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average 1 hour per volume, including the time for reviewing instructions, searching existing data sources, gathering the collection of information, Send comments regarding this burden estimate or any other aspect of this Washington Headquarters Form, Directorate for Information Operations and Reports, 1215 Jefferson Management and Budget, Paperwork Reduction Project (8704-0100), Washington, DC 20503.

1. REPORT DATE: ANNUAL 15 Jan 91 TO 14 Jan 92

4. TITLE AND SUBTITLE: GPS Measurements at Vandenberg AFB  
5. FUNDING NUMBERS: 61102F, AFOSR-90-0339, 2309, AS

2

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8. PERFORMING ORGANIZATION REPORT NUMBER: AFOSR-TR-92 0822

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES): Dr Dickinson, AFOSR/NL, Building 410, Bolling AFB DC 20332-6448  
10. SPONSORING/MONITORING AGENCY REPORT NUMBER:

DTIC  
ELECTE  
S A D  
AUG 27 1992

11. SUPPLEMENTARY NOTES:

12a. DISTRIBUTION/AVAILABILITY STATEMENT: Approved for public release; distribution unlimited  
12b. DISTRIBUTION CODE:

13. ABSTRACT (Maximum 200 words): The objective was to measure directly the tectonic deformation in the Santa Maria Fold and Thrust Belt (SMFTB), northwest of Santa Barbara California. The principal measurement technique was space geodesy; using microwave signals transmitted by Blook II satellites of the Global Positioning System (GPS), from March to August 1990. Geodetic observations were analyzed to resolve tectonic deformation across the SMFTB. The geodetic network forms a braced quadrilateral with 40 km sides whose southwest corner is the Vandenberg very long baseline interferometry (VLBI) station. Three different types of data were combined to estimate two-dimensional station position and strain rate parameters simultaneously. Significant strain rates were discovered using a model which constrains the relative velocity field to be linear in space and constant in time. The maximum compressive strain is oriented N17e±5E, and the compressive strain rate in that direction is 0.13±0.03 strain/yr. Under the assumption that the unresolved rotational component of the velocity field is zero, the integrated rate of deformation across the basin was estimated at 7±1 mm/yr oriented at N3E±13. This vector can be decomposed into 6±2 mm/yr of crustal shortening on the general structural trend of N30E and 3±1 mm/yr of right-lateral shear across the axis. On the basis of these values and earthquake

14. SUBJECT TERMS  
15. NUMBER OF PAGES  
16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT: (U)  
18. SECURITY CLASSIFICATION OF THIS PAGE: (U)  
19. SECURITY CLASSIFICATION OF ABSTRACT: (U)  
20. LIMITATION OF ABSTRACT: (U)

focal mechanisms in the area, deformation was inferred on northwest trending folds and thrusts within the belt. These results are consistent with the rate and direction of deformation across the central California Coast Ranges inferred by balancing Pacific-North America plate motion against San Andreas slip and Basin and Range extension. They imply that the SMFTB is the primary active element in transforming motion from the Coast Ranges to the western Transverse Ranges and the Santa Barbara Channel. Five years of GPS measurements were used to measure the relative velocities of five stations in the SMFTB. When considered with respect to the GPS mark nearest the Vandenberg VLBI station, the horizontal velocities of three stations are significantly different from zero at the 95% confidence level. The velocities indicate the importance of N-S compressional deformation in the area, as indicated by geologic cross sections, seismicity, earthquake focal mechanisms, and borehole breakout data. The compressional components of the three most significant velocities are grossly consistent with the deformation predicted by a simple dislocation model involving two thrust faults in the SMFTB, in addition to deep slip on the San Andreas fault.

