SFBAY

Data Report and Description of Techniques for the 1993 Season of the San Francisco Bay Area Regional Broad-Band Transect, California

by
John R. Evans, John M. Coakley
and the Broadband Transect Working Group
(H. M. Iyer, Stan Ruppert, Susan Schwartz, John Vidale, George Zandt)

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1408 NE 45th Street
2nd Floor
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I have made this letter longer than usual, because I lack the time to make it short.
—Blaise Pascal, Lettres Provinciales, #16, 1656–1657

Contents

1. Introduction

We are searching for the San Andreas fault. The surface trace of the fault is very well mapped, of course, but the location of deeper shearing, particularly in the Earth's upper mantle, is poorly known. The location of this shearing is a matter of ongoing conjecture and study (e.g., *Furlong et al.*, 1989), and is important because it constrains and may modify interpretations and modeling of Earth-strain measurements. These, in turn, affect the evaluation and mitigation of earthquake hazards, particularly for areas with long quiescent periods between earthquakes.

We are using a polarization effect called "shear-wave splitting" in the waves of distant earthquakes to identify and characterize deforming regions in the mantle (cf. *Silver and Chan*, 1991). Succinctly, the slow, shearing distortions of the upper mantle line up crystals in those rocks. These crystal alignments affect seismic wave velocities, making them depend strongly on the polarization of the waves and the direction of wave travel. One result is that the shear wave splits into two waves of slightly different speeds. The time lag between these waves' arrivals and the polarization direction direction of the waves allow us to measure the crystal alignment, and from that infer the location, direction, and amount of shearing in the mantle. This mantle shearing distorts the Earth's overlying crust, causing earthquakes.

This "Transect" experiment was to be the prototype of its genre, to demonstrate the technique's efficacy in a relatively simple region possibly sporting a large lateral offset between surface and mantle shearing locations. The southern part of the San Francisco Bay Area has a small number of subparallel major faults (San Andreas, Hayward, and Calaveras) and some authors (e.g., *Furlong et al.*, 1989) propose that the mantle shearing is occurring near the Hayward and Calaveras faults, some 40-60 km east of the San Andreas. Hence, we designed a linear array of seismographs running perpendicular to the fault traces (Figure 1*a*).

Because of uncertainty in the distribution of mantle shearing, and to evaluate older and neighboring tectonism that could affect our interpretations, we spanned the whole region from near the coast, north of Santa Cruz, California, to the foothills of the Sierra Nevada, near Columbia, California (a State historic park in the Mother Lode). We planned seven to eight broadband-seismograph vaults along this line, spaced to obtain the maximum detail available from these (long wavelength) shear waves. Our array also takes advantage of two permanent broadband seismographs operated by the University of California, Berkeley (stations MHC at Mount Hamilton, and CMB at Columbia). Each or our vaults was to be occupied by continuously recording digital seismographs and modern broadband seismometers whenever such equipment was available. We planned a total of about 12 months recording, distributed over about three years, and mostly from Autumn into Spring, due to the limited availability of such equipment.

This project was begun in December, 1993, then cancelled unexpectedly in October, 1994. It is not clear whether it will be restarted by the USGS or others in this working group in a later year. In our one year of operation, we installed three of the vaults (Table 1), obtained preliminary data from two of them, developed and refined all major field procedures and major data processing methods and software, obtained most materials required for the remaining vaults, and were close to receiving permission for two more vault sites. Indeed, permitting sites proved the most onerous part of the study, since each vault's construction disrupts a moderately large area (about 10×10 m) and requires dirt-road travel in the wet season, while USGS policy and budget do not permit substantial compensation to landowners. We are deeply indebted to the landowners who allowed us to construct these vaults.

This report describes the methods we developed, releases the data obtained to date, and releases some related software, particularly a reliable, robust automatic WWVB time-code reader.

2. Description of Vaults

The necessity of using broadband instruments (which require both hard rock sites to mitigate site-response anomalies, and thermal stability to reduce long-period instrumental noise); anticipated rainy season operations over a period of several years; and the high value of the equipment to be used (~$40k per site), drove the decision to build semi-permanent, secure, winter-rated, hard-rock vaults. We explored numerous design alternatives, and the practices of other investigators using temperature- and tilt-sensitive equipment. Budgetary limitations necessitated a simple, relatively inexpensive design—our solution is illustrated in Figure 1*b*. Indeed, construction of these vaults proved to be largely a one-day task, with an expenditure of about $2k per site in materials and contracts.

The vault consists of two short sections of 42-inch diameter (107-cm) galvanized steel culvert placed on end in an excavation, with at least the longer of them bottoming on bedrock (the "sensor vault"). A four-inch diameter (10-cm) ABS plastic pipe connects the culverts below ground, so that signal and power lines may pass between the "sensor vault" and the "recorder vault". In the most recent variant, standard T and U fittings and two-inch (5-cm) ABS pipe create a rain-resistant cable route to the surface near the recorder vault, to support external solar panels and time-code receivers. All three ends of the ABS fixture are pressure fit with removable polyethylene-foam stoppers, to reduce air circulation, water-vapor condensation, and invasion by animals such as endemic black widow spiders and cable-chewing rodents. The entire assembly, including the joints in the culvert, is sealed with industrial-grade silicon rubber caulking. Both culverts are floored by four to six inches of sidewalk-grade premixed concrete (10-15 cm; about ¾ ton). A few strands of heavy-wire reinforcing are used in any recorder vault not bottoming on bedrock Once adequately cured (i.e., about a week after pouring), the concrete is sealed with a commercial mix of Latex™ and Portland cement—a widely available basement sealer. In addition to choosing sites with relatively deep water tables, the various sealant efforts to date have been effective in eliminating water seepage into the vaults, reportedly a major problem with some vault designs. Even so, some condensation, particularly on the upper parts of the vault walls and on the inside of the lid was observed, and more so in the less-insulated recorder vault.

