 and PIN2—though, it is to be hoped, many fewer ones.

Acknowledgments

The efforts of many individuals are described in the log. We owe special thanks to the ongoing efforts by Yehuda Bock and his PGGA (later SOPAC) group to establish continuous GPS in Southern California. Special thanks also to David Jackson of UCLA for providing the PIN2 Trimble receiver for what turned out to be a *very* long-term loan. The monument construction phase was much helped by the practical skills of Harold Bolton. Hadley Johnson spent a great deal of effort getting the early telecommunications set up, and in an early analysis of these data. Adrian Borsa provided the photographs in Figure 2. The construction and operation of these sites has been funded by grants from the NSF, NASA, and the USGS.

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Appendix A: Log for PIN1/PIN2 Continuous GPS Sites

A log of activities at GPS points PIN1 and PIN2 at Piñon Flat Observatory, compiled from logs and other information kept by PFO and SOPAC personnel, primarily Frank Wyatt, Steve Bralla, Hadley Johnson, Stephen Dockter, Yehuda Bock, Keith Stark, and Jeff Behr.

1989:132 (21-May-89)

1. The initial decision on where to put the Piñon continuous-GPS monument was made this day, during the PFO Annual Picnic. We selected a site on the 25-m-diameter semicircle of the existing five NGS class A rod marks; these were installed in 1986 for long-term monument stability testing, as compared with ground-truth from the optical anchor nearby. For the Class-A marks holes, 9-m deep, were augered into the ground (hardest drilling the NGS crew had done) and the rods were cemented along their bottom 0.5 m. It is most valuable to have these marks nearby, as we can easily survey to them and monitor relative vertical displacements which may be interpreted as monument instability. The first 0.5 m of the ground surface in the immediate area is loose fill and hence very soft.
2. Subsequently we decided to go a little farther to the east and south, to make construction logistics easier (drill rig won't have to maneuver so close to the other marks), and to reduce disturbance of the existing marks. This also gets us a little farther away from any possible reflections (multipathing) from the A-frame over RHO, but not appreciably farther away from the EW Laser Strainmeter pipe (24 m). The site is still within 100′ (30 m) of RHO to permit easy routing of the signal and power cabling to the antenna.

1989:200 (19-Jul-89)

1. At second UCSD Geodesy Group Meeting, Yehuda Bock suggested that enough holes be drilled at PFO for 2 monuments: we'll see if that is feasible and if there is money.
2. A secondary monument at Piñon could be used both for "baseline" tests and for developing a simplified monument design. The site for the secondary mark was chosen (after the meeting) to be due south of borehole UQA, and about 50 m away from the first monument, due east (i.e., also 24 m south of the EW laser strainmeter pipe).

1989:summer (Jul/Aug-89)

1. Planning for monuments at PFO: For the primary monument we want to fix the position of each corner of the pad's stainless-steel triangular frame with three support rods: one in a vertical hole, and two more in angled ones—a good challenge. Three holes at each corner are wanted because the support rods we will be using (actually concrete-filled pipes) provide essentially no lateral support, but are quite rigid longitudinally. And, we need support at each corner of the triangle because of the commitment (initially at least) to put the primary antenna at Piñon on a 1.75-m-high tripod mounted on the ground-surface pad; any tipping of the pad, and hence the tripod, will look like antenna movement.
2. For the secondary monument we want to build a much simplified, more readily constructed GPS antenna mount without sacrificing any stability. The basic design is a number of pipes intersecting at a single point above the ground surface—unconventionally. The antenna is to be mounted at this intersection point. For redundancy, we chose to use five pipes, one vertical, and four at even azimuths at an angle of 35° from the vertical. The intersection point chosen to be at a height of ~ 1.75 m, to agree with the height of the tripod at the primary site.
3. The support-rod arrangement is intended to follow NGS Class A rod-mark design with the rods anchored at depth, and as unconstrained as is reasonably possible toward the surface. Our plan is to use galvanized pipe, with a special non-shrink grout forced (pumped) down the inside and part way

back up the outside of the pipe. The top 1/2-1/3rd of the pipe is to be ungrouted, though sleeved by PVC pipe to help constrain and center the pipe in the borehole while allowing for some lateral motion near the surface. The specifications for the holes and their contents at the primary site are:

A. 5½″ diameter hole to 10′, for surface casing.

B. 3½″ diameter hole to 40′-45′, for 2½″ PVC casing to 20′, and the anchor pipe to just above the bottom of the hole.

C. Surface casing: 10′ of 4″ PVC

D. Internal casing: 20′ of 2½″ Schedule 40 PVC: ID 0.1042′ (0.03175 m), OD 0.1224′ (0.03730 m).

E. Anchor pipe: 42′ of 1¼″ pipe, Schedule 80 galvanized: ID 0.0533′ (0.01625 m), OD 0.0691′ (0.02106 m). The top part of this has compliant foam wrapped around it.

At the secondary site, we omit items A and C.

4. The site for the primary GPS monument was chosen to be 9 m (30′) due east of **NGS #3**, with its tripod stand having a flat side facing due west. The secondary site was located another 50 m due east (also 24 m south of the EW LSM) from the first site.

1989:236 (24-Aug-89)

1. Drilling holes for PIN1 and PIN2 monuments.

2. PIN1: For the first vertical hole, to be at one corner of the 1-m-wide triangular frame, we drilled a 6″-diameter hole about 11½′ deep from the ground surface and set 4″ PVC-pipe surface casing (4.5″ OD). While this was going on, we dug away the floor and sidewalls of the borehole area, for a hemispherical hole about 18″ in depth, to allow us to drill the other holes (the angled ones) in the correct position, by inspection, and to cap each of the borehole casings below the ground surface. Using the drill rig, we pushed the 10′-long 4″ surface casing so it was flush with the excavation's bottom. We used driller-provided paper bags to seal around the outside of this surface casing to keep sand from filling in. It's important to seal the hole well.

3. Next, drilled a 3½″ hole through the 4″ surface casing, to a total depth of slightly more than 12.0 m (39′5″). In fact, we fell short of this because of our misunderstanding on drill-rod lengths. Ideally we would have drilled to 13 m depths to leave some room for any loose material knocked into the holes. A hole depth of 13 m is just deep enough so that two full-length sections of standard-length 21′-long steel pipe needn't be sitting on the hole bottom if it is sticking out about 2′ above the ground surface.

4. We then inserted a full section (20′) of 2½″ PVC pipe, supported at the surface with a specially made 5¼″-diameter donut (½″-thick disk bored with ~3″ hole; diameter of our donuts was a little too small here, 6″-dia would be better) followed by a coupling (or just the pipe's belled end); these pieces were assembled in advance. The donut is supposed to end up resting on the mouth of the 4″-pipe surface casing. We capped off the 2½″ casing with a very short piece of pipe and PVC cap. The caps were not glued in place. This entire arrangement must end up about (more than) 1′ below grade to allow drilling of the other holes. This 2½″ casing is to improve the odds that the hole will stay open during the subsequent drilling operations. There are some dimensions to be reckoned with here: the borehole is to be 3½″ in diameter, and the OD for 2½″ pipe is 2.875″ leaving only 0.3″ on each side for clearance in a perfectly straight hole. This is a tight fit. Again we needed the drill rig to push the pipe into the hole.

5. We want to do the three vertical holes first, at one time, to fix the position of the triangular frame, and to give us something to shoot at with the horizontal holes. We do need good alignment of all the boreholes here. The vertical holes being drilled in very close proximity, meant that each site was partially buried after it was done. For subsequent drilling of the horizontal holes we needed to

remove these spoils. This involved digging with shovels near the borehole mouth as the spoils were being blown out. We drilled the angled-holes in the same manner as the vertical one, except for waiting until the hole was completed before installing both the 4″-pipe surface casing and the 2½″-pipe borehole casing. Also, because of the angle, the drill rig couldn't penetrate to 11½′ with a single drill rod, so we simply made the 4″-pipe shorter (9′), to make sure it would fit into the 6″-diameter part of the hole. The angled holes were drilled to intersect with the vertical hole about 7″ below the ground surface, and, if possible, slightly offset from the vertical one. Surprisingly, when all was said and done, we did generally get the holes within 1-2″ of where we wanted. Despite these holes (vert and each angled hole) being drilled to intersect, we didn't have any problem with aligning the pipes side-to-side. It was an easy matter to push them sideways slightly. At the ground surface the 1¼″ pipe fits inside of the 2½″-pipe casings, which fits inside of the 4″-pipe surface-casing which in turn fits inside of the 6″-diameter boreholes (at the surface); combined, this allows for considerable adjustment.

6. The angled holes were drilled at 35° from the vertical. Any shallower than this is a headache, because: (1) you do not necessarily get into good rock due to the bottoming depth not being great, (2) it's hard for the drill rig to operate because of shifting tower weight as the drill-rod drive moves up and down, and (3) the holes tend to have greater curvature. We believe increased hole curvature (upwards) is caused by the drill bit hitting the vertical gradient of rock strength at a glancing angle.

7. Azimuthal Orientation — we wanted two angled holes for E Vertical hole to be at: 45° (~29° magnetic, assuming 14° easterly deviation) & 135°; for SW holes: 165° & 255°; for NW holes: 285° & 15°. Each pair of holes should be at a 90° angle from one another. We did fairly well at this.

8. PIN2: We simply drilled a 3½″ hole to depth and then emplaced the 2½″-pipe borehole casing. This went very quickly, only 15-20 min to complete each of the five holes. We first put five stakes in the ground, one in the center and four at equal spacing on a 35″ radius, for the angled holes to intersect at 1.75 m height. The drill rig proceeded to drill the four angled holes (35°) from vertical. Finally, we drilled the center hole, whose position was reselected to be the midpoint of the first four holes drilled. This turned out very well. With relatively little effort on our part, we ended up with all the anchoring pipes intersecting as desired, only offset by 1-2 cm — amazing.

9. Timing of drilling (summary):

PIN1:
8:24 Started drilling NW Vertical Hole with 5″ bit for surface casing.
8:30 4″-pipe casing wouldn't fit; redrilled with 6″ bit.
8:40 Pushed casing with drill head; casing wedged in hole (not on bottom ledge).
8:44 Soil @ 24′ (~ 6″ thick)
9:02 At final depth: ~ 41′- 42′ (about 6′ into #4 steel). End of first hole

9:11 Start SW Vertical Hole: 35″ south, and 6″ west of 1/9
9:48 255° Angled Hole , From vertical: ~55°, and likely curving up. @ 234° Mag 10:45 Off hole.
Poor result here: (1) Angle too shallow (especially w/ any upward hole
curvature), bad ground (nothing but weak material).
10:50 165° Angled Hole begun . From vert: 35° @ 148° Mag.
11:06 End steel #3, soil layer under brown/grey. Good result with deep dip.

11:34 E Vertical Hole started about this time

12:10 135° Angled Hole . From vertical: 35°, and @ 119° Mag
12:40 45° Angled Hole started, after 5 min driving; 38° Mag
1:40 15° Angled Hole finished — −8° Mag, 35° again
2:00 285° Angled Hole at ~ 35° from vertical

2:30 Off first 9 holes; lots of soil lenses, but generally good.

