Potential of a superconducting long-period seismometer
Introduction to GWR Instuments' Poster
Richard J. Warburton

1. Brief history the Superconducting Gravimeter

The Superconducting Gravimeter (SG) was invented and developed by John Goodkind and William Prothero at the University of California, San Diego (UCSD) during the mid-1960s. Their purpose was to build a gravimeter that achieved a precision of 1 μGal and a stability of 1 μGal/year. The design was focused on long-term (years) stability and did not consider seismic applications. R. Warburton joined Goodkind's laboratory in 1971 as a postdoctoral candidate to complete development and to deploy SGs to field sites for making long-term gravity measurements. In response to a series of papers published by Warburton and Goodkind (1975 to 1978), German and Belgium scientists became interested in doing similar research in Europe. GWR Instruments was formed in 1979 to manufacture SGs for these groups. There are about 25 SGs operating worldwide and most are in the Global Geodynamics Project (GGP) network that was formed in 1991.

2. Current development at GWR

GWR is actively developing a less expensive Field SG with a lower sensitivity for hydrological, volcanic, and seafloor applications. The goal is to significantly improve measurements that are limited by large and variable drifts present in LaCoste-Romberg and Scintrex spring-type gravimeters. In the last 3 years, GWR has submitted SBIR proposals to both DTRA and DOE for developing a superconducting seismometer for use in discrimination between nuclear and non-nuclear explosions. These were rejected because there was no evidence that long-period seismic signals could improve discrimination, and because the projected sales volume was too small. As a result, GWR's seismometer research and development is dormant.

3. Development of a superconducting seismometer

Data are shown in the GWR Poster comparing the STS-1 and SG that operate at the station in Canberra, Australia. These data and recent publications analyzing GGP data demonstrate that the SG noise is below the STS-1 noise for frequencies below 1 mHz; and that the SG data can be corrected for atmospheric effects while the STS-1 cannot. Recent data also shows the splitting of the 0S2 mode at 0.31 mHz with a background noise of less than 0.5 nanoGal. The lower frequency normal modes are of particular interest since they are sensitive to distribution of the earth's density profile.

Measured SG noise is close to estimates of instrumental Brownian noise, which is proportional to temperature/(mass)^2. Although the SG has a low temperature advantage, its 4 to 6 gram mass is small compared to the 80 gram mass of the LaCoste-Romberg and the 300 gram mass of the STS-1. Increasing the mass to 80 grams will decrease the Brownian noise well below the Peterson NLNM. Such a SG should be far superior to the STS-1 in the frequency range of 0.1 to 30 mHz and would significantly improve studies of earth noise and small amplitude normal mode signals.

4. New cryogenic refrigerators

Initially the SG was a very complicated instrument operated in a large 200 L Dewar full of liquid helium (LHe). The 4 ^{O}K temperature was maintain by the LHe, which slowly boiled and was released to the atmosphere as gas. By necessity, Dewars were large since the time between refilling was proportional to the Dewar volume. In the last decade, new cryogenic refrigerators have been developed that operate below 4 ^{O}K. This enables using a small refrigerated 10 to 30 Liter Dewar that operates as a closed cycle system in which helium gas is reliquefied and no LHe is lost. In essence, the LHe is needed only as a stable thermal reservoir and to preserve the 4 ^{O}K temperature during power or refrigeration failures. Therefore, SGs can now operate in most preexisting seismic vaults that have enough power (1.3 kWatts) to operate the refrigeration system. In addition, improvements in the SG and its electronics allow remote control and monitoring of the instrument.

5. Company goals for attending this conference

- Re-introduce the SG to the US seismological community

For many years, GWR and SG research has largely been supported by European and Japanese sales and by interest generated from their research publications. In contrast, utilization of, knowledge about, and interest in the SGs are minimal in the US. GWR is looking for individual scientists (US or foreign) who are highly motivated and interested in gravity and long-period seismometry. They would write proposals for funding to develop, purchase and test the new seismometer. Additionally, they would analyze performance and publish first results.

- Collaboration with universities, research laboratories or other companies

Several manufactures produce electronics and data acquisition systems for seismic sensors. As a small company, GWR prefers to concentrate on new sensor development and to outsource seismic electronics and data acquisition to a larger company that is well respected in this field.

The SG is fundamentally the same as it was designed 25 years ago. A potential problem is that the levitated sphere has 5 unconstrained degrees of freedom, which may cross couple noise to the vertical at very low noise levels. One solution is to constrict motion by using magnetic bearing through the vertical axis of the sphere. Several universities and research laboratories have long histories of utilizing superconductivity for developing advanced instrumentation. One relevant example is Stanford University who is a major participant in the STEP program (Satellite Test of the Equivalence Principle). The superconducting bearing technology developed for STEP may also be applicable for: constraining the SG sphere, or for developing a superconducting horizontal seismometer. These possibilities need to be investigated further.