Some PBO Implementation Issues

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This note, like much of my thinking about the PBO, has been suggested by earlier experiences with the SCIGN project. Looking back to SCIGN, and forward to PBO, some ideas come to mind about possible implementation issues—though I hasten to say that these ideas may not be agreed with by all associated with SCIGN. I wish to address two quite different issues: the first is to argue for extending a small part of PBO far from the plate boundary, and the second is to discuss some ''nuts-and-bolts'' issues of building the PBO.

1. Should PBO Measure Outside the Plate Boundary?

SCIGN currently extends as far into the Pacific plate as can be done in California, with sites on the islands in the California Borderlands. and plans a site on Guadalupe Island to get to this plate in Baja California. These outlying sites, plus some additional ones in southern Baja California, would seem to be all the PBO can do in getting to this side of the boundary. (The NSF Margins program may well take care of Baja.) In keeping with the suggestions made below for North America, we should consider some added redundancy for these existing installations. However, PBO should also consider putting some stations well east of the plate boundary, to provide a clear reference for what we can mean by ''stable North America''. This would seem important especially for understanding the distribution of motion from the Rockies to the Eastern California Shear Zone: the total is small, and we will need a well-defined reference for it.

Given the number of GPS sites in the central and eastern U.S., adding sites in this area might appear unnecessary. However, many of these are affected by postglacial rebound, and many more are not well monumented. It would thus seem reasonable for the PBO to include a small component whose avowed purpose would be to provide as stable a tie to North America as possible.

I would suggest that this can best be done through a hierarchy of interstation baselengths:

A. At the smallest scale, each *site* should have at least two identical *installations*, an installation being a receiver, antenna, and monument. If these installations are spaced of order 100 m apart, single-frequency analyses of the resulting data can be used to track offsets between the two at the 0.1 mm level. There does not seem to be any other way to do this—and we can be sure that such offsets will occur when equipment needs to be changed. Note that while duplicate installations double the equipment cost they do not double the site cost: monument construction, power, and telemetry costs will not double.

B. At the next scale, three (at least) sites spaced tens of km apart would form a *location*. At this spacing any hydrological effects (say) would not be common to sites, but they would still be close enough to allow precise inter-site monitoring,

correcting for global reference frame changes using a local network filter. The prime site criteria would be safety, permanence of land title, absence of tall vegetation, and shallow weathering.

C. The locations would be chosen to make possible sites with the characteristics just mentioned, while avoiding post-glacial rebound (as much as possible), tectonics, or other loading. Some possibilities would be the Black Hills, Ouachitas, Ozarks, or southernmost Appalachians; again, three seems like a minimum number. This would give 9 sites, or 18 installations— not a large part of the total.

Getting It Built—Some Challenges

Viewed just as a construction project, PBO will be quite a task; I have found it useful to think about how the different components can be most efficiently manufactured. As the SCIGN experience shows, it is all too easy to miss a schedule even when everyone works hard—and it is very undesirable. There are two ways to manufacture a lot of anything quickly. One is mass production: make the capital investment in specialized tools to enable many items to be produced in a short time (SCIGN did this with the antenna domes). The other is to parallelize the process: farm it out to many small producers who can each make part of the total needed. The first is more efficient, the second is more flexible.

How do the elements of PBO look when viewed in these terms? My own breakdown would be:

1. GPS equipment (receivers/antennas/telemetry). Not a problem, because for this PBO is a small part of a larger market, and this larger market supports mass-production methods.
2. GPS site construction (monuments, boxes, fences). Like everything but item 1, not a mass-produced item. However, building these, like any other multiple construction project, can easily be parallelized, with multiple construction teams operating in different areas. The skills needed are not difficult to find. (Of course, each team might subdivide tasks, as has been done for SCIGN).
3. Site permits. Can be done in parallel, though in this case the main barrier to getting permits quickly will be delays beyond our control. This was an important lesson from SCIGN: permits take effort and time, and there is no ‘‘magic bullet’’. PBO must start on this early, and allocate resources for it: not just for PBO personnel, but also to reimburse agencies for their time, and perhaps private landowners for their permission.
4. Strainmeter boreholes. As with (2), this can be parallelized to some extent, as the necessary drilling capabilities are not uncommon. We should examine very carefully the merits and demerits of owning a drill rig: this might not be something to take on, but it is not absurd given the number of holes to be drilled—and unlike a drilling company, we would not be covering depreciation. (We certainly do not want to become a drilling company).

5. Borehole strainmeters. USArray has found that a major concern is getting the number of broadband seismometers needed, since the global market is so small that it supports only two small manufacturers (Guralp and Streckheisen). There is even less of a market for borehole strain, as shown by the absence of any commercial firm in this area. Because of the special care needed in quality control, this is not a procedure that can obviously be parallelized, and yet the number of instruments to be made is too small to justify tooling up for mass production. Though there are methods available for intermediate-scale production (C/NC machining) getting these instruments built would appear to be an area of considerable possible concern. It will be very important as part of the PBO process to develop a detailed and credible plan for manufacturing and installing instruments at the rate needed.
6. Long-base strainmeters. Everything said about borehole strainmeters applies even more to long-base instruments: indeed, since they are built as much as manufactured, mass production is not even an applicable concept. However, this should not pose a major problem, given that the number likely to be included is not large. sourthern