PIN2 drilling: 2:40 S Hole (1/5); 44″ offset from center, @ 35° from vertical
3:00 W Hole (2/5); ran out of drill water, and refilled.
3:50 Started N Hole (3/5)
4:15 Started E Hole (4/5)
4:30 Vertical Hole (5/5); all holes in good rock, but easily drilled.
4:45 Done, moved off holes to reload equipment on flat bed.

1989:250 (07-Sep-89)

1. Cleaning out drilled holes—blowing out the dirt. Procedure was to insert a small (1″) tube into each hole, and blow compressed air through it to remove material that had caved since the drilling, or was left after drilling (should have had the driller do this at the finish of each hole). By measuring the length of the inserted tube we can find the current depth of the hole, and comparison with the depth recorded on Aug 31 determines whether we may have a caving problem. Blowing out the sand worked in all holes; when the bottom of each hole was reached, the sound of tapping the aluminum tubing on the bottom of the hole produced a solid, almost metallic, sound in comparison to the soft sandy feel when the tubing was first inserted.

2 When blowing was completed, we inserted the pipe that forms the anchor and sealed around the hole as well as possible. The pipe was two sections of 21′-long, 1¼″ Schedule 80 galvanized steel pipe. Because we thought the drill steels were 12′ not 10′, the holes were not as deep as we had originally thought so that all our pipe ends protruded more than we originally estimated.

3. At **PIN1** all but three of the pipes went in just as planned. For the hole “135° Angled,” we had to remove the wrapping from the top section before we could insert the second section. The friction was too great to allow us to insert the wrapped section. At holes labeled “165° Angled” and “255° Angled,” we were not able to insert the second section more than 1′. Therefore we left these holes empty, to insert smaller pipe later.

4. At **PIN2** the pipe insertion went just as planned with the friction generated by the wrapped pipe requiring us to push hard for the final 10-15′.

5. Table of hole depths as found and after cleaning, in order done. Note that these are depths measured along the hole, not vertically (except for the vertical holes, of course).

Site	Hole	Before	After	Before (m)	After (m)
PIN2	Center	36′10″	37′	11.2	11.3
PIN2	South	35′	37′7″	10.7	11.5
PIN2	West	35′10″	38′2″	10.9	11.6
PIN2	East	35′8″	38′	10.9	11.6
PIN2	North	36′	38′	11.0	11.6
PIN1	165°	24′9″	38′	7.5	11.6
PIN1	255°	19′6″	39′5″	5.9	12.0
PIN1	285°	28′	39′5″	8.5	12.0
PIN1	15°	32′5″	38′10″	9.9	11.8
PIN1	45°	36′	38′6″	11.0	11.7
PIN1	135°	26′4″	37′9″	8.0	11.5
PIN1	E vert	25′	36′5″	7.6	11.1
PIN1	S vert	36′	36′2″	11.0	11.0
PIN1	N vert	36′3″	36′3″	11.0	11.0

1989:255 (12-Sep-89)

1. At PIN1, in two of the holes (165° and 255°) we were unable to insert the final 20′ of 1¼″ steel pipe.

   For angled hole 165° we made the lower section of 1″ pipe with the 1″-1¼″ adaptor already attached. We then twist tightened and pipe wrench tightened the *unwrapped* 1¼″ pipe to the 1″ pipe and lowered the assembly to depth. For angled hole 255° the procedure was essentially the same (1″ pipe for the lower section) only we used a *wrapped* 1¼″ pipe for the second section.

2. Our other job was to position the earlier inserted pipes and secure them for grouting. At PIN2 this consisted of raising the pipes until the four angled holes could be symmetrically arranged around the center vertical hole whose height was minimized above the angled pipes, and securing them in this position using a combination of U-clamps and baling wire. At PIN1 we wrapped the three groups of three pipes with two sections of twist tightened wire.

3. At PIN2, we needed to make sure things would align at the elevated intersection point. All four angled pipes must cross over one another (symmetrically) at the same height, which was intended to be at ~63″, actually at 60″ (1.52 m), and just below the vertical-pipe's end flange. The top of the flange was designed to be at 69″ height (1.75 m), but this is not critical and it should be wherever we get the best closure with the angles pipes. We seek to minimize the distance between the end-flange top and the angled-pipe intersection, to minimize the effects of tilting of the vertical pipe.

4. We decided not to do any welding at this time, though we could have, but we decided it would be nice to use some of the pipes' remaining lateral adjustment) slop for the final assembly. The grouting stage uses up much of this slop. For these reasons, it's really important to have the pipes clamped together, just as they will need to be for welding, when the grout goes in.

5. All pipes pulled about 1′ above their ''rest positions'' to allow grout to flow out the bottom. Final depths (along-hole) for bottom of hole, and of pipe:

Site	Hole	Hole Depth		Pipe Depth	
PIN1	165°	38′9″	(11.8 m)	37′4″	(11.4 m)
"	255°	40′2″	(12.2 m)	38′10″	(11.8 m)
"	15°	39′7″	(12.1 m)	37′7″	(11.5 m)
"	45°	39′3″	(12.0 m)	37′3″	(11.4 m)
"	135°	38′6″	(11.7 m)	37′10″	(11.5 m)
"	E Vert	37′2″	(11.3 m)	36′2″	(11.0 m)
"	S Vert	36′11″	(11.3 m)	36′4″	(11.1 m)
"	N Vert	37′	(11.3 m)	35′11″	(10.9 m)
"	285°	38′9″	(11.8 m)	35′1″	(10.7 m)
PIN2	Center	36′10″	(11.2 m)	36′	(11.0 m)
"	South	37′7″	(11.5 m)	34′8″	(10.6 m)
"	East	38′	(11.6 m)	35′2″	(10.7 m)
"	North	36′	(11.0 m)	35′2″	(10.7 m)
"	West	38′2″	(11.6 m)	34′11″	(10.6 m)

1989:257 (14-Sep-89)

1. Grout filling of boreholes. We aim to have a minimum of 3 meters of 1¼″ pipe anchored at the bottom of the hole. Upper 3 meters of pipe is to remain decoupled from the concrete. Some degree of this is guaranteed by our trust in the foam and tape which we have wrapped around the upper 20′ of the 1¼″ pipe.

We have only rough values for the volume of concrete pumped per stroke of pump, the exact volume of the hole, and absorption of the water added to hole. So we verify the accuracy of pumped grout depth by a general agreement of the ticks made by the pumper to a calculated approximation based on previous experience with the same pumper. If the appearance of water (pushed ahead of the grout) at the top of the holes is fairly consistent and falls within 4-8 ticks of the calculated value, we can have confidence that our holes are filled to the needed level. We have placed a compliant material around the portion of the pipe which is to remain decoupled. This protects us from grout pumped into this area. Our main concern therefore is to make sure sufficient grout has been pumped to insure anchoring the lower section of 1¼″ pipe. We seek to be on the high side of the calculated volumes of concrete pumped per hole.

3. Review of the data sheet indicates that an error was made as to the choice of holes that had grout pumped to the ground surface. We had decided that, since we did have the compliant foam to insure that the pipes could be moved after pouring, we needed to test one hole per site as to verification of grout being able to pump to the surface. This was done at the southern hole at PIN2 with the grout being extruded through the inside of the 2½ PVC. No problem here, but at PIN1 inadvertently chose the 135° angled hole of the eastern group of holes as the one to check. This oversight has caused this hole to be filled with concrete and there is no foam here to insulate the concrete from the 1¼″ pipe — whoops. As a result we have a firmly anchored hole all the way to the surface of this hole. No grout appeared outside the 2½″ PVC at this hole. We still have then some spacing left between the outside of this 2½″ PVC and the inside of the 3½″ hole wall. Though natural caving will fill this in, in time. There still is compliance of the pipe due to this gap.

4 At PIN1 the grout is estimated to be between the bottom of the 4″ surface casing and the top of the hole, except for the 15° angled hole, which was filled to just below the bottom of the 4″ surface casing.

5. At PIN2 it is estimated that the concrete rose outside the 2½″ PVC and in the inner annulus to near surface height for all holes except the East hole. This hole is more likely filled to 4—6′ above the bottom of the 2½″ PVC.

These estimates of grout heights are quite crude. Realizing that a variance of only ½″ in hole diameter produces a hole volume change of almost 20%, and that vol/pump estimates could vary by 10-15%, it is possible that grout depths are overestimated by 30-40%. Even if this were true we would still have sufficient depth to have the necessary anchoring.

1989:261 (18-Sep-89)

1. Get ready for welding which is to take place tomorrow, and estimate the orientation of the 1¼″ pipe relative to the 2½″ PVC. To ready the sites for welding we need to clean the dried grout from the 1¼″ pipe around the area of the welds. We will need to remove the wire and clamps attaching the pipes. At this time we will make our estimates of pipe displacement. This procedure applies for both sites. We will then reclamp and wire the pipes into position and be ready for welding at PIN2. At PIN1 cut off the angled pipes and clamp the tripod base level to the vertical pipes.

1989:262 (19-Sep-89)

1. At PIN1, to weld the three groups of three pipes and to weld the tripod base to the resulting structure. In fact, only got the tripod base welded to the vertical pipes, and several of the pipes welded. Although the welds were not the prettiest they looked as though they would be sufficient to hold the frame in place. The the welders motor stalled and after several attempts to restart, we were unable to get more than another 10-15 minutes of welding completed. Welder to come back tomorrow to finish PIN1, and at PIN2, weld the 5 pipes into their clamped position.

1989:271 (28-Sep-89)

1. Added cement (dry) outside the 1¼″ steel pipe, and inside the 2½″ PVC pipe, to react with (absorb) the water there, added initially to indicate when the grout was nearing the surface; we do not want water there as it will lead to corrosion of the anchoring pipes. When the tape at their tops was unsealed to add the cement, moisture was quite evident in all the holes. They have been sealed with tape again, with the hope that the extra cement added as above will absorb and hold the moisture so that it won't corrode the anchoring pipes. (Recall they are galvanized.) It was hard to get the cement powder into the annulus, because the foam took up most of the space.
2. Built and installed the form necessary for pouring the PIN1 concrete pad, and filled the installed form with ‘‘play sand’’ to approx. 6″ depth. In this case the pad is mainly for esthetics. We added sand just under the pad, to give a compliant base with no lateral stresses on the 2½″ casings; we want to limit temperature swings as much as possible.
3. Measured the force-to-displacement response of the welded anchoring assemblies at both sites, using dial gauge and bathroom scale.

PIN1 (before concrete pad and without Tripod)

Direction	Force	Displacement	(Or)	Result
N	150 lbs	0.0033″	0.084 mm	
N	75 lbs	0.0017″	0.043 mm	
S	75 lbs	0.0020″	0.051 mm	
S	150 lbs	0.0036″	0.091 mm	
				0.056 mm/100 lbs
				0.062 mm/500 N
E	120 lbs	0.0010″	0.025 mm	
E	75 lbs	0.0007″	0.018 mm	
W	75 lbs	0.0009″	0.023 mm	
W	150 lbs	0.0015″	0.038 mm	
				0.025 mm/100 lbs
				0.028 mm/500 N

These values are 1.2×10^{-7} m/N and 5.6×10^{-8} m/N.