Each culvert section is sealed by a custom-made steel lid ($140 each, $280 per site) fabricated by a local metal-spinning shop. They are of eighth-inch thick (3.2 mm) galvanized steel, with handles of bent stainless steel bar welded to two opposite sides. The inside of each lid is covered with a two-inch thick (5-cm) layer of polyethylene foam for thermal insulation, lid-vibration damping, and the vault air-and-animal seal. Hardened steel chain passes over the lid, through each handle, and down into the concrete on either side for security. The chain is pulled tight to prevent wind damage and lid rattling. They are bolted to the culvert at the bottoms and again about one foot (30 cm) below the lid, the latter to prevent the chain from being pulled off to the side of the lid, and the vault opened. The chains are locked with hardened padlocks having boron-steel hasps. This, and any other security system, can be overcome—site-access control and low site visibility from traveled roads and trails remain the principal sources of security. Remote areas on ranches often are optimal in this regard.

Inside the sensor culvert, a ¼-inch plywood inner lid supported by "2×4" (inch) studs maintains free air-space around the seismometer, and holds up bags of polystyrene foam between the inner and outer lids. This foam and the surrounding soil are the thermal insulation for the sensor. The thermal "mass" of underlying rock and concrete, and of the sensor package, damp remaining temperature variations. The foam layer should be at least 24 inches thick (61 cm), but was only about 18 inches thick (46 cm) in early vaults, including the one tested for thermal stability (Section 2.1).

Vault construction requires about one day of labor by about three people, plus about six hours (and travel time) for a full-sized backhoe *equipped with a narrow bucket and "rock teeth"*. A standard 90-psi jackhammer also may be required for more massive rock—the contractor should bring several spare bits since they are likely to dull or break in such use. Bids for backhoe services ranged from $60/hour to $100/hour in central California, with $65-$75/hour being the norm. Jackhammer rentals typically ranged from $140 to $150 per day, with compressor. We paid about $800-$900 per vault for these services. An additional day of labor by two people is required to prepare the culvert vault modules and other items (cleaning, sealing, edge preparation, and installing lids and chains), and to load two pickup trucks with the required items. Finally, another two hours are needed about a week later, after the concrete cures, for applying concrete sealant and affixing metal sensor baseplates (which we attached with concrete-patch material), and for curing of these items to the point where an instrument can be installed. Our materials and equipment checklist for these operations is in Appendix A.

2.1 Vault Temperature Stability

To test the sensor vault for thermal stability, we used a Type-K thermocouple with an inexpensive commercial adaptor (Fluke™ 80TK) designed for use with digital volt-meters. Output of the adaptor (1 mV/°C) was recorded at a low continuous sample rate on an available seismograph channel. The RefTek™ 72A-07 used has a ~0.5 MΩ input impedance, while Fluke™ DVMs have 10 MΩ input impedance. Based on conversations with Fluke™ engineers and a simple shunt resistor test on a Fluke™ DVM, this difference depressed temperature readings about 0.4°C on the RefTek™ at room temperature—less than the precision of the thermocouple (±1.1°C) and the 80TK (±2°C) at 20°C. On a RefTek™ 72A-02, with ~2 MΩ input impedance, the reading would be depressed about 0.1°C. The internal 9-V battery of the 80TK appears to operate it continuously for several weeks, at least. (Note that the battery-check mode of the Fluke™ 80TK fails completely for anything but a 10 MΩ impedance.)

We made several abortive attempts to use this setup, which yielded erratic voltage anomalies but also suggested large (~6°C) diurnal fluctuations in vault air temperature near the seismometer. We guessed that condensation on the exposed thermocouple tip might be altering leakage-current resistances, and subsequently immersed the thermocouple tip in heat-sink silicon grease. We also put the thermocouple tip in thermal, but not electrical, contact with the dome of the Streckeisen™ STS-2 inside the vault. Because of the large suspected diurnal cycle, at this point we also stacked two wooden freight pallets on top of the vault lid and covered them with a canvas tarpaulin, open on the north but shading the vault lid fully. (The alternative is burying the vault lid under 20 cm of soil.) In combination, these techniques seemed to work, providing credible data and a greatly reduced diurnal cycle. The 5.8-day long record for this arrangement is shown in Figure 2. It indicates a one-day exponential cool-down period, followed by a ~0.3°C peak-peak diurnal cycle, plus a long linear drift that may be due to outside weather changes (the drift is −0.2 °C/day). The diurnal cycle has a maximum of about 0.4°C peak-peak and RMS of 0.084°C.

With the 36-inch long (91-cm) culvert section of our early sensor-vault design, protruding about 3 inches (8 cm) from the ground, a 12-inch (30-cm) air gap at the bottom, and four inches (10-cm) of concrete, there are only 17 inches (43 cm) left for styrene insulation from the ground surface down to the inner lid. We conclude that this 43-cm insulation layer is inadequate without additional surface insulation. The vault design in Figure 1*b* shows a 42-inch long (107 cm) culvert section for the same reason. We have not determined whether this culvert length (yielding a 58-cm insulation layer) is sufficient. Providing shade to the vault lid is a reasonable precaution in all cases, only being careful not to create any wind-driven rattle in these surface-insulating materials.

