



DOE SBIR/STTR Success

Brad Averson, an engineer with Silicon Audio, sets up seismic sensors on Gulkana Glacier in Alaska to see if a NASA lander would work on icy Europa.

SILICON AUDIO LLC.

*Photo by Meghan Murphy, reproduced with permission from the Anchorage Daily News**

Detecting and identifying events associated with the development of foreign nuclear weapons are central goals for the U.S. DOE's National Nuclear Security Administration (NNSA), and other government agencies. These objectives rely on advanced technologies including detection of radiation and radioactive particles, satellite imaging, and seismic monitoring, which all complement each other in nature. For example, while radionuclide monitoring has the definite advantage of being able to confirm whether an explosion resulted from a nuclear test, if the nuclear explosion is detonated underground, the radioactive particles and gases are largely contained, and seismology becomes, in this case, the tool of choice for learning about the event.

FACTS

PHASE III SUCCESS

Silicon Audio was included in the U.S. Geological Survey's approved vendor list. Sales to repeat customers have doubled each year since 2015 and production scale-up is planned for the near future. A private investment of \$1.2M supported early product development.

IMPACT

Silicon Audio's optical seismic sensor offers unprecedented dynamic range, replacing multiple sensors in the analysis of any seismic event or nuclear explosion, with reduced costs and superior performance.

DOE OFFICE/PROGRAM

National Nuclear Security Administration (NNSA), Office of Nuclear Detonation Detection.

Modern seismic sensors can actually reveal where and when the nuclear test occurred even if the explosion took place on the other side of the globe. This is because the low frequency signatures associated with a nuclear explosion travel very long distances. Moreover, the sensitivity of seismic sensors and related monitoring software has increased to the point that even signals coming from small and distant nuclear explosions can be distinguished from say a building demolition done with conventional explosive. A nuclear blast has a ground-motion signal profile that looks different than that of manmade explosions or earthquakes.

Within the field of seismic sensors, Silicon Audio has developed a new technology that allows industry and scientists to use a single sensor for applications that generally require two or three types of sensors operating in different frequency ranges, with obvious implications on cost, deployment, and portability. In addition, in many situations Silicon Audio's seismometer performs better than traditional instruments because it has a larger dynamic range and responds over a broader range of frequencies. Traditional seismic sensors generally fall into two categories: very sensitive instruments that can be located far from the blast, and sensors that can be located close to the blast and retain a linear response for very intense signals. "Silicon Audio's sensors do both "explains Dr. Hall, Silicon Audio's CTO, "being able to simultaneously detect a whisper and a shout with high fidelity". The innovative technology proposed by Silicon Audio is based on advanced optical interferometry for displacement/motion detection methods. Most seismic instruments measure displacements of a small mass attached to a spring using the electrodynamic induction principle; specifically, by measuring the voltage induced in a coil by the change in the applied magnetic flux that occurs when the mass moves inside the coil. By contrast, in Silicon Audio's optical seismometers, the mass attached to the spring is a small mirror, which when moving changes the optical path of a laser beam, causing optical interference with a reference beam. By this principle, displacements as small as 1 femto-meter (10^{-15} m) can be detected. In addition, the instrument response remains linear in a large range of frequencies and even at high signal intensities, which enables a very large dynamic range.

The basic concept for Silicon Audio's sensor was developed by Dr. Hall when he was a graduate student at Georgia Tech. In 2007, Dr. Hall founded a company after obtaining license to Georgia Tech's patents of which he was a co-inventor. The initial objective for the newly founded company was to commercialize a better microphone for emerging smart phone devices based on the same optical interference technique explained above. However, in the search for seed funds, Dr. Hall and his team realized that DOE SBIR/STTR grants were available for developing better seismic sensors and these could be produced through a spin-off of Silicon Audio's core technology.

Silicon Audio received a Phase I SBIR grant from DOE in 2008, and subsequently was awarded a three-year Phase II, which ended at the end of 2012. The DOE SBIR awards were funded by the NNSA under the supervision of senior program manager Leslie Casey, who directs research to advance U.S. ground-based nuclear explosion monitoring capabilities.

Dr. Hall recognizes that the SBIR grant was very beneficial to the advancement of Silicon Audio's technology. Thanks to the SBIR grants, Silicon Audio's team could focus on the technical aspects of building a prototype without having to constantly look for supporting funds. Later on, towards the end of Phase II, Dr. Hall realized that he could not rely on the government being Silicon Audio's only future customer, and for business to grow, additional markets besides the government's needed to be identified. Dr. Hall and his colleagues started to attend trade shows for the oil & gas industry in the

United States, following the rationale that the oil & gas industry uses ground-motion sensors in large volumes to identify deposits. Among the various events Silicon Audio's team attended, "one particular trade show organized by the Society of Exploration Geophysicists led to an interesting development", Dr. Hall recalls. It was there that Dr. Hall and his team learned that their technology, although too sophisticated and costly for conventional oil & gas surveys, was ideal for the point-receiver (i.e., node) and ocean-bottom survey niche. In the latter type of survey, higher performance and reliability are highly preferred to less expensive equipment because, given the higher overall cost of the deployment, poor data quality due to shortcomings in sensor performance is unacceptable. This realization led to a strategic investment deal from a company in Houston, TX. The company