PIN2

Direction	Force	Displacement	(Or)	Result
NE	100 lbs	0.0043″?	0.109 mm	(suspect)
NE	50 lbs	0.0010″	0.025 mm	
SW	50 lbs	0.0013″	0.033 mm	
SW	100 lbs	0.0029″	0.074 mm	
				0.063 mm/100 lbs
				0.071 mm/500 N
NW	100 lbs	0.0031″	0.079 mm	
NW	50 lbs	0.0013″	0.033 mm	
SE	50 lbs	0.0016″	0.041 mm	
SE	100 lbs	0.0027″	0.069 mm	
				0.076 mm/100 lbs
				0.085 mm/500 N

These values are 1.4×10^{-7} m/N and 1.7×10^{-7} m/N.

1990:004 (04-Jan-90)

1. Attempted to install Scripps' TI at PIN1: many full days of work and travel invested in this effort, unsuccessfully.

1990:040 (09-Feb-90)

1. Yehuda Bock and Harold Bolton centered and leveled tripod at PIN1. Measured vertical height from mark to top of "hat" on tripod is 68 11/16 inches, or 1.7447 m; height from top of hat to bottom of ground plane 6 7/32 inches (0.1580 m), which includes the Trimble stand-off. [All this from Bock log]. This sums to 1.9027 m. Subtracting 0.0597 m (bottom of preamp to bottom of ground plane) gives 1.8430 m, which is 1.7447 + 0.0983; the Trimble standoff is 0.0984 m according to Hadley's measurement. **Note** that as of the end of 2003 the SOPAC site log gave the height at 1.9030 to the bottom of the preamp, an error (not that there is any data from this time period).
2. Trimble programmed to start running session: 4000SST, S/N 496, firmware 4.11; antenna TRM14532.00; with height (in SOPAC site log) of 1.9030 m.

1990:045 (14-Feb-90)

1. SOPAC site log: PIN1 Trimble changed to S/N 422. First PIN1 data at SOPAC is from 1990:046, though very incomplete.

1990:061 (02-Mar-90)

1. At PIN2, Yehuda and Dan Slayback:
   A. Installed PIN2 adaptor #1, finding some problem with getting things vertical. Later measurements, (see 1990:088) gave about ¾° tilt to SW for antenna; measurement on 1993:174 gave 1.4° down to SW. See measurements with new adaptor, 1998:295, for an estimate of the pipe tilt. Angled adaptor machined to have a 1.5° tilt. This adaptor in place until **1998:295, when replaced by SCIGN D3.**

   B. Installed antenna/receiver on secondary mark and began three-day tie to PIN1. Bock's measurement (see his log) from "top of adaptor base to bottom of plate that supports the antenna" was 1 3/8 inches, or 0.0349 m. (This appears to be to the bottom of the preamp - DCA 7/12/90). That is, TAB to BPA is 0.0349 m. The more-detailed measurements made on 1990:100 give 0.03475 m for this.

   C. Also put a Trimble at the NASA pad. This means that a total of five Trimbles are in operation for the weekend. Slant heights to bottom of ground plane (at three points) are 58 15/16, 58 31/32, 58 31/32 inches; average 1.4975 m. [Bock log].
2. SOPAC site log shows, for day 62 at PIN2, a Trimble 4000SST installed (and unchanged until 1997—**not true**-there were lots of changes, though the receiver type always remained the same).
3. PIN2 antenna, according to the SOPAC site log: TRM14532.00, height 0.1330 m to BPA. (See 1990:100 for the source of this number, which is from the top of the divot).

1990:064 (05-Mar-90)

1. Recovery of Trimbles at NASA pad and PIN2; at NASA pad, need to check centering of tripod and height of antenna groundplane to make sure there has been no motion. Measurements [see Bock log this date] are 59, 58 15/16, 58 15/16 inches, close enough to earlier ones. Antenna slightly off-center, probably from high winds after end of survey.

   Left antenna installed at PIN2.

   Ref: Yehuda's "To Breakdown Trimble GPS Equipment at Piñon" (5-Mar).

1990:073 (14-Mar-90)

1. Osborne Choke Rings do not have 5/8″×11 threads, nor are the cable connectors where we'd like them: only 1.3″ from center of antenna, and pointed down on bottom surface. Worked on a plans to make Osborne Choke-Ring Adaptor, decision: square or cylindrical. Mert decided on the latter, but this meant making an upper adaptor ring to fit the bolt circle of the Osborne Choke Ring, as the diameter of these holes was 8 3/8″ and the only aluminum cylinder we had available was 8 ¼″ OD. Adapter height chosen to match Trimble TNL PN 14791: 3.890″, which is 0.0988 m.

1990:074 (15-Mar-90)

1. The second adaptor to Piñon for installation of the Piñon Rogue on PIN1. SOPAC site log shows receiver installed at PIN1 was ROGUE SNR-8, firmware 2.3, recording data with UTC time tags; antenna was AOAD/M_B, with height (referenced to bottom of choke ring) of 1.8435 m; this is 0.0988 plus 1.7447, so the latter would be the inferred height of the top of the hat.
2. However, no data available at SOPAC from this installation until 1990:253. Data from PIN2 starts on day 75, however—no overlap with PIN1.

1990:088 (29-Mar-90)

1. Messed with Trimble recording times at Piñon yesterday, and make notes for finishing installation at PIN2; it needs conduit for antenna cable and a little more.

   Verticality of Trimble antenna is not as good as we would like. Steve Bralla estimates that it's tipped ¾° to the south-west.

1990:090 (31-Mar-90)

1. PIN1: SOPAC site log has Rogue firmware change to 2.31.

1990:100 (10-Apr-90)

1. PIN2 antenna height measured for this first (and so far only) antenna run there, which hadn't been moved since Yehuda first put it on 1990:061 for initial "3-day" survey. (Left there through 1990:169)

   Dimensions (see file [1503]):

   > All measured from base of preamp (BPA): 0.03475 m to top of screw-piece (TAB, measured both N and S), 0.05825 m to junction of screw-piece and threaded adaptor (MAB, measured both N and S), 0.0945 m (S side) and 0.0965 m (N side) to bottom of threaded adaptor (BAB), and 0.133 m (N side) to *top* of punch mark made on galvanized pipe (TOD).

1990:125 (05-May-90)

1. New version (5.0) Rogue software put in at PIN1 (done the day before at SIO). This changes the **time-tags** to match the CIGNET times. (**Note**: SOPAC site log has version going to 2.31 on day 90, and not changing again until day 170, when JPL Rogue installed at PIN1 with 5.6.)

1990:127 (07-May-90)

1. Hadley Johnson set up receiver SIO6 at PIN2: Trimble 4000SST. Set observing time to 21:04 to 08:04 for May 8th (day 128) and advanced this by 4 minutes per day till 19:12 to 06:12 for June 5 (day 156).

1990:132 (12-May-90)

1. Swapped 4000SST receiver's at PIN2, replacing SIO6 with SIO1.

1990:156 (05-Jun-90)

1. Hadley, Duncan Agnew, and Frank Wyatt went to Pinyon and Anza with 4 receivers today (plus the continuous receiver at PIN2)—for a total of 5—to measure two of John Langbein's 2-color lines and to tie the center mark at Pinyon (GREEN) to the center mark at Anza (ROAD).
2. Removed Peter Worchester's Rogue (S/N 104?) from PIN1 mark and brought it back to SD. He will be using it in a sea experiment, being shipped tomorrow. Plan is for Steve DiNardo to show up at PFO tomorrow and install a JPL Rogue in its place.
3. **NOTE**: The antenna on mark PIN1 was **NOT** pointed north as was supposed. Someone had tried to align it to north, but they were off by 32.5° from being correct. The ''north mark'' on the antenna was pointed at +32.5° (clockwise) from true north. We made marks on the adapter for adding anti-rotation screw holes in the adapter plate, for this antenna. If we do not get this antenna back, with the same choke ring, these holes won't be useful.
4. Downloaded the last week's worth of data from PIN2 to the Datel PC.

1990:169 (18-Jun-90)

1. JPL Rogue at Piñon, (firmware 5.6) but not showing any data recorded. Much subsequent fiddling with the sample interval noted in SOPAC site log; no data until about day 250 (which is from the SIO Rogue).
2. Brought back Trimble from PIN2, to send to Indonesia: all parts, including the antenna. Measurements of antenna height checked against those on 1990:100.

1990:218 (06-Aug-90)

1. PIN1: Steve DiNardo at SIO to replace JPL Rogue with SIO (Worcester) Rogue. UCSD antenna standoff returned from the anodizing factory, undone. That JPL and UCSD standoffs are nearly the same height is pure coincidence.

1990:250 (7-Sep-90)

1. PIN1 may have been disturbed by Art Sylvester's leveling group.

1990:317 (13-Nov-90)

1. Brought back the DATEL 286 PC used to record Trimble data at PIN2.

1991:045 (14-Feb-91)

1. PIN1: Jeff Genrich replaced Rogue with a new internally-recording, remotely-accessible Ashtech receiver; ASHTECH LM-XII3, S/N 825, firmware 5F. This is not a precise P-code receiver, but can be downloaded via the phone. There is the promise of new P-code receivers soon.
2. PIN1: new antenna; according to the SOPAC site log, ASH700228A, height 1.8435 m to BPA.

1991:052 (21-Feb-91)

1. Apparently a lightning strike last Sunday PM (17-Feb) tripped up the new Ashtech system at Piñon. Yesterday, Frank tried to contact someone in the lab to conduct some experiments, but no luck. Today, Eric Husmann. and Yehuda successfully revitalized things by simply cycling the power.

1991:064 (4-Mar-91:

1. UCLA Trimble arrived in the lab for possible use at PIN2, during this week's southern California campaign.

1991:066 (7-Mar-91)

1. Start of data from PIN2—installation of UCLA Trimble.
2. SOPAC site log shows antenna installed: TRM14532.00, height 0.1435 to BPA. This number probably based on Hadley's measurements from the top of the divot at the time of installation, which were 0.0453 m TAB to BPA, 0.1435 m TOD to TAB (implying 0.0982 TOD to TAB).

1991:074 (15-Mar-91)

1. Keith Stark went to Piñon today, to swap Ashtech at PIN1, the LJ one for the PFO one. (NOT noted in SOPAC site log). It seems the one at Piñon has problems with its clock. It's a good thing we have the UCLA Trimble (#5) running.

1991:078 (19-Mar-91)

1. Since neither Ashtech in La Jolla is working properly, we removed the one good Ashtech from PIN1 to use at SIO1.

1991:100 (10-Apr-91)

1. PIN1: brought up Ashtech M-XII 6 Meg Receiver SN 700227A0825 and 40 m of cable, and moved the whole show into the AFGL enclosure about 34 m from PIN1. This took a lot of time, to sort out the cabling and move things. Nice drawing of all this is in [1050]. [17-Apr finding: antenna which has been there for some time is Mod L1-L2, S/N 700228A0592, and 700229A0051 on sticker next to the cable connector.]
2. At PIN2, reprogrammed the Trimble to record at 30 s. Checked the antenna height, at the base of the preamp to be ~0.144 m (±0.003) above the divot in the pipe, which agrees with the antenna height given by Hadley of 0.045 m above the top of the adaptor screw-piece (TAB). (See 1991:066).