3. Field Procedures

For several reasons, we chose a very cautious and thorough operational procedure. This study was the first-author's first with broadband seismometers and IRIS/PASSCAL RefTek™ recorders (called a "DAS" by PASSCAL). The vaults are few, expensive, and widely spaced. Suitable teleseisms ($\Delta \approx 100°$ and $m_b \geq 6.0$) are rare. Most of those recorded in the western United States have northwest, southwest, or southeast azimuths—about parallel or perpendicular to anticipated anisotropy axes. So they will excite only one of the mantle's polarization directions and cannot generate the other polarization of shear wave, and there is no shear-wave splitting to measure. Hence, it is desirable that all stations run with high reliability, to be certain of capturing the rare useful events. To obviate events lost by triggering errors, we recorded continuously. Available disk sizes allowed a maximum of 10 to 20 samples per second, which is sufficient for teleseismic work but not really adequate for the local and regional earthquakes that we also recorded. Servicing intervals ranged from one to two weeks, depending on sample rate.

To speed field operations and allow more reliable data recovery, we swapped disks rather than copying data in the field. Lastly, we anticipated that some servicing personnel would be relatively inexperienced with these instruments. Our resulting field procedure is described best by our field notes form (Appendix B). It is methodical, detailed, and deliberately redundant.

3.1 GPS Timing Stability versus WWVB Radio

Because of reported problems with timing in some older PASSCAL instruments, particularly with Omega radios, we chose to use the new GPS time-base receivers, which are used to correct the internal RefTek™ TCXO at hourly intervals whenever a GPS lock can be obtained. We also chose to record WWVB radio timecode as a backup. We recorded 80-s bursts of WWVB at 250 samples per second every three hours, from True Time™ 86-3 receivers. The recording window began 10-s before the minute, yielding one full code cycle and 10-s end buffers. Because this receiver first detects the signal, then attempts to clean it up with a comparator circuit and signal-following threshold, the time of signal transitions (which mark the seconds) can be more variable than in the raw, detected signal. One of us (J. Evans) earlier developed a successful WWVB time-code reader (*ahwwvb*—Appendix F) that preprocesses the signal through running-median filters (Evans, 1982) and an edge-finding algorithm. This processing cleans the signal in a manner that preserves the transitions times of the input signal, and is highly robust to radio noise typical of WWVB. Hence, we chose to record only the detected output of the receiver (pin E, "DC test", of the 86-3).

Reading these time-code bursts with program *ahwwvb*, and comparing these automatically derived time readings to the GPS-tracking internal RefTek™ time base, yielded very hopeful results (Figure 3). No GPS errors were detected, and the two time bases tracked each other very closely—nearly always within one sample interval of the WWVB time-code (4 ms). The new GPS time base receivers appear to be very reliable in the field, with all detected errors attributable to noise and reading errors of the WWVB time-codes.

Several WWVB segments were unreadable because of a large spike very near the minute mark. This spike may be caused by power cycling in the RefTek™, from which the WWVB receiver draws its power; hence, it may be appropriate to move the WWVB recording window off the even hour. However, we have not pursued the cause of these occasional spikes.

Bob Busby of PASSCAL reports (E-mail, 05 January 1994): "We have compared the accuracy of Omega and GPS external clocks to a pulse input from a GOES and find the PHASE ERRORS reported by the DAS to be correct, when properly interpreted. There are rare cases during a hardware failure of the clock that things go awry. There also remain occasional mislabeling of packets by the DAS which can result in a file start time mislabeled by a sample or two-these errors are tracked in the .err file ref2segy produces." Those phase errors are generally well under 1 ms.

4. Description of the Data

In 1993, we obtained data at two vault sites (SFT2 and SFT5, Table 1) during two brief recording periods, one in the Spring and one in the Summer (Table 2). The most useful data set is from the Summer recording period, which was mostly with Streckeisen™ STS-2 broadband sensors, and was largely simultaneous at the two vaults. Events extracted from these continuous records are described in Table 3. Time bases for both recording periods were GPS clocks; the Spring period had WWVB backup, successfully verifying GPS accuracy.

In the field, data disks were swapped to save time and reduce field-operations errors. In the lab, these data were double copied to ExaByte™ tapes, first with *wrendump*, a simple image of the disk, and then with *ref2segy* (to disk) and *tar* (disk to ExaByte™), making a set of PASSCAL SEG-Y files in day-sorted subdirectories. These SEG-Y files were then checked with the *pql* program for quality control and event discovery or event evaluation. As the experiment progressed, we developed partially automated techniques for event identification. (An effort to start a triggered channel to collect a local trigger list was abandoned. It was impeded by the high microseism levels on broadband instruments, difficulties in making the triggered stream work consistently, and our wish to extract every conceivably useful event for coauthors and the IRIS DMC. Further efforts in trigger tuning might be effective, but the ready availability of near-real-time catalogs for this region made such efforts redundant.)