**Investigation of Crustal Deformation in the Vicinity of  
Vandenberg Air Force Base**

**Grant AFOSR-90-0339  
(MIT OSP No. 74324)**

**Annual Technical Report  
for the period**

**22 August 1990 - 31 August 1991**

**Submitted to**

**Air Force Office of Scientific Research**

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**30 September 1991**

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**DTIC QUALITY INSPECTED 3**

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## INTRODUCTION

Recent geological and geodetic studies have suggested that the region surrounding Vandenberg AFB is undergoing active crustal deformation, with important implications for both the geodetic stability and the seismogenic potential of the Western Test Range (WTR) [Feigl *et al.*, 1990]. Part of the evidence for significant deformation was obtained from GPS measurements over a broad area of central and southern California which we carried out in cooperation with other university and government scientists from 1987 through 1991. Although useful in defining the regional tectonic setting, these measurements are of insufficient spatial and temporal density to answer many important questions about the seismogenic potential of Vandenberg.

In 1989 we received funding from AFOSR under the Commander's Reserve Fund (Grant AFOSR-89-0400), with matching funds from MIT, to purchase five GPS receivers and to begin a series of measurements designed to determine the magnitude and spatial distribution of deformation in a region encompassing the major faults and folds within 50 km of Vandenberg. The present grant (AFSOR 90-0339) supports a follow-on, 3-yr study including four major elements:

- Remeasurement and extension of the GPS network
- Analysis of the GPS data to determine horizontal strains with a precision of  $5 \times 10^{-8}/\text{yr}$  within the network
- Compilation of the historical geodetic data available for the area
- Synthesis of the geodetic, geological, and seismological data to assess the tectonic setting and seismogenic potential of Vandenberg

The pre-grant studies of Vandenberg tectonics and our progress during the first year of this grant have been completely described in the doctoral thesis of Kurt L. Feigl, completed at M. I. T. in September 1991 and attached to this report. We give here only an overview of our work, along with reference to the appropriate chapters of the thesis [Feigl, 1991].

## GPS MEASUREMENTS

Since February, 1990, we have carried out four GPS experiments involving the stations of the Vandenberg network. Two of these experiments (February and September 1990) included most or all of the current network; the other two (March 1990 and February 1991) included two or three Vandenberg stations as part of a remeasurement of the regional central and southern California networks. The details of these experiments are given in Chapter 4 of Feigl [1991], especially Figures 4.1–4.3, Tables 4.1–4.6, and the text on pp. 124–125 and 137.

## DATA ANALYSIS

In order to determine the most accurate (vector) motions of the stations in the Vandenberg network, it is necessary to estimate the geocentric positions of the sites and the motions of the GPS satellites using a continental- or global-scale GPS network. Thus, our analysis of the Vandenberg data has been carried out simultaneously with data from the central and southern California network and the stations of the (global) Cooperative International GPS Network (CIGNET). This analysis is described in Chapter 4 of *Feigl* [1991], especially pp. 138–145, and in *Murray* [1991]. A discussion of GPS strain estimates from our preliminary analysis is also given in Chapter 4 of *Feigl*, on pp. 162–185.

Coincident with our March, 1990, experiment in central and southern California the DoD activated Selected Availability (SA) in the Block II GPS satellites. This presented a particular problem in our analysis since for this experiment we used receivers which sampled the GPS phase at times separated by up to .08 seconds. Such a mismatch of sample times can cause errors of several centimeters in station-position estimates unless the variations in transmitted frequency caused by SA are properly modeled. Our work in developing a model led to the publication [*Feigl et al.*, 1991] of a simple algorithm that should be of use to other investigators. This model is described in greater detail in Chapter 2 of *Feigl* [1991].

## SYNTHESIS OF GEODETIC, GEOLOGIC, AND SEISMIC DATA

In *Feigl et al.* [1990], we summarized the geologic observations, as well as the historical geodetic and seismic data available for the Vandenberg; this paper is reproduced as Chapter 1 of *Feigl* [1991]. In Chapter 4 (pp. 191–201) *Feigl* discusses some inferences that can be made from our GPS measurements and some additional geologic studies completed within the past two years. The greater spatial resolution provided by the recent studies allow him to suggest likely locations for the measured deformation, guiding the future course of our measurements.

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