1991:121 (01-May-91)

1. Day 2 of three day campaign to survey the Pinyon Geodolite net with the Geodolite and a mixture of USGS Ashtech receivers and UCSD Trimble receivers. The PIN1 Ashtech hadn't been in communication this past week, and with the now 15-s sampling it overflowed on 2-May. When this happens it starts to overwrite the front end of whatever file it was in (today's). Unfortunately, today was the day the USGS was running one of their receivers at the NASA pad (NCMN). The day before we were running one of our Trimbles there. Keith downloaded some data 2-May, which made for space, but this was only after Duncan reset the receiver, to reestablish communications.
2. As of this date we have PIN1, PIN2, and ROCH running continuously.

1991:131 (11-May-91)

1. PIN1 Ashtech firmware changed from 5F to 1.0 (SOPAC site log).

1991:135 (15-May-91)

1. Today is the big GPS occupation of John Langbein's 2-color EDM network at Pinyon Flat. We removed Trimble system from ROCH this morning to be used in the survey, and put it back in the evening. All seemed to go well.

1991:155 (04-Jun-91)

1. Some issues with the continuous trackers:
   It seems the Ashtech (at SIO1 and PIN1) and Trimble (at PIN2 and ROCH) are troubled when running in continuously in the "sessions" mode. They lose their position at the start of each session (just after UCT 0:00) and so estimate terrible (1000 km-off) pseudo-ranges. The automatic processing then chokes on the data.
2. JPL wants to install Rogues at PIN1 and SIO1 again. At Piñon they will need an antenna cable connector, and power cable. We have the antenna adaptors ready, and anodized (finally).

1991:179 (28-Jun-91)

1. Sierra Madre earthquake. M_L 5.8. Dave Jackson called Yehuda and Hadley about getting one or both receivers off the 10-km line for postearthquake response. Eventual result: Dave's students came and pulled the UCLA Trimble at PIN2; ROCH was left alone.

1991:181 (30-Jun-91)

1. Steve DiNardo installed a Rogue at PIN1 and moved the Ashtech to PIN2 (conveniently vacant).

1991:183 (02-Jul-91)

1. Jim Happer and Tracy at PFO to do EDM survey #1. In the afternoon measured from PIN1 to PIN2, so antennas were off for a while. See *localsurveys.log* for more on this.
2. PIN1: the PIN1 antenna lacks an obvious north-point mark, and it came back on rotated from its earlier position, was pointed at N45°W through 1991:205.

3. PIN2: the antenna at PIN2 is not actually recording anything.

1991:198 (17-Jul-91)

1. UCLA Trimble returned to lab from UCLA.

1991:205 (24-Jul-91)

1. Re-installed UCLA Trimble at PIN2. Because a cable was missing, not left running.
2. Removed the Ashtech antenna and cable from PIN2 and returned to the lab.
3. Rotated the Rogue antenna at PIN1 to north.

1991:236 (24-Aug-91)

1. PIN2: UCLA Trimble receiver now recording; lots of changes to the phone hookup.
2. PIN1: fixed.

1991:247 (04-Sep-91)

1. Keith found out that the Trimble at PIN2 is writing all the data into one monster file; this, as the result of the ‘‘quick start’’ last week while Bob McDermott was at Piñon dealing with the files stuck in the receiver (again, the PC had crashed somehow).

1991:267 (24-Sep-91)

1. PIN1’s Rogue is unavailable—blown up by lightning.

1991:276 (03-Oct-91)

1. JPL Rogue at PIN1 pulled (about) this day.

1991:297 (24-Oct-91)

1. Re-installed Scripps Rogue at PIN1; SOPAC site log has ROGUE SNR-8, firmware 5.60.

1992:085 (25-Mar-92)

1. Hadley stopped by PFO to try to get PIN2 running. The receiver does not appear to hear any satellites. Removed to SD to try to fix there.

1992:091 (31-Mar-92)

1. Steve Bralla took Trimble (fixed by full reset) back to PFO and re-installed it at PIN2. Looks like the last day of data was 20-Mar, so we lost a total of about 10 days of data.

1992:116 (25-Apr-92)

1. Firmware on PIN1 Rogue changed to 7.0 (SOPAC site log).

1992:223 (10-Aug-92)

1. Steve Bralla found that the PIN2 receiver at PFO was in sleep mode; returned it to lab.

1992:225 (12-Aug-92)

1. The word from UNAVCO is that a few transistors were blown on the UCLA-5 Trimble receiver power supply board. They have been fixed and we will get it back on 17-Aug-92.

1992:231 (18-Aug-92)

1. PIN2: replaced the Receiver/antenna/OSM/(trailer)modem; watch out for odd new antenna height, measured by Steve Bralla at 5″ (0.127 m) from top of divot (TOD) to bottom of locking plate (washer). (2004 note: since washer is 0.5″ thick, this would be 5.5″ overall, or 0.1397 m TOD to BPA. This number does not seem to be otherwise confirmed).

1992:248 (04-Sep-92)

1. The PIN1 Rogue has been down since the lightning of 1992:232:20:45. Keith went out and swapped in the lab Rogue, not so long ago pulled from SIO1. He even swapped antennas but had no luck in locking onto satellites. (*NOTE*: the antennas have been changed so the antenna heights may be different.)

1992:269 (25-Sep-92)

1. PIN1: Keith went to Piñon, removed Rogue, and installed ASHTECH P-XII3, S/N 700363B1426, firmware 6M (SOPAC site log; note that Hadley's table made this 1992:256. No entry either day in PFO lab books). Steve Bralla brought back the nonfunctioning Rogue receiver (2 mini racks) and antenna (Receiver ID = 05).
2. Antenna change to ASH700228D, S/N 700328A0703, height 1.8435 m to BPA (SOPAC site log).

1992:318 (13-Nov-92)

1. PIN2 antenna: I believe the repaired unit is sitting in the lab, still boxed.

1992:319 (14-Nov-92)

1. EDM survey #2, Steven Dockter, between PIN1, PIN3c, and PIN2.
2. PIN2: the antenna for this receiver was **temporarily unscrewed** from its mount. It took six turns to unscrew it, all done with the antenna cable still connected, and every attempt was made to resecure it in the exact same way.
2. PIN1: despite some serious banging, all of the locks on this stand refused to open. It's possible, though highly unlikely, that this banging might have affected the antenna position.

1993:004 (04-Jan-93)

1. All three Ashtechs (PIN1, SIO2, and VAND) quit recording when the year changed; they're receiving but not recording the info anywhere. The solution: cycle their power off/on, or reset time and wait for 24-hour turnover.

1993:058 (27-Feb-93)

1. Stephen Dockter and Joe Jarboe performed EDM survey #6 at (Two-color) Green, PF5, and at PIN1, PIN2, and PIN3. The antennas were disturbed at

PIN1	1993:058:	off	23:05	on	23:45
PIN2	1993:058:	off	23:07	on	23:53
PIN2	1993:059:	off	00:00	on	00:05

Obviously the second removal of PIN2 was not as planned, but that's what happened. We hope that no net displacements were introduced by these activities but the continuous GPS measurements should show them at the 0.1-0.2 mm level if they exist.

1993:105 (15-Apr-93)

1. PIN2: measurement by David Akulian gives the values from TAB to BPA as 0.0442 m N side, 0.0440 m S side (PFO lab book).

1993:161 (10-Jun-93)

1. At Piñon, Hadley remeasured heights at PIN1 and PIN2.
2. PIN1:
   66 11/16″ from ground mark to bottom of hat (1.6939 m)
   2″ bottom to top of hat (0.0508 m), giving a height for the top of the hat of 1.7447 m.
   3 7/8″ black anodized standoff: the Trimble one (0.0984 m).
   Sum of these is 1.8431 m.
   In addition, 2 3/8″ (0.0603 m) from bottom of preamp to bottom of ground plane (checks against 0.0607 ‘‘official’’ measurement).
3. PIN2:
   1 15/32″ from center of divot to bottom of adaptor (0.0373 m, COD to BAB)
   4 6/32″ from bottom of adaptor to BPA, on S side (0.1064 m, BAB to BPA)
   5 5/8″ from center of divot to BPA, on N side (0.1429 m, COD to BPA; the two above sum to 0.1437 m, 1/32″ higher).

1993:162 (11-Jun-93)

1. Ties at Piñon one-more-time—PIN1, PIN2, PINY, PF05, but failed at getting PIN3c): Jim Happer there on a solo to tie together (again): PIN1 (permanent Ashtech) PIN2 (permanent Trimble), PIN3 (survey Trimble, failed) PINY (survey Trimble), and PF05 (survey Trimble). At PIN3 the SIO-3 receiver had a lot of apparent power failures. Should however be useful as a PINY to PIN2 tie.
2. Some confusion over PIN1 height; what we thought was a double spacer was actually the standoff and preamp.
3. Hadley struggling with the history of the IGPP continuous receivers' antenna heights—lots of loose ends. Relevant files:

ties.pinon	attempt to unravel earlier observations
ant.hts.tbl	antenna heights of tracker stations (etc)
contgps.sumtab	summary of notable antenna events

1993:174 (23-Jun-93)

1. PIN1: Converted receiver from Ashtech to SIO Rogue SNR-8, firmware 7.30 (SOPAC site log).

2. PIN1 antenna changed to AOAD/M_B, height 1.8435 m to bottom of choke ring (SOPAC site log); this is 1.7447 (to hat) plus 0.0988 (adaptor).

   PIN1: Keith checked the levelness and instrument height (1.7455 m to hat top), but didn't get the centering checked. Note that adding the standoff (0.09881) gives 1.8443 m, 0.8 mm above the SOPAC value.

3. PIN2: Steve Bralla measured the tripod and the antenna's levelness (not the support screw which would have required pulling the antenna). Level measurements made on the ground plane with a 22-cm level, turned end-for-end to produce two numbers. Results: N side, down to S by 0.45/0.40 cm; S side, down to S by 0.40/0.45 cm; E side, down to W by 0.35/0.40 cm; W side, down to W by 0.30/0.35 cm. Average of these is down to S by 1.10°; down to W by 0.91°: or a tilt of 1.4° down to the SW. This is suspiciously similar to the wedge angle we wanted to have machined into this adaptor; was that ever done, or was the issue forgotten in the machine shop. The drawings show a 0.070″ wedge was wanted: 1.3°. In any event it's tilted now and probably always has been.