We recording all three components continuously at 10 sps (samples per second) when using the RefTek™ 72A-02 (Spring recording period) and at 20 sps when using the RefTek™ 72A-07 (Summer), since the latter does not support 10 sps (it lacks the DSP chip required to compute the necessary decimation filters). Lists of events were gathered from the CalNet regional 1-Hz network operated by the USGS, and from the USGS National Earthquake Information Service (NEIS), which monitors several world-wide and regional networks. Data from both centers are available on-line. We used the QED service of NEIS (Appendix E) via *telnet*, and the *qfetch* program supported here in Menlo Park for CalNet (Appendix D). We produced software to sift each data set and produce input for our event-extraction script, *cutpaste* (Appendix C), which runs several PASSCAL-supported programs to extract events from the continuous data stream. It remains necessary to move continuous files between day-directories manually when events overlap day boundaries in the continuous stream.

The IRIS DMC, with this Open-file Report, receives for general distribution copies of the *wrendump* tapes and *tar* tapes of all extracted events, the latter in both SEG-Y and *xdr-ah* format.

Our philosophy and the details of event extraction evolved over the course of this experiment. We eventually settled on extracted generous windows around every QED teleseism with any *pql*-visible phase on station SFT5 (often only a weak surface wave), plus local and regional CalNet events as follows: two annuli are taken about SFT5, extracting all events of $M_L \geq 2.0$ from 0 to 200 km away, and all events of $M_L \geq 3.5$ from 200 to 400 km away. A few smaller local events noted during *pql* scans were also extracted, but this latter effort was intermittent. Teleseisms were extracted for windows from one minute before the earliest *iasp91* phase to at least one minute after the last visible surface wave. This is a very generous extraction policy, so many of the extracted events are very small. Only one large *SKS* phase at appropriate distance was obtained (event "93219.001221" during the Summer run), which has about 25 s of *SKSac* and *SKKSac* before the *S* arrival (Figure 4). The large event near Guam also was captured (event "93220.084555"). Both these events were recorded with STS-2 sensors at both SFT2 and SFT5 at 20 sps.

5. Acknowledgements

We wish to thank the generous landowners who let us build and operate these vaults (Helen Gerber and the Wells family at SFT5, J. Howard Craven at SFT2, and Gary Stoddard at SFT4), and in all cases showed special interest, thoughtfulness, and forgiveness of our learning curves. Such people make this work possible and often a joy. In addition, we would like to thank the many people who helped us find vault sites or install the vaults. Their names are numerous, but Larry Cox, Arlene Evans, Bud McCrary, Satish Sheth, Roberta Smith, Gene Tobar, David Toshikian, Jim Weaver, and Gerry Weber stand out.

We thank the IRIS consortium and PASSCAL program for the use of their instrumentation and the generous assistance supplied by both PASSCAL instrumentation centers, particularly Bob Busby, Marcos Alvarez, Steve Michnick, and Paul Friberg. Bernard Chouet gave us liberal access to his Streckeisen™ STS-2 throughout this recording season, and Joe Fletcher gave us full use of his two low-power STS-2's during the Summer recording interval. Barbara Romanowicz and many others at the University of California, Berkeley and Santa Cruz, gave advice and support. Bob Urhammer performed noise analysis for SFT2 and SFT5. Malcolm Johnson and Doug Myren provided extensive and invaluable advice on thermally and geometrically stable vault design issues from their broad experience with tilt meters.

Several stalwarts helped us in the heavy construction of these vaults, and the sometimes arduous preparations for it. They are Marcos Alvarez, Bill Lutter, Gonzalo Mendoza, Angus Miller, and Alwyn Ross.

The following are trade names, trade marks, or model names of various organizations. They are cited subject to the disclaimers on the title page of this report: 72A-02, 72A-07, 80TK, 86-3, Brunton, DAS, EHT, ExaByte, Fluke, IRIS, Latex, PASSCAL, RefTek, SCSI, SEG-Y, Sharpie, Streckeisen, STS-2, Trimble, and True Time. Some of the software names used are also recognized product names of various organizations, cited as above (at least, *fsc*, *ftp*, *pql*, *QED*, *qfetch*, *qselect*, *ref2segy*, *segymerge*, *segy2ah*, *tar*, *telnet*, *troff*, and *wrendump*).

Lastly, we would like to thank Mother Earth, which put on the most remarkable display of California Spring wildflowers we have ever seen—and the first two authors are California natives.

6. References

Evans, J. R., Running median filters and a general despiker, *Bull. Seismol. Soc. Am.*, 72, 331–338, 1982.

Furlong, K. P., Hugo, W. D., and Zandt, G., Geometry and evolution of the San Andreas fault zone in northern California, *J. Geophys. Res.*, 94, 3100–3110, 1989.

Silver, P. G., and Chan, W. W., Shear wave splitting and subcontinental mantle deformation, *J. Geophys. Res.*, 96, 16,429–16,454, 1991.

7. Appendix A: Vault Construction Checklist

The following file is available *via* anonymous *ftp* on computer "andreas.wr.usgs.gov", in file "~ftp/pub/outgoing/evans/equipment_list".

