Design of a Five-Axis Flux-Gate Magnetic-Gradiometer System
Tracking Code: #93-SR-035

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Principal Investigators: Ronald W. Hoard and Steven Hunter

During the past few decades several worldwide researchers have started using magnetometers to monitor the extremely-low-frequency (ELF) electromagnetic signals sometimes emitted prior to major earthquakes. On April 26, 1992 a single-axis magnetic gradiometer magnetometer (operated by the first author at LLNL) serendipitously detected unexplained fluctuations in the vertical gradient of the earth's local magnetic field starting four and one-half hours prior to the Ferndale, Ca. earthquake. A build-up of similar ELF signals were reported by Stanford University researchers several days before the October 17, 1989 San Francisco Bay-Area earthquake.

Our goal for this LDRD project was to construct and field two five-axis flux-gate magnetic-gradiometer magnetometers. A five-axis gradiometer sensor arrangement not only measures the magnetic-field variations but also yields information on the direction, distance and size of the source responsible for the magnetic disturbance. Previously the US Navy used these instruments to track submarine traffic and locate sunken ships. This is the first time that such equipment is being fielded for earthquake research. If these low-frequency magnetic fluctuations correspond to phenomenon occurring at or near the earthquake's epicenter a monitoring station equipped with this instrument may provide research data on the location and size of epicenters prior to major earthquakes.

This LDRD project is a joint partnership between the US Geological Survey, LLNL and Applied Physics Systems (APS) in Mountain View, Ca. The USGS allowed us to piggy-back onto two of their existing seismic research monitoring stations; one located at their Valecitos station, outside of Livermore, Ca. and the other is in the hills at Parkside, Ca. APS is the Bay-Area magnetics measurements company building the five-axis sensors. Since we did not receive the capital equipment funds until the last quarter of FY-93, their scheduled delivery date for the sensors slipped to middle calendar year 1994. We completed site preparation (set up solar cells and battery power) and installed a single-axis gradiometer at each site to obviate the final sensor installation slated for March 1995. The data links and communications are a combination of microwave and data phone-lines between the monitoring sites, LLNL and the USGS at Menlo Park, Ca. We show the project tasks and expenditures below.

Task Description	Capital Costs	Operating Costs
1. Sensor Design		\$30,000
2. Sensor Fabrication	\$ 30,000	
3. Software Design		\$20,000
4. Initial Site Preparation		\$10,500
5. Geophys. Modeling		\$6,000
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Totals	\$30,000	\$ 66,500

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