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Task 1: Geodetic monitoring of the Yucca Mountain region using continuous global positioning system measurements

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Task 1 Geodetic Monitoring of the Yucca Mountain Region
Using Continuous Global Positioning System Measurements
(A Non-Quality Affecting Task)
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Final Quarterly Report
07/01/03-09/30/03and Final Report for the period 06/23/98-09/30/03
Account 7271

Statement of Work:

The principal purpose of the cooperative agreement is to develop and continue providing the public and the Yucca Mountain Site Characterization Office (YMSCO) with an independently derived, unbiased body of scientific and engineering data concerning the study of Yucca Mountain as a potential high level waste repository. Under this agreement, the University and Community College System of Nevada (UCCSN) will perform scientific or engineering research, and develop and foster collaborative working relationships between the Government and academic researchers. The following describes the objectives of Task 1 "Geodetic Monitoring of the Yucca Mountain Region Using Continuous Global Positioning System Measurements" under the cooperative agreement.

The specific tasks for this funding are:

1. to subcontract with the California Institute of Technology (Caltech), under the supervision of Professor Brian Wernicke, for geodetic monitoring of the Yucca Mountain region;

2. to develop a quality assurance plan for geodetic monitoring using continuous GPS measurements; and

3. to double-check the assumptions and processing done under the Cal Tech subcontract.

Progress for the Period 7/1/03-9/30/03:

This represents the final report of Task 1 which formally ends on September 30, 2003. This project has progressed as originally planned. To summarize the technical status:

1. Prof. Wernicke at Cal Tech reports that the 30-station network has now been fully operational for 4.25 years with only minor problems.

2. All collected data have been analyzed by Dr Davis' group at Harvard Center for Astrophysics

using MIT's GAMIT software. As an independent check, all data have also been analyzed by Prof. Blewitt's group at UNR using NASA/JPL's GIPSY software. Solutions files for daily station coordinates were formally submitted in September to the UCCSN Technical Data Archive (TDA) which is linked by the YMP Technical Data Management System.

3. All data have been checked using community-standard software known as TECQ, and then distributed to collaborators and the scientific community via the UNAVCO Archive Facility in Boulder, Colorado. Performance statistics are given at http://cfa-www.harvard.edu/space_geodesy/BARGEN/Data. Quality assessment shows station positions repeating to within the expected standard deviation of 2-3 millimeters.

4. Wernicke and Davis report that the solution from 1999 to 2003 continues to yield a velocity field across the Yucca Mountain site cluster characterized by nearly homogenous N20°W right-lateral shear of 20 ± 2 nstrains/yr, or a net velocity contrast of ~1.2 mm/yr across a 60 km aperture that includes the proposed repository site. Within the next week, they will submit a manuscript to *Journal of Geophysical Research* reporting on the tectonic implications of the velocity field, aspects of which were reported on last spring in Bennett et al. [2003, *Tectonics*] and Davis et al. [2003, *Geophysical Research Letters*]. A synopsis of the conclusions from the manuscript follows. Both the magnitude of the strain rate and the linear velocity gradient across the area make it difficult to attribute the strain pattern to elastic bending of the crust adjacent to the Death Valley fault zone to the west. A significant fraction of the strain, equivalent to a structure with displacement rate in the 1 mm/yr range, is therefore likely associated with structures in the Yucca Mountain area. A simple model of strain accumulation on vertical strike-slip faults including 3.5 mm/yr on the Death Valley fault zone and 0.9 mm/yr on the Pahrump-Stateline fault system, projected northward into the Yucca Mountain area, provides a good fit to the geodetic data, although other two-fault models are also possible. Combined with earlier campaign studies [*Wernicke et al.,* 1998, *Science*] the results indicate that the anomalously high strain rates of 50 to 64 nstrain/yr observed between 1991 and 1997 reflect in part accelerated post-seismic strain following the 1992 Little Skull Mountain earthquake, which does not appear to affect velocities measured after 1998. These conclusions are contrary to the conclusion of *Savage et al.* [1999, *Journal of Geophysical Research*, p. 17,627] that strain accumulation in the Yucca Mountain area "is not significant at the 95% confidence level," once the effects of the Death Valley fault zone are removed. Their conclusion was based on the fact that the errors in their strain rate estimates from two campaign occupations just five years apart (~ ± 10 nstr/yr) were of the same order as the estimates themselves (10-20 nstrains/yr). The lower bounds of their strain rate estimates therefore overlapped with a value of zero once nominal strain rates for the Death Valley fault were subtracted. Their conclusion presumed that geological data provide a robust upper bound for any geodetic estimate. It neglected the fact that the high geodetic rates at the upper bounds of their estimates, equally probable to those at the lower, were both significant and consistent with those based on the temporally dense

campaign data reported in *Wernicke et al.* [1998]. The continuous GPS data from Task 1, in a period of less than four years, has settled the issue by providing an estimate of the strain rate at ten standard deviations that is significantly greater than geologic estimates, and by providing a useful upper bound on the spatial curvature of the velocity field across Yucca Mountain that is inconsistent with intermediate-field elastic bending adjacent to the Death Valley fault zone. Determination of how the strain field relates to geological structure at Yucca Mountain will require denser coverage of structures in the area, especially the in the southern Amargosa and Pahrump Valleys to test the "Amargosa Desert fault system" hypothesis of Schweickert and Lahren [1997, *Tectonophysics*] and detailed continuum models of strain accumulation in the area.

5. Prof. Blewitt's group at UNR confirms negligible differences in velocity results derived using the precise point positioning GPS technique (GIPSY software) as compared with those derived by Davis's group using the double-difference approach (GAMIT software). The average difference (root mean square) in horizontal station velocities is 0.23 mm/yr, which is statistically consistent with formal errors of 0.14 mm/yr. Vertical velocities agree with an RMS of 0.56 mm/yr. GIPSY results show a pattern of N6± 4°W right-lateral shear of 18 ± 2 nanostrains per year, which agrees within the error bars of the GAMIT results. The dual-method approach therefore allows very high confidence to be placed in the results.6. The quality assurance plan has been completed and submitted (last quarter).

6. A paper is attached (Hill et al.) which has been submitted for publication in the proceedings of the April 2003 Luxembourg workshop, "Improving the GPS vertical."

7. Hill has continued to produce InSAR images of Yucca Mountain using two independent InSAR processing software packages, using stacking to mitigate tropospheric delay.

<u>Problems</u>:

We have no technical problems to report.

<u>Status of Funds</u>:

All funds for Task 1 are anticipated to be fully expended by September 30, 2003. We have requested approval of additional equipment purchases, particularly needed for following the quality assurance procedures described in our Quality Assurance Program Plan, dated 3 June 2003, submitted with the quarterly report covering the period through 30 June 2003.

<u>Plans for Next Quarter</u>:

This is the last quarterly report for Task 1. Our plan is to proceed with a follow-on task commencing October 1, 2003, following approval the proposal that has been submitted. The Quality Assurance Program Plan, dated 3 June 2003, was submitted with the quarterly report covering the period through 30 June 2003. The Department of Energy (in an e-mail message from Dr. William Boyle, dated 4 August 2003) has indicated that this plan is adequate for the continuation of the task.