TOOLS AND MATERIALS TO TAKE FOR THE CONSTRUCTION OF ONE SF-BAY TRANSECT VAULT
(August 1993)

(C = vault Construction; I = vault finish and instrument Installation; S = regular Servicing of instrument)

Class: Item	For: C	I	S	Quantity
Materials:				
Tubs (with chains & locks attached)	*	_	_	2 each
Lids (fit checked, insulation in)	*	_	_	2 each
A389 locks (hardened)	*	_	_	2 each
ABS pipe (4" ID)	*	_	_	1 8-foot length
Foam plugs for ABS pipe	*	_	_	2 each
Inner lid	_	*	_	1 each
dry-wall screws	_	*	_	9 each
legs	_	*	_	3 each
Styrofoam peanuts	_	*	_	20 cubic feet
Small, thick garbage bags	_	*	_	20 each
Recorder vault inner lid	_	*	*	as needed
Resources:				
Vehicles (with spark arrestors)	2	1	1	as shown
Tie-down rope and rug scraps	*	_	_	as needed
People	4	4	1	as shown
Making concrete:				
Sidewalk concrete premix (90# bags)	*	_	_	20 bags
Wheel barrow	*	_	_	1 each
or, mixing barrel	*	_	_	1 each
Hoe (for mixing)	*	_	_	1 each
Concrete trowel	*	_	_	1 each
5-gallon water jugs	*	1	_	10 each
Concrete sealant	_	*	*	100 square feet
Brush for concrete sealant	_	*	*	1 each
Turpentine or paint thinner	_	*	*	1 quart
Concrete patch	_	*	*	20 square feet
Wire brush (surface preparation)	_	*	_	1 each
Scrub brush (surface preparation)	_	*	_	1 each
Digging:				
Backhoe and operator	*	_	_	1 each
Jackhammer, compressor, operator	*	_	_	1 each
Small jackhammer	*	_	_	1 each (if rock is fragile)
Sledge (3#)	*	*	*	1 each
Sledge (10#)	*	_	_	1 each
Pick (large; good fit)	*	_	_	1 each

Breaker/Digger bar	* * *	1 each
Cold chisels (rock)	* * *	1 set

General Tools:

MacCloud tool	* * *	1 each
Shovels	* * *	as needed
Crosscut saw for ABS	* _ _	1 each
12 V water pump and hoses	* * *	1 set
Metal-cutting saw for culvert	* * _	1 each
Caulking gun	* * *	1 each
Caulking (clear silicon rubber)	* * *	4 tubes
Drill (hand)	* * _	1 each
Bits	* * _	1 each
Crescent wrench	* * *	2 each
Files (metal, flat)	* * *	2 each
Files (metal, round)	* * *	1 each
Rasp (fine, ABS)	* _ _	1 each
Solvent (alcohol) and wipes	* * *	4 bottles + 4 boxes
General tool box	* * *	1 set
Soft brush, broom, dust pan	_ * _	1 set
4-foot 2X4 (straight edge)	_ * *	1 each
Level (2-3' long)	* * _	1 each
Bucket (1-2 gal)	* * *	1 each
Mixing stick	_ * *	1 each
Scoop (small)	* * *	1 each
Sponges	_ * *	2 large
Duct tape	_ * *	1 roll

Site protection:

Plywood covers	* _ _	8 small
Pallet (for concrete bags)	* _ _	1 each
Tarpaulin (for concrete bags)	* _ _	1 each

People protection:

Ear protection	* * _	1 per person
Eye protection	* * _	1 each
Tick repellent and/or insect spray	* * *	2+ bottles/cans
Sun hat	* * *	1 each per person
Sun screen	* * *	1 bottle
Helmets (when near backhoe)	* _ _	1 per person
Gloves	* * *	1 pair per person
Hand soap for cleanup	* * *	1 each
3/4" plywood, ~3X6' (to lie on)	* * *	1 each

Fence making (as needed):

Barbed wire	* * _	1 spool
"T-bar" Posts	* * _	15+ each
Post Driver	* _ _	1 each
Pliers (fencing)	* * _	1 each
Pliers (locking)	* * *	1 each
Pliers (regular)	* * *	1 each
Wire ties	* * _	60 each (at least)
Wire stays	* * _	24 each (at least)

Instrumentation:

Seismometers	_	*	_	1 3-component set
Jug line	_	*	_	1 3-component set
Low-noise amps	_	*	_	as needed (STS-2)
Battery, 12V, 100 AH	_	*	*	as needed (STS-2)
Solar panel, 40W	_	*	_	1 each
Power regulator for solar	_	*	_	1 each
Terminal strip and leads	_	*	*	1 set
Battery cover	_	*	*	1 each
Spare battery and cable for retrieving a DAS still powered up	_	*	*	1 set
Base plate(s)	_	*	_	1 set
Epoxy for leg anchor	_	*	*	1 set
Manual(s)	_	*	*	1 set
DAS	_	*	_	1 each
Disk, 230 MBytes	_	*	*	1 each
SCSI cable, DAS-Disk	_	*	_	1 each
Power cable, DAS-Disk	_	*	_	1 each
Power cable, Battery-DAS	_	*	_	1 each
Power cable, Battery-Solar	_	*	_	1 each
Grommets for cables	_	*	_	1 per exterior cable
WWVB radio	_	*	_	1 each
Antenna	_	*	_	1 each
Cables (antenna, DAS)	_	*	_	2 each
Lead brick to hold down cables	_	*	_	1 each
GPS clock	_	*	_	1 each
Cable, DAS-GPS	_	*	_	1 each
Battery, 12V, 100 AH	_	*	*	1 each
Solar panel, 40W	_	*	_	1 each
Power regulator for solar	_	*	_	1 each
Thumb screws	_	*	*	1 set
Battery cover	_	*	*	1 each
Manual(s)	_	*	*	1 set
Wooden blocks--DAS off concrete	_	*	_	1 set
Maps, site and adjacent	_	*	*	>=1 set
Master clock	_	*	*	1 each
Box-cable	_	*	*	1 each
WWV radio and antenna	_	*	*	1 set
Desiccant	_	*	*	as needed
Glass tape for desiccant	_	*	*	1 roll
Camera and film	*	*	*	as needed
Brunton compass	*	*	*	2 each
Recording thermometer or thermocouple	_	*	*	1 set, as needed
Grommets for antenna leads	_	*	_	2 each
Blank field notes	_	*	*	>=1 per DAS
Last trip's field notes	_	_	*	1 per DAS
Gardening knee pad	*	*	*	>=1 each
Small stool or vault-rim seat	_	*	*	1 each
DVM	_	*	*	1 each
EHT, with external-battery adaptor	_	*	*	1 each
Lap-top PC with fsc software	_	*	*	1 each, if available
Labels for used disks	_	_	*	plenty
Pallet and plywood for shade	_	*	*	2 sets