1993:188 (07-Jul-93)

1. EDM survey #7 included PIN1, so its tripod was removed today, though it was not currently recording.

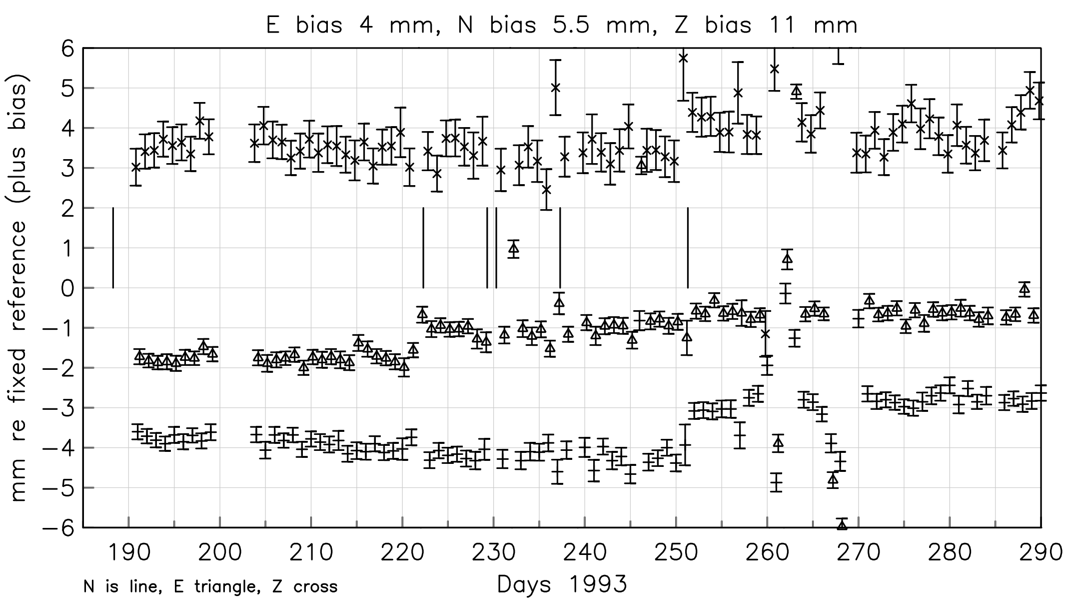

Figure A-1

1993:222 (10-Aug-93)

1. EDM survey #9: The PIN1 and PIN2 GPS antennae were disturbed and replaced as follows:

PIN1	1993:222	Off 22:45	On 23:58
PIN2	1993:223	Off 00:49	On 02:05

We were working in the vicinity of these sites throughout the rest of day 223, so I'd be interested if there were any anomalous signals in the data outside of the above noted times. We hope there are none. Jeff Behr

1993:228 (16-Aug-93)

1. 2:30 PM: Help Jeff Behr tear down PIN1, making centering measurements (two different ways, one with the antenna still in place, and one with it removed) and height measurements of the ‘‘before’’ condition. Yehuda decided to leave the Rogue antenna connected, but on the ground next to the tripod. Disconnecting it risks hanging the receiver and/or insulting the electronics. Place it as far away as possible to reduce any chance of the antennas interfering with one another.

   Keep a good log on the times of what was done when to the Rogue (and also to PIN2).

   Help pull the antenna off at PIN2 for EDM work.

   ~3:00 PM: Work with Jeff making EDM and then Autolevel measurements to both PIN1 and PIN2. You need a **step stool** at PIN1 *if* the plan is to use a tribrach there (& hollow spindled screw, without the centering insert) for the EDM measurements. Without a step stool we risk a bad tribrach siting, because it's not possible to get your eye near the tribrach's telescope. Use the best calibrated tribrach we've got for PIN1, on account of its height and PIN1's critical role in the Piñon network.

   ~4:00 PM: Set up one Trimble at PIN3c and the second at PIN1, again recording lots of measurements on antenna centering and height—details are valuable.

   4:45 PM: The aim is to be done with the set up for the GPS ‘‘ties’’ (PIN1, PIN2, PIN3c, and PINY) by this time. It's critical that PIN2 be running for this experiment, and that depends (obviously) on the antenna being back in place (and that we have a confirming measurement of its position—Jeff), and that the PC in the trailer is recording.

1993:229 (17-Aug-93)

1. Performed another EDM survey (#10) just prior to Piñon tie VII. This involved pulling off the antennas at PIN1 and PIN2 (also PIN1's tripod on/off). Summary:

PIN1	1993:229	Off 21:43	On 230:23:59 (over a day later)
PIN2	1993:229	Off 22:42	On 23:20

2. PIN1 details: Rogue and Tripod off at 1993:229:21:43 for EDM work (as settled on yesterday by Yehuda, Frank and Jeff). PIN1's antenna was left connected and facing the sky for the day-plus it was off the tripod. This was to allow Keith to check with Steve DiNardo about health of swapped in/out boards. Got ‘‘before’’ slant height measurements to Trimble's ground plane, with the antenna sitting right on the hat (no standoff), but the inferred hat height from this is 1.7465 m vs. PGGA's standard number of 1.7447 m, nearly 2 mm lower. Keith recently got 1.7455 which is closer to new number. The hat appears to be level to within our hand-level's capabilities of ±¼°. (Joe Jarboe calibrated our GPS-tripod-kit hand level and found ±¼° to be range of inner lines). Single-handed, easterly-breezed, holding string in center of 5/8″ insert, gave centering readings of 1 mm N and 1 mm SE. The next day, without any ‘‘after’’ height readings (Keith, Jeff, and Hadley were trying to beat the clock having spent all the time removing the Askania form its borehole), final centering was judged to be ½ mm off to N-NE with one person holding wind guard (plastic shroud), one person holding the plumb-bob in the insert, and one person reading the plumb-bob. Very encouraging answer. PIN1 antenna-height not remeasured when reestablished (w/ Rogue reinstalled).

3. PIN2 details: Trimble's antenna off at 1993:229:22:42 for EDM work. Height measurements taken before and after removing the antenna yielded 5.55 cm from joint of cylindrical base-parts to lower edge of support washer (0.0555 m, MAB to BLP; since support washer is 0.5″ thick, this gives 0.0682 m MAB to BPA).

4. All-Trimble tie #VII at Piñon: PIN1 (Rogue displaced), PIN2 (continuous UCLA #5), PIN3c, and PINY. David Akulian, with Jeff Behr heavily involved because of overlap with EDM survey #10—this didn't work at all well, despite considerable discussions yesterday. (David had to make round trip (10:10 AM PDT, to 2:25 PM) because he forgot one set of battery cables.) Lots more could have been done with set-up observations; much had to be inferred in the lab.

   Tribrachs checked for perpendicularity (calibrated) but not adjusted before the survey. Tribrach LA-04 (used at PINY) maybe off by 0.3 mm in one axis, but we still do not have a procedure for quantifying bubble-misalignment error, so positioning error could be more or less.

   PIN3c: Set up on Tripod, using Tribrach LA-02 which seems to be in pretty good calibration. Hadley recalls tribrach's eyepiece directed NE.

   PINY: Set up on Tripod, using Tribrach LA-04 not in great calibration, but probably OK. Oddly, David got constant slant-height measurements, while Hadley, a day later, found things tipped by 3 mm at the edge and yet the bubble and centering looked perfect. How can this be?

   Summary of antenna heights for survey:
   PIN1 (1993:230:00:30) 1.8213 m SLBGP
   PIN2 (1993:230:00:00) 0.1432 m DHPAB
   PIN3 (1993:230:00:07) 1.0733 m SLBGP
   PINY (1993:230:00:52) 1.061 m SLBGP

1993:237 (25-Aug-93)

1. PIN2: Perhaps installed 3 mm too low this day, subsequent to EDM Survey #11. [But, not so according to measurements made the next week; it looks fine with SDHPAB of 0.1426 m.]
   PIN2 1993:237 Off 18:10 On 23:25

2. Lots of measurements of the PIN2 adaptor:
   TOD to BAB (N side) 1 7/16″ (0.0365 m)
   TOD to BAB (S side) 0.0350 m
   TOD to MAB (N side) 2 15/16″ (0.0746 m)
   TOD to MAB (S side) 0.0740 m
   TOD to TAB (N side) 3 15/16″ (0.1000 m)
   MAB to TAB (all sides) 59/64″ (0.0234 m)
   BAB to TAB (N) 1 1/2 ″ (0.0380 m) also 1.51″ (0.0383 m)
   BAB to TAB (S) 1 7/16 ″ (0.0365 m) also 1.44″ (0.0365 m)
   BAB to TAB (E&W) 1 15/32 ″ (0.373 m) also 1.47″ (0.0373 m)

1993:244 (01-Sep-93)

1. More measurements at PIN2, by Steve Bralla:
   TAB to BPA 0.0445 m
   MAB to BPA 0.068 m
   BAB to BPA 0.107 m whence BAB to TAB would be 0.0625 m
   TOD to BPA 0.143 m
   TOD to MAB 0.074 m
   TOD to BAB 0.036 m

TOD to TAB 0.098 m

1993:251 (08-Sep-93)

1. EDM survey #12, a two-day affair with Jeff Behr and Joe Jarboe.

PIN1	1993:251	Off 22:40	On 23:58
PIN2	1993:251	Off 22:25	On 23:55
And on second day,			
PIN1	1993:252	Off 22:50	On 23:58
PIN2	1993:252	Off 22:35	On 23:58

Steve Bralla says, that Joe says, that one of PIN1's feet are loose.
Post-survey measurements (see 1993:252) show PIN1 to be at the correct height, at least.

1993:252 (09-Sep-93)

1. PIN 2 measurements:
   TOD to BPA 5.61″ (0.1425 m)
   TAB to BPA 1.74″ (0.0442 m)
   TOD to BAB 1.44″ (0.0365 m)
   TOD to MAB 2.87″ (0.0729 m)
   TOD to TAB 3.86″ (0.0980 m)
   BAB to MAB 1.51″ (0.0383 m)

2. PIN1: slant heights to bottom edge of hat are 1.6997, 1.6990, 1.6990 m. Since hat is 5″ radius (0.1270 m), and 2″ high (0.0508 m), these give vertical heights to top of hat of 1.7457, and 1.7450 (twice). Note that standoff is still in place between hat and antenna.

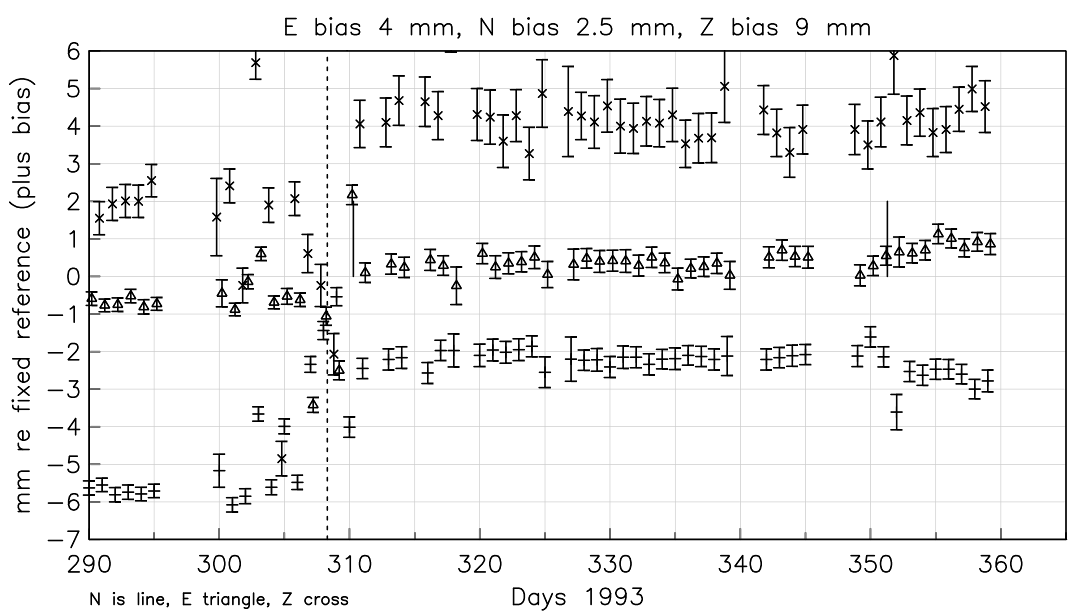

Figure A-2

1993:309 (05-Nov-93)

1. PIN1 receiver: Rogue replaced with ASHTECH Z-XII3, S/N 700570A03001, firmware 1B10 (SOPAC site log). **End of data from the Rogue: Ashtech hereafter.** The plan had been for Jeff B. to go with Keith and together get a good centering and height measurement, but Jeff didn't make the trip.
2. PIN1 antenna: changed the Rogue antenna to an Ashtech antenna: new antenna is ASH700228D, S/N 700228D2616 (SOPAC site log). This is the Geodetic L1/L2 ‘‘REV. B’’ with 8 L-shaped slots in the ground plane, mounted on our old friend, the Trimble standoff; the Ashtech antenna will not work without this standoff as it is impossible to hook up the antenna cable. Keith measured the height and checked the leveling, but not the centering (no help). Antenna height = 1.745 m *without* Trimble standoff, and it was level. SOPAC site log makes height 1.8435 m to BPA; this is 1.7447 + 0.0988. Change made at 4:00 PM local time (00:00 UT), but first data from the Ashtech was not until a few hours later because forgot Trimble standoff and to get it had to meet someone at I-15.