Office:

Calculator (with trig)	*	*	*	1 each
Drawing compass	_	*	*	1 each
Protractor	_	*	*	1 each
Triangle	_	*	*	1 each
Notebook for general use	*	*	*	1 each
Clip board	_	*	*	1 each
Labeling pens (Sharpie, etc.)	*	*	*	several

Other:

Canvass/plastic mat	*	*	*	as needed
Mirror (small)	*	*	*	as needed
Mirror (large)	*	*	_	as needed
Sun umbrella, IR blocking	*	*	*	1 each
Umbrella stand	*	*	*	1 each
Backpack for regular gear	_	*	*	1 each

8. Appendix B: Standard Field Notes for Transect

The following field notes are designed very conservatively since these are high-value sites that may be serviced by relatively inexperienced personnel. They are part instruction manual and part data sheet. They are specific to our procedures (continuous broad-band recording with dual GPS and WWVB time sources). A copy of the *troff* input script for these notes is in anonymous *ftp* on computer "andreas.wr.usgs.gov", in file "~ftp/pub/outgoing/evans/DAS_SFTransect_data_sheet". It may be a useful starting point for some other PASSCAL studies. This Open-File Report serves to release them to the public, subject to the limitations cited on the title page.

PASSCAL Station-Visit Instructions and Notes

(form last modified 02 August 93; Evans and Coakley, USGS)

1a. **Arrive:** ____M/____D/1993 = ________ Julian, ____:____UTC (**all dates and times are to be in UTC**).

Purpose: ☐ Regular visit; ☐ Install (do 18a and 20 *now*); ☐ Remove; Other: ________________

1b. Plug in EHT, and then do COMMNCTNS—RECV PRMS: ☐, or explain why not ________________

2a. Verify STATION—EXP NAME: **SF BAY LP TRANSECT**; STATION—EXP CMMNT: **P9220** ______

2b. Verify STATION—STN NUMBR; STATION—STN NAME (code); STATION—STN CMNT (full name):

☐ #1, SFT1, SANTA CRUZ VAULT
☐ #2, SFT2, FERN PEAK VAULT
☐ #4, SFT4, SAN ANTONIO VALLEY VAULT
☐ #5, SFT5, INGRAM CANYON VAULT
☐ #7, SFT7, WOODWARD RESERVOIR VAULT

or #___, ________, ______________________________

3. Weather:

Wind	**Temp.**	**Clouds**	**Humidity**	**Precip.**	**Lightning**
☐ still	☐ cold	☐ clear	☐ low	☐ none	☐ none
☐ light	☐ cool	☐ scattered clouds	☐ moderate	☐ light	☐ nearby
☐ moderate	☐ mild	☐ partly cloudy	☐ high	☐ heavy	☐ distant
☐ strong	☐ warm	☐ mostly cloudy			☐ active
☐ gale+	☐ hot	☐ fully overcast			☐ rare

4. Sensor: ☐ STS-2 (S/N: ____________) ☐ Fluke 80TK (set for °C only ☐)

☐ SV/H-1 (S/N's: V=____________, N=____________, E=____________)

S/N(s) read from ☐ sensor, ☐ DAS, or ________________________

For your information: Expected Channels and Streams

Signal	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6
Vertical	**72A-07**			**72A-02**		
North		**72A-07**			**72A-02**	
East			**72A-07**			**72A-02**
WWVB		**72A-02**				
Temperature			**-02 or -07**			

Stream	Signals Recorded	Rate (sps) 72A-02 (-07)	Data Size 72A-02 (-07)	Trigger Type	Comment (expected events/day; cf. step 7)
1	V, N, E	10 (20)	32 (32)	Continuous	3600-s blocks (24)
2	V, N, E	1 (N/A)	16 (N/A)	Continuous	3600-s blocks (24)
3	raw WWVB	250 (N/A)	16 (N/A)	Timed	Every 3 hours (8)
4	V, N, E	100 (20)	32 (32)	Triggered	For locals and regionals (~20?)
5	Fluke 80TK	1 (20)	16 (32)	Continuous	3600-s blocks, °C (24)

5a. EHT software version: ________________ (UTILITIES—VERSN NOS—FST)

5b. DAS serial number: ________________ (UTILITIES—VERSN NOS—ID ≡ DAS faceplate: ☐)

5c. DAS software version: ________________ (UTILITIES—VERSN NOS—CPU)

5d. DSP software version: ________________ (UTILITIES—VERSN NOS—DSP)

6. Check battery voltages *via* DVM:

Primary DAS supply: __________ VDC (DAS will fail below 11.5 VDC).

This supply is a ☐ 72A-04 (Pins D-A) or ☐ deep-discharge marine battery (measured at lugs).

Solar panel: __________ VDC or ☐ none installed.