1993:310 (06-Nov-93)

1. PIN2: The antenna was removed for EDM Survey #15:

   PIN2 1993:310 Off 22:30 On 23:08

1993:324 (20-Nov-93)

1. PIN1 receiver: Keith at PFO to change PIN1 from the just-installed Ashtech, which doesn't seem to be working, to old-style Ashtech. This change **not** listed in SOPAC site log.

1993:351 (17-Dec-93)

1. PIN2 antenna removed and replaced for EDM survey #16.

1994:026 (26-Jan-94)

1. PIN1 receiver changed to ASHTECH Z-XII3, S/N 03207, firmware 1C01-1C00 (SOPAC site log).

1994:185 (04-Jul-94)

1. Signal cable from PIN2 destroyed by Palm brushfire; receiver OK, despite scorch marks on the wooden enclosure. (Though receiver now always comes up with an error).

1994:281 (08-Oct-94)

1. EDM survey #20: PIN1 and PIN2 removed and replaced.

1995:214 (02-Aug-95)

1. PIN1 receiver firmware changed to 1E00-1C50 (SOPAC site log).
2. 2004 note: the antenna change attributed by the SOPAC site log (June 2004) to 1995:245 seems to have happened at this time. There is a gap in the Rinex files from 213:23:34:30 to 214:00:53:00, but no long gaps in the data from 244—246. The Rinex header shows a change of antenna serial

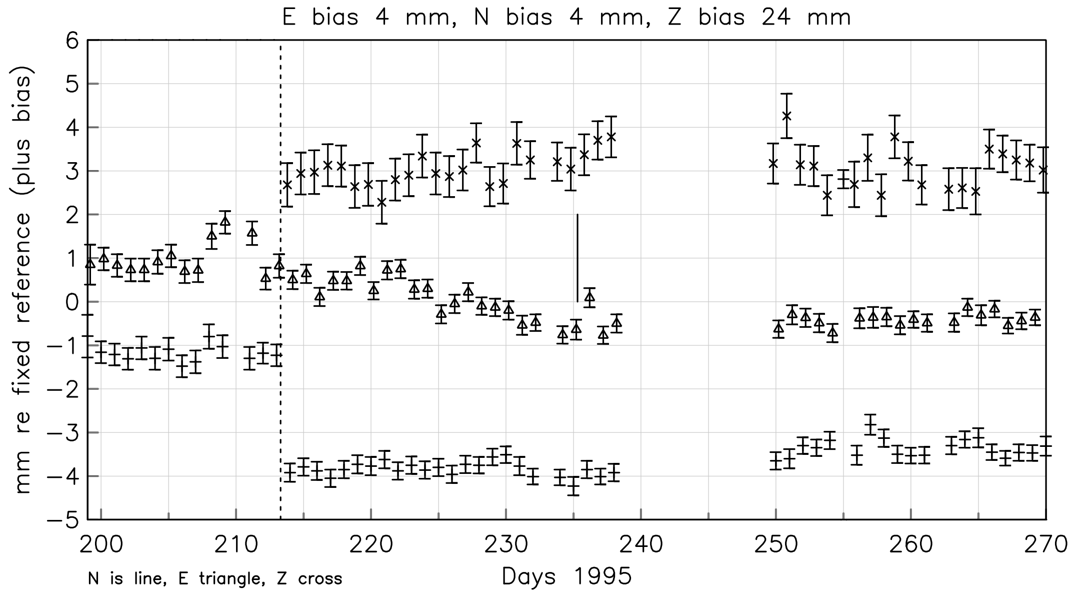

Figure A-3

number to 101 at day 214, which is the number for the new antenna. And, there is an offset in the N and Z components from 213 to 214.

3. The SOPAC site log makes the antennas height 1.8450 m to the BCR point on the JPLD/M_RA_SOP antenna. However, a height 14 mm higher (1.859 m) is needed to avoid an offset; this also reduces the offset to < 2 mm when (in 2001) a standard SCIGN antenna and dome are put on.

1995:235 (23-Aug-95)

1. EDM survey #23: PIN2 removed and replaced.

1995:245 (02-Sep-95)

1. PIN1 antenna: changed to JPLD/M_RA_SOP, S/N F101. This is the JPL Rogue Dorne Margolin with chokerings, retrofitted with the Ashtech LNA to work with an Ashtech receiver; there have only been two of these, both used in the PGGA.

1a. 2004 note: this is **incorrect** on two counts. First, the change was on 1995:214 (see that date). Second, the antenna type was to an Allan Osborne antenna, Dorne-Margolin B, serial number 101. The antenna type is thus AOAD/M_TA_NGS, though the phase center is the same distance above the antenna reference point as for the JPLD/M_RA_SOP.

2. SOPAC site log (as of May 2004) gives height of 1.8450 m to bottom of choke ring, as opposed to 1.8435 m used earlier. This could be 1.7465 m to top of hat, plus 0.0985 for adaptor.

2a. July 2004 note: direct measurement of the adaptor gives 3.85″, or 0.0978 m. If we take the height of the hat as 1.7447 m, this gives a height of 1.8425 m. This does not agree with the offset observed on 1995:214.

1995:252 (09-Sep-95)

1. EDM survey #24: PIN1 and PIN2 removed and replaced.

1995:315 (11-Nov-95)

1. PIN1 receiver firmware changed to 1E76-1D01 (SOPAC site log).

1996:052 (11-Nov-95)

1. PIN1 receiver firmware changed to 1E81-1D01 (SOPAC site log).

1996:354 (19-Dec-95)

1. PIN1 receiver firmware changed to 1E95-1D01 (SOPAC site log).

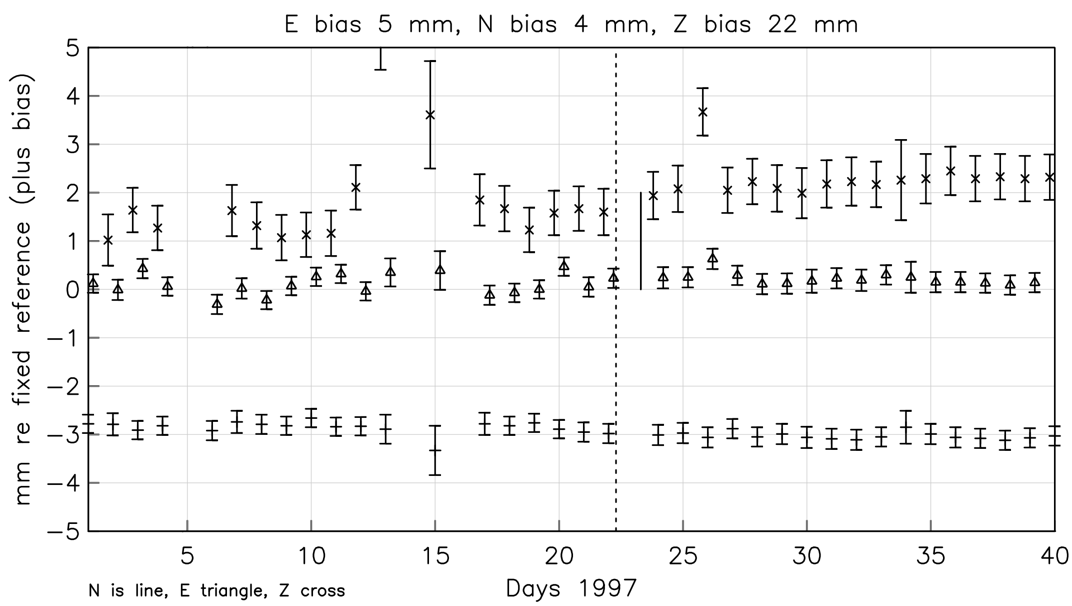

Figure A-4

1997:023 (23-Jan-97)

1. PIN1 receiver: changed to ASHTECH Z-XII3, S/N LP01391, firmware 1E95-1D01 (SOPAC site log).
2. PIN1 antenna: according to the SOPAC site log, replaced by ASH700936D_M, S/N 12655, height 1.790 m to BPA, for the day, then previous system replaced.
3. PIN2 receiver: UCLA's Trimble removed after a very very long run (since 1991:066, with interruptions). Replaced by Ashtech Z-XII3 (Model 700724-6(B)) SN 01894, firmware unknown.
4. PIN2 antenna: UCLA's Trimble removed after a very very long run (since 1991:066, and in place (with removes and replacements) since 1992:231 (perhaps)). Replaced by Ashtech milled choke ring (ASH700936D_M), S/N 12749, with height given as 0.1430 m to BPA (SOPAC site log—**note** change from 0.1435 m used for Trimble).

PIN2 antenna Height, with 5 7/8 turns onto the adaptor (measurements by Jeff Genrich):

From	To	Measured (inches)	Converted (m)
Adaptor Bottom (BAB)	Top of divot (TOD)	1 13/32	0.0357
Adaptor Top (TAB)	Adaptor bottom (BAB)	2 14/32	0.0619
Preamp base (BPA)	Adaptor Top (TAB)	1 25/32	0.0452
Adaptor Top (TAB)	Top of divot (TOD)	3 7/8	0.0984
Preamp base (BPA)	Top of divot (TOD)		0.1429

The summed value (of the first three entries) is 4 52/32 = 5 20/32 = 5 5/8″. This changes from the earlier 0.1435 m, but only by 0.6 mm; since the measurements are only given to within 1/32″, which is 0.8 mm, the sum could easily be in error by that much.

5. **Pinyon Ties VIII** — an "all Ashtech LPZ-12" exercise (last done 1993:231). Jeff Behr measured between: PIN1, PIN2, PIN3c, and PINY. All data are at SCEC Data Center.

6. PIN1: The tripod was removed from the monument and placed next to the pad. (This was done without first disconnecting the receiver from the antenna there is about 5 minutes of antenna displacement.) The antenna was then disconnected from the receiver. A tripod and tribrach were set up on the PIN1 ground mark for about 23 hours.

   After the GPS survey, the reflector was placed on the tripod and I did the EDM work (see below). When that was completed, I placed the white tripod back on the pins in its original orientation. I shook the tripod legs to confirm that it had seated properly onto the pins. I observed no secondary motion. I dropped the locking bolts through the clear holes in the cross braces and found that they seated directly into the threaded adaptors in the concrete. I threaded the bolts in until tight and replaced the padlocks.