Sensor supply: __________ VDC or ☐ no sensor supply installed. ☐ solar panel also installed for sensor.

WWVB supply: __________ VDC or ☐ none or powered by DAS (for 72A-02, circle two as *found*):

For 72A-02, want DIAGNOSTICS—ACQUISITION—C1—12V. Got C1: OFF CS 12V BOTH

For 72A-07, N/A. Got C4: OFF CS 12V BOTH

7. Check DAS status (UTILITIES—DAS STATE). Record:

KIN OMGA ☐ 500, ☐ 50, ☐ 5; or ☐ NO UTC CLOCK, or UTC _______ _______

ACQ STRT ON (circle one each column)

STOP OFF

EVENTS: __________ (Is "EVENTS" reasonable (estimate *via* stream table, p. 1)? ☐ yes, ☐ no)

BLKS US: __________ Streams: ☐ are as expected,

BLKS AV: __________ or ________________________________

If no Master Clock is available: DAS time is ☐ visually close, or is ☐ fast, ☐ slow by

~ ____________________ w.r.t. reference standard of ____________________

8. Check external clock status (UTILITIES—XCLK STAT)

☐ Omega or ☐ GPS; Time of last lock: ________ Julian, _____:_____ UTC. TYPE _______

S/N of radio (from box): __________

For Omega clock, verify that leap second is 18 (STATION—XCK SETUP—LEAP SECS): ☐.

(Have you received parameters from this DAS so the value is meaningful?)

9. If Master Clock is available, use it to check and reset DAS clock: TIME—SET TIME—enter next minute—set up Master Clock (5V positive going pulse, thumb wheel to same next-minute)—connect to COMM, press PULSE (but not more than 30-s before the minute), wait for that minute, then:

Old time: ________Y:________J:______H:______M:______.________s

New time: ________Y:________J:______H:______M:______.000s

Disconnect Master Clock and reconnect GPS, if in use: ☐

10. Verify mass-position offsets: for STS-2, measure VDC with a DVM at host-box Monitor connector (notice the order); for SV/H-1, draw it as you see it relative to the ticks:

STS-2 (old)	Element U: (Pins F-T)		Element W: (Pins F-U)		Element V: (Pins F-V)	
STS-2 (new†)	Element U: (Pins F-T)		Element W: (Pins F-U)		Element V: (Pins F-V)	
SV/H-1 (old)	Vertical: Connector at this end		North: Connector at this end		East: Connector at this end	

☐ † **did** or ☐ **did not** recenter STS-2.

11. **For STS-2**, recenter if any element is more than ±1.0 VDC. Depress the button on the "host box" for at least 0.5 s. You should hear clicks and motor sounds from the sensor, if it is exposed. The recentering sequence lasts about 30 s. Re-check offsets and recenter again if necessary. Repeat up to 8 times; after that tilting one support legs away from bubble-center may be necessary as a work-around (turn power off and lock **all three elements first!**), though this is a rarely needed option.

Never open the sensor package in the field (or at all if you haven't been instructed in that risky operation). For that matter, never move an unlocked STS-2, or significantly bump even a locked one—$20K and a 15-month waiting list—the manufacturer will not repair these instruments.

For SV/H-1, if you doubt centering (due to a dead channel, for example) open the vault and recenter mass to tick marks *via* the knurled support leg of the SH-1 and the knurled spring-tension knob of the SV-1.

☐ **vault opened before calibration** ☐ **vault opened after calibration** ☐ **vault not opened**

Recentered SV/H-1: ☐ Vertical, ☐ North, ☐ East.

Other actions taken: ______________________________

12. If acquisition has stopped and RAM is full, or if installing site: check here ☐ and wait to do this step until after step 24 (that is, after restarting the DAS and shortly before leaving the site).

Calibrate the sensor (72A-02 only): DAS *must* be acquiring data, that is, "START ON" (verify: ☐).

For STS-2 install the jumper plug in the Monitor connector of the host box (☐), press DIAGNOSTICS—ACQUISITION—C4 (it responds "CS"—note this time below) (☐), and leave it on for *15 minutes* while you remain *very still* or leave the vicinity (at least 10 m and be quiet). (The "free period" of this instrument is 2 *minutes*, and the sensor is very tilt sensitive. The C4 relay connects the DAS "test bus" to the input-connector of channels 4, 5, and 6 and starts the calibration sequence. The DAS performs a series of mass-drop calibrations *via* the calibration coils.) After the allotted time, press C4 *three* times, until it responds "OFF" (☐). Lastly, *remove jumper* (☐). (Standard settings: duration 60 s, step ON, interval 360 s, step size 361 s, amplitude 8.0 V, output to COIL.)

For SV/H-1 sites, there is no jumper. Press DIAGNOSTICS—ACQUISITION—C4 (☐). *Wait very quietly for 2 minutes.* Then turn C4 to "OFF" *via* three strokes (☐). (Standard settings: duration 120 s, step ON, interval 30 s, step size 31 s, amplitude 1.0 V, output to COIL.)

Calibration start time: ________ Julian, ____:____:____ UTC

Turn off EHT until 30 s from end (or it shuts itself off at the most inconvenient moments).

13. **Stop acquisition.** (From the main menu, do COMMNCTNS—STOP ACQ—YES, and wait for it to return to COMMNCTNS menu with a beep)
    Time of the beep: ________ Julian, ____:____:____ UTC

14. Verify reasonable sensor signals on active channels (MONITOR—enter 15 s—CHAN, 72A-02: 2,4,5,6; 72A-07: 1,2,3; Temperature: 3):

Channel	1	2	3	4	5	6
Max/Min and Sketch and/or Comment	/	/	/	/	/	/

(Press "X" to exit back to CHAN menu.)