7. **EDM Survey #25**: Measured from PIN3C to PIN1 and PIN2, though it was stormy and difficult to get the azimuth sighting.

1997:264 (21-Sep-97)

1. PIN2 antenna: on 263/264 boundary, changed to cast antenna, Choke Ring 700936-02 Rev E; (ASH700936E_C), S/N 14631, height 0.143 m to BPA (SOPAC site log). Swapped by Jeff Genrich as part of a test to establish whether noise apparent in the "new" SCIGN-array antennas is real or some site-dependent artifact, seen only at SIO2.

   Jeff's observations at PIN2 were that "before" the antenna height was 0.0445 m (5 3/4 turns), and after was 0.0440 m (6 turns); note the discrepancy "before" with the measurements on 1997:023 (assuming the same measurement, from TAB to BPA).

1997:276 (03-Oct-97)

1. PIN2 antenna changed to different number, still cast: ASH700936E_C, S/N 14653, still 0.143 m to BPA (SOPAC site log).

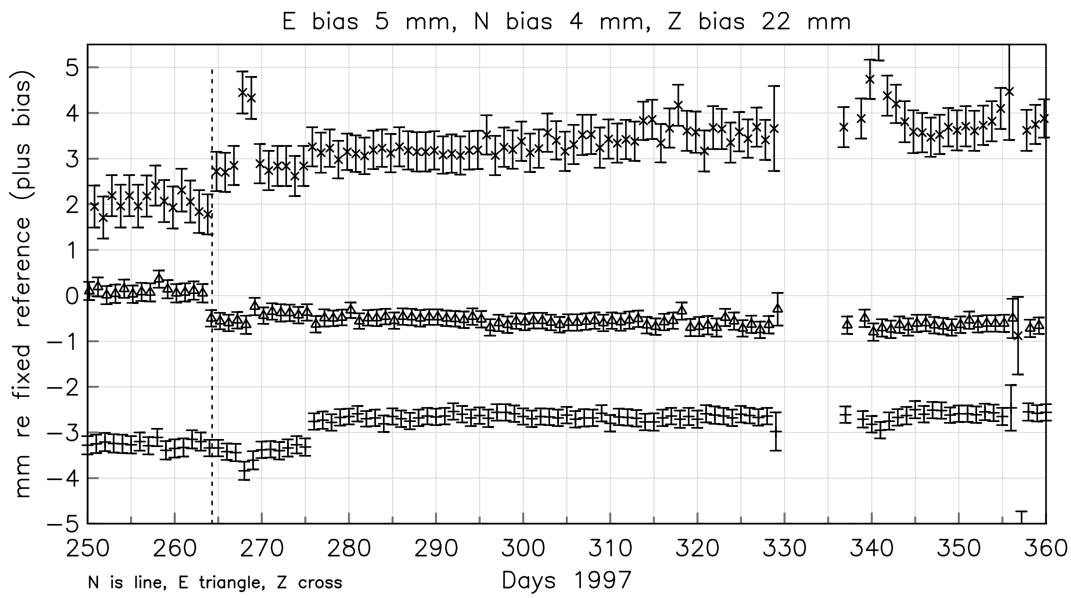

Figure A-5

1997:310 (06-Nov-97)

1. PIN2 receiver: changed to ASHTECH Z-XII3, S/N LP02806, firmware 1F50; Model Z-XII 700845-10(F) (SOPAC site log).

1997:336 (02-Dec-97)

1. PIN1 back on after being off (or at least no data being produced) since 1997:330 (26-Nov-97); first observation is at 22:12:30. After this day the number of double differences in the PIN1-PIN2 solution jumps to a higher level. No mention of any change in SOPAC site log; the RINEX headers on either side have the same information. Comparing the processing on 328 and 338, the difference is that PRN 8 and 13 are present on the later date only. This appears to be a consequence of a change in the SOPAC g-file.

1998:162 (11-Jun-98)

1. PIN2: fence #1 put in place through the end of day 188. Fence installed in a "U" shape with the bottom of the U to the south; this "bottom" section, 87″ long, was mounted on a plywood sled. The fence was 6′ tall so the top is even with the antenna, 8′ to the south from the antenna and 6½′ on the east and west sides. 3/4″ EMT conduit was used as a top rail on the fence. Table giving fence motions is (days in parentheses are those for which the change applies):

Time	Action
161:23:30	Set in place (162-174)
174:23:43	Moved away (175)
176:00:00	Replaced (176)
176:23:20	Moved away (177)
178:00:35	Replaced (178)

178:23:05	Moved away (179-180)
180:22:30	Replaced (181)
181:23:10	Moved away (182)
182:23:40	Replaced (183-184)
184:22:50	Moved away (185-186)
186:22:40	Replaced (187-188)
188:22:15	Removed completely (189-)

1998:174 (23-Jun-98)

1. PIN1 receiver: new receiver swapped in, ASHTECH Z-XII3, S/N 02780, firmware 1F50 (SOPAC site log).

1998:189 (08-Jul-98)

1. Fence removed from around PIN2 just before the start of this day.

1998:197 (17-Jul-98)

1. PIN2 tree test #1. Converted porta-fence sled to base for porta-tree. The tree trunk is 3″ PVC 15′ tall with 1¼″ through holes with branches through the holes. Built the tree with the guy wires installed before raising the tree, and fresh branches. Tree was moved close enough to antenna (on S side) so that its top was at 45° elevation, viewed from the antenna phase center. Schedule of movements:

Time	Action
197:19:30	Tree moved in (198)
198:23:50	Moved away (199)
199:22:25	Tree moved in (200)
200:23:10	Moved away (201)
201:21:40	Tree moved in (202)
202:23:30	Moved away (203)
203:23:30	Tree moved in (204)
204:23:05	Moved away completely (205-210)

1998:210 (29-Jul-98)

1. PIN2 tree test #2. Cut fresh branches for tree. Tried to make tree fuller using small branches to fill holes in PVC.
2. Tree moved into place 1998:210:23:40; sometime in the next day (before 1998:211:21:33) the tree fell on the PIN2 monument, It appears that the tree might have hit, twisted, and loosened the antenna; it was later (1998:295) found twisted 26° to West; see the log for that day for other possibilities. Again, the tree was moved into position N of the antenna, close enough for its top to be at 45° viewed from the antenna phase center. Schedule of tree movements:

Time	Action
210:23:40	Into place, ~8′ due south (211-212)

212:23:15	moved away (213)
213:22:50	into place (214)
214:23:30	moved away (215)
215:23:20	into place (216)
216:23:05	moved away (217)
217:23:10	into place (218)
218:23:35	removed (219-239)

1998:239 (27-Aug-98)

1. PIN2 tree test #3. Cut fresh branches for tree. Tree set up for this test series was 9′ to southwest of antenna. (Still had 45° elevation).

Time	Action
239:22:45	Into place (240)
240:22:30	Moved away (241)
241:23:00	Into place (242)
242:23:10	Moved away (243)
243:22:10	Into place (244)
244:23:30	Moved away (245)
245:23:00	Into place (246)
246:23:10	Removed (247-259)

1998:259 (16-Sep-98)

1. PIN2 fence test #2. This time fence is raised to be 20° above antenna. No top rail on this fence. Schedule:

Time	Action
259:23:15	In place (260)
260:23:28	Moved away (261)
261:23:38	In place (262)
262:23:10	Moved away (263-264)
264:23:10	In place (265)
265:23:35	Removed (266)

1998:266 (23-Sep-98)

1. PIN2 fence test #3. Fence installed to 20°, as before, but with a top rail added so Bud could easily install it. Schedule:

Time	Action
266:22:00	In place (267)
268:00:00	Moved away
269:00:12	In place (269)
269:23:00	Moved away

270:23:40	In place, but both end posts on sled collapsed
271:23:25	Moved away, and came apart.
281:22:15	In place after repair (282)
282:23:14	Moved away
283:23:35	In place (284)
284:23:15	Moved away
285:23:25	In place (286)
286:22:20	Moved away
288:00:22	In place (288)
288:23:45	Removed (289-)

1998:281 (8-Oct-98)

1. PIN2: measurements by Steve Bralla. Not completely clear which of these numbers are measurements, and which derived, for the metric numbers:

From	To	S″	S m	S m	N″	N m	N m
BPA	TAB	1.72	0.0436	0.044	1.72	0.0436	0.044
BPA	MAB	2.62	0.0665	0.0675	2.66	0.0676	0.0678
BPA	BAB	4.08	0.1036	0.103	4.16	0.1056	0.093
BPA	TOD				5.10	0.1296	0.129

and, the divot is even with the 4.12′ on the vertical scale attached to the monument.

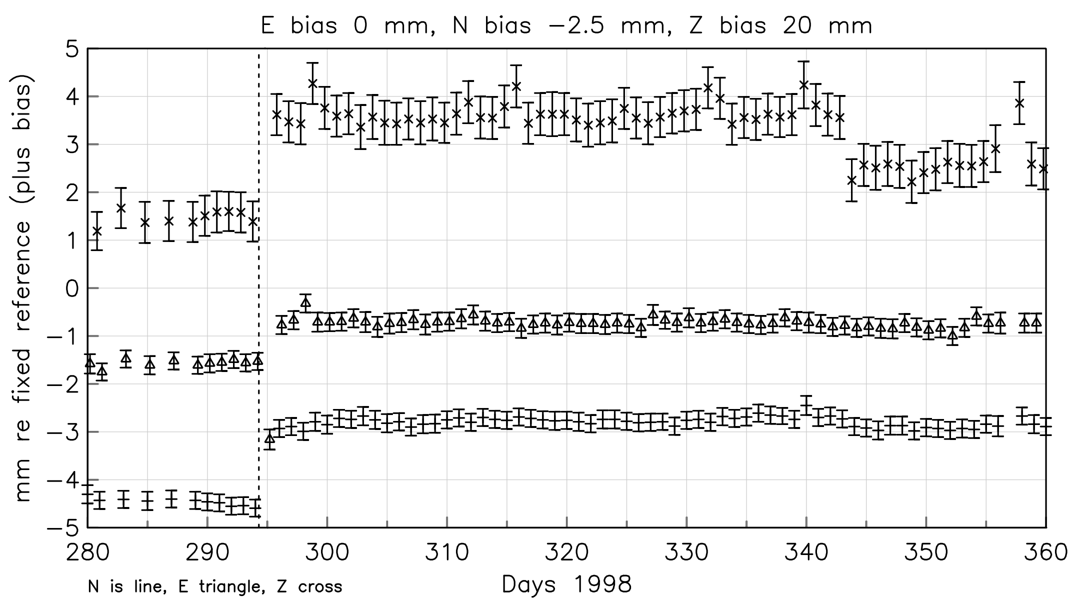

Figure A-6

1998:295 (22-Oct-98)

1. PIN2 antenna was found **twisted** 15° west of true north. Not clear if this was the case since 1997:276, when milled antenna was replaced after cast-antenna test, or only since 1998:211:21

when “Tree #2” fell onto the antenna. (See 1998:210).

2. Removed original PIN2 adaptor, originally put on 1990:061. Final measurements by Steve Bralla (originals in inches, values in m in parentheses).