15. Check SCSI status (UTILITIES—SCSI STAT). Spins disk and indicates length used.
    Write **all 7 digits** of length used: __ __ __ __ __ __ __

Do 16a and 16b for 72A-02 OR 16a and 16c for 72A-07:

16a. Label old disk (for 72A-02) or transfer disk (for 72A-07) with:
- ☐ Station name (and, if huddled, which sensor(s))
- ☐ DAS S/N
- ☐ Time of STOP ACQ (Year:Julian day:hour:minute UTC)
- ☐ Your initials

16b. **Swap disks** (☐ Yes or ☐ N/A) (for 72A-02): remove power cable, remove SCSI cable, attach power cable, attach SCSI cable. Take home the old disk—it contains the data!
Write down the size of the *new* disk you attach: ______ MBytes (typically 230 MBytes).
(If unsure, try UTILITIES—SCSI STAT and write down **total** + 1000.)

16c. Copy data from internal disk to transfer disk (for 72A-07) (☐ Yes or ☐ N/A): connect the transfer disk to its battery, wait 15 s for it to spin up, connect its SCSI cable to DAS, do UTILITIES—NEXT MENU—COPY SCSI—(COPY DISK TO) DISK—YES, wait until "WAITING ..." goes off and EHT beeps, disconnect SCSI cable, power down transfer disk. **Remember not to bump or move the transfer disk while it is spinning.**

17. **Swap batteries as needed:**
    ☐ none changed
    Primary DAS supply: _________ VDC (**DAS will fail below 11.5 VDC**).
    This supply is a ☐ 72A-04 (Pins D-A) or ☐ deep-discharge marine battery (measured at lugs).
    If in use, is solar panel properly connected? ☐ Yes
    Sensor supply: _________ VDC or ☐ no sensor supply installed. ☐ solar panel also installed for sensor.

18a. **Only upon initial site installation (☐), DAS replacement (☐), or serious DAS trouble (☐) (check one):** Consider doing COMMNCTNS—RECV PRMS, then do a rigorous DAS initialization (UTILITIES—NEXT MENU—SYS INIT, then give password "IRIS"). **Warning:** this function clears *everything* in the DAS, including wiping out your parameter set—everything is set to factory default values. If you do this step (18a), then skip step 18b but **do step 20** (reprogramming the DAS).

Or

18b. Clear the DAS's RAM (UTILITIES—NEXT MENU—CLEAR RAM—YES): ☐

19. Format (that is, erase) the disk (UTILITIES—NEXT MENU—FRMT SCSI—DISK—YES): ☐
    (You may see "—WREN" instead, which is an anachronism meaning "—DISK"). Should hear clicks.

20. If necessary, reprogram the DAS, typically as follows:
    (a) Load existing parameters from DAS to EHT (COMMNCTNS—RECV PRMS) OR ☐ done in step 1b.
        Upon site installation or other SYS INIT, the EHT *may or may not* have a more correct
        set of parameters to start from (☐). You *may* need to do COMMNCTNS—LOAD PRMS first (☐).
    (b) Modify parameters on EHT as needed (e.g., add or change sensor S/N's, which are generally
        unknown to the author of an fsc file). Write any changes in "Synopsis", below.
    (c) Send modified parameters from EHT to DAS (COMMNCTNS—SEND PRMS) (☐).

Synopsis of parameter changes: ☐ none, ☐ all new (fsc file: ________________), and/or: ____________

____

____

21. Verify that you still have reasonable sensor signals (DIAGNOSTICS—OFFSET—set 0:15—CHAN, 72A-02: 2,4,5,6; 72A-07: 1,2,3; Temperature: 3) (At your discretion, instead use MONITOR—enter 15 s—CHAN to get an actual picture of the data):

Channel	1	2	3	4	5	6
Max						
Min						
Ave; or Sketch and/or Comment						

++

Perform steps 22 and 23 within 3 minutes of one another (limited by the WWVB stream). This restriction is a work-around for a bug that eats up pre-event memory in DAS software versions 2.46 and 2.47. (For the fastest sampling rate possible, the lag would need to be under 10 s.)

22. Perform system reset (UTILITIES—SYS RESET—YES—CONTINUE): ☐

23. **Start acquisition** (COMMNCTNS—START ACQ—set 0:0—YES and wait for the DAS STATE display).
    Time STRT ON is verified by beep and status display: ________ Julian, ____:____:____ UTC
    EVENTS: ________
    BLKS US: ________
    BLKS AV: ________
    Streams: ☐ are as expected, or ____

++

24. Restart power to the WWVB radio (for 72A-02, **circle two** as you *actually* see them):
    For 72A-02, want DIAGNOSTICS—ACQUISITION—C1—12V. Got C1: OFF CS 12V BOTH
    For 72A-07, N/A. Got C4: OFF CS 12V BOTH

Remember to do step 12 (calibration) now, if it was deferred.

25. **Remember not to unplug anything from the DAS except the EHT.**

26. **Depart at** _____M/_____D/1993 = ________ Julian, ~____:____UTC.

27. Operator(s) name(s):

☐ John M. Coakley; ☐ John R. Evans; ☐ Gonzalo Mendoza

Others present: ____

____

Comments, and any troubles noted (as needed, use margins (except left margin), and use backs of sheets):