From	To	N	S	W	E
BPA	TAB	1.72 (0.0437)	1.71 (0.0434)	1.71 (0.0434)	1.74 (0.0442)
TAB	BAB	2.43 (0.0617)	2.38 (0.0605)	2.41 (0.0612)	2.40 (0.0610)
TOD	TAB	1.43 (0.0363)			
BCR	4.3′	4.80 (0.1219)			
TAB	BAB	2.435 (0.06185)	2.409 (0.06119)	2.377 (0.06038)	2.372 (0.06025)

where the last set of measurements of the adaptor were made with calipers. The 4.3′ is on the scale attached to the monument.

3. PIN2 antenna: installed new D3 Adaptor (SN 44) today, between 1998:295:20:05 and 20:50. SOPAC site log sets antenna height to 0.0083 m, as the standard for the D3 adaptor. However, it acknowledges that antenna has been lowered by 0.0447 m. Steve Bralla’s measurements:
   COD (it appears) to bottom of D3 adaptor (pipe-thread section) 1.58″ (0.0401 m).
   Gap between top and bottom D3 plates in inches and meters, measured with calipers: N 0.280 (0.00711); W 0.304 (0.00772); S 0.232 (0.00589); E 0.208 (0.00528).
   From 4.3′ mark on scale to BCR: 2.98″ (0.0756 m).

1998:344 (10-Dec-98)

1. PIN2 antenna had SCIGN tall dome installed, between 344:00:27 and 344:01:08. The SCIGN D3 adaptor on the monument was unscrewed, baseplate introduced, and then reassembled; the adaptor was re-aligned to within a fraction of a degree to true North.

1998:357 (10-Dec-98)

1. PIN2 antenna: start of first round of dome tests (see p. 40 of lab book). Schedule:

Time	Action
1998:356:23:50	Dome removed (357)
1998:358:23:45	Back on (359-360)
1998:361:23:44	removed (362)
1998:362:23:15	Back on (363)
1998:363:23:58	removed (364)
1998:364:23:30	Back on (365)
1998:365:23:33	removed (001)
1999:002:00:25	dome on, and water on baseplate (002)
1999:002:23:55	baseplate dried (003)
1999:004:00:14	wet (004)
1999:004:23:48	baseplate dried (005)
1999:005:23:45	wet (006)
1999:006:23:50	baseplate dried (007)
1999:007:23:55	wet (008)
1999:008:23:30	baseplate dried (009)

1999:010:00:52	Raise dome 0.014m (010)
1999:010:23:48	lower dome (011)
1999:011:23:57	Raise dome 0.014m (012)
1999:013:00:02	lower dome (013)
1999:013:23:55	Raise dome 0.014m (014)
1999:014:23:40	lower dome (015-016)
1999:016:23:44	Raise dome 0.014m (017)
1999:017:23:45	lower dome (018-019)
1999:020:00:00	Tip to N, while raised on EW screws (020-025)
1999:025:23:52	return (026)
1999:026:23:57	Tip to N (027)
1999:027:23:50	return (028)
1999:028:23:54	Tip to N (029)
1999:029:23:47	return (030)
1999:030:23:58	Tip to N (031)
1999:031:23:47	return (032)
1999:032:23:59	Tip to S (033)
1999:033:23:52	return (034)
1999:034:23:51	Tip to S (note: baseplate wet) (035)
1999:035:23:56	return (036)
1999:036:23:30	Tip to S (037)
1999:037:23:57	return (038)
1999:038:23:50	Tip to S (039)
1999:039:23:50	return (040)
1999:040:23:53	lower dome back down to original location

1999:057 (26-Feb-99)

PIN2 antenna: short dome tests.

Time	Shift
1999:057:00:25	Short dome on, shift to south
1999:057:23:56	To north (NS shift is 0.21″)
1999:058:23:55	Shift to south
1999:059:23:57	To north
1999:060:23:45	Shift to south
1999:061:23:54	To north
1999:062:23:50	Shift to south
1999:063:23:52	To north
1999:064:23:40	Shift to East
1999:065:23:48	To West
1999:066:23:51	Shift to East
1999:067:23:57	To West
1999:069:00:07	Shift to East
1999:070:00:09	To West
1999:071:00:42	Shift to East
1999:072:19:40	Back to Center (½ displacement of others.)

1999:090:00:05	Dome Off
1999:091:00:00	Dome on (centered)
1999:091:23:45	Dome Off
1999:092:23:32	Dome on
1999:093:23:25	Dome Off (more snow)
1999:094:23:23	Dome on
1999:095:23:16	Dome Off
1999:096:23:16	Tall dome reinstalled.

1999:110 (20-Apr-99)

1. PIN2 antenna: Change of tall dome (to SN 0000D), and baseplate: installing the (split?) baseplate required removing the adaptor. Receiver off at 110:21:25; dome on, and receiver back on, at 110:22:00

1999:117 (27-Apr-99)

1. Start of multiday tests of paneled-fence (four 10′ by 6′ panels, so 10′ square and 6′ high) being moved in and out. (This is Fence Test #4). Panels make this fence much more secure than previous setups: it should be stable (no movement) when in place.

Time	Action
1999:117:22:38	Fence put up (118-121)
1999:121:22:35	taken down
1999:124:23:37	Fence put up (125-128)
1999:128:23:20	taken down
1999:131:23:30	Fence put up (132-135)
1999:135:23:17	taken down
1999:139:23:40	Fence put up (139-143)
1999:143:23:15	taken down

1999:153 (02-Jun-99)

1. PIN2 antenna: a number of choke rings swapped in and out, to check consistency. Dome was removed with first antenna, at 153:23:25.

S/N	Installed	Removed
CR14653		153:23:25
CR519991719	153:23:39	154:23:05
CR519991715	154:23:17	155:23:10
CR519991710	155:23:22	156:23:08
CR519991721	156:23:14	158:01:47
CR519991705	158:01:55	159:22:41
CR14653	159:22:51	

2. Dome replaced on 160:23:30.

1999:180 (29-Jun-99)

1. PIN2 antenna: a second round of testing, with the dome left on.

S/N	Installed	Removed
CR 14653		181:00:04
CR519991761	181:00:13	182:00:30
CR519991755	182:00:38	183:00:00
CR519991754	183:00:08	184:23:36
CR519991756	184:23:49	186:00:00
CR519991751	186:00:08	186:23:48
CR519991760	187:00:02	187:23:48
CR 14653	187:23:56	

1999:194 (13-Jul-99)

1 PIN1 receiver: changed to ASHTECH Z-XII3, S/N LP02973, firmware CC00, to prepare for GPS week rollover.

2. PIN2 receiver: changed to ASHTECH Z-XII3, S/N LP02912, firmware CC00, to prepare for GPS week rollover.

1999:208 (27-Jul-99)

1. Another round of fence tests (#5), in this case making only a small change, moving the south panel of fence, at the west end 18″ out (to south) and then back in.

Time	Action
1999:208:20:51	Moved in 18″ (209)
1999:209:22:40	back out to original position (210)
1999:210:23:25	Moved in 18″ (211)
1999:212:02:46	back out (212)
1999:212:23:58	Moved in 18″ (213)
1999:214:00:09	back out (214)
1999:214:23:11	Moved in 18″ (215)
1999:215:23:06	back out (216-)

After this test was ended, the fence was left in place, squared-up.

1999:243 (31-Aug-99)

1. The fence was lowered this day by 5″; this moved the top rail from being even with the bottom of dome curve (near the phase center?), to being even with bottom of the antenna/dome This was called Fence configuration #6, the same, horizontally, as #4, only with different heights for the top of the fence (and the bottom: the whole fence was moved up and down by putting cinderblocks under it).

Time	Height ″	Action
1999:243:22:30	0	Lowered 5″: even with bottom of choke ring.

1999:258:23:25	16	Raised 16″
1999:265:23:00	0	Lowered 16″
1999:272:23:15	16	Raised 16″
1999:279:23:45		Removed.
1999:286:23:30	−8	Replaced; fence rail even with pipe junction
1999:292:23:25		Removed.
1999:300:23:50	−8	Replaced at previous level
1999:314:00:30	8	Raised 16″
1999:321:23:30		Removed.
1999:327:23:40	−8	Replaced at same level as 1999:286 and 1999:300.
1999:334:00:05		Removed—end of test.

All heights relative to bottom of choke ring (so on this scale, the top of Fence 4 was at 5″).

2000:088 (28-Mar-00)

1. PIN2 antenna; change to SCIGN model of antenna: ASH701945B_M, S/N CR519991760, with SCIGN tall dome. Change completed by 088:18:52 (SOPAC site log).

2001:059 (28-Feb-01)

1. PIN1 antenna changed to SCIGN standard by Jeff Genrich: that is, to ASH701945C_M, S/N CR620005001, with SCIGN short dome 208. This replaced JPL D/M, in place since 1995:245.
2. SOPAC site log (June 2004) gives height of 1.790 m to BPA, noting that "Height was 1.745, corrected based on physical measurement at site. It is presumed that the previous model has a bad set of antenna dimensions, and that the old height for this antenna, which was based on the previous model minus the removed antenna adaptor, was incorrect."
3. However, setting the height to 1.745 (top of the hat) makes for only a small offset (1.6 mm) in the PIN1-PIN2 height, provided that the height up to this change (see 1995:214) is set to 1.859 m, which minimizes the offset at that date in 1995. A small offset is acceptable because of the effect of the dome.
4. Jeff also ran receivers at PIN102 (nearby mark), PINY (VLBI mark) and two more distant marks. All these data archived at the SCEC Data Center.

2004:175 (23-Jun-04)

1. PIN1 (Steve Bralla and Don Elliot): preamp base is sitting on the hat. Could not measure to lower rim of hat because height rod hits the choke ring (which has a short dome on it)—slightly shorter would work. So measured slant height to point on scale flush with lower edge of hat, and 2.7″ outside its outside diameter. Heights were 1.706, 1.705, 1.705 m. Since (1993:252) hat is 5″ radius (0.1270 m), and 2″ high (0.0508 m), these give vertical heights to top of hat of 1.7455, and 1.7445 (twice). Average is 1.7448 m—unreasonably close to the initial measurement (1990:060).
2. PIN2: from TOD to base of D3 adaptor is 2.52″ (0.0640 m); from TOD to inside of burn ring is 2.78″ (0.0706 m); from TOD to bottom of pipe-thread section of adaptor is 1.55″ (0.0394 m); from top of scale (4.28′) to bottom of baseplate (not choke ring) is 0.22″ (0.0056 m); from 4.2′ mark on scale to bottom of baseplate (not choke ring) is 1.2″ (0.0305 m).

2004:334 (30-Nov-04)

1. Steve Bralla measured distances to the ground from points on PIN1 and PIN2. For PIN2, measurement was along the pipe; for PIN1, to a point 60″ from the center. Results are (vertical distance from preamp base, computed by DCA):

	N	E	S	W
PIN1	1.67	1.77	1.83	1.71
PIN2	1.61	1.67	1.77	1.65
PIN2	35.4°	35.0°	32.4°	33.7°

Taking the mean of the EW values suggests that PIN1 is about 0.08 m higher than PIN2 (1.74 vs 1.66 m). The measurements at PIN2 also allow estimates of the angles of the pipes, which are as given above on the third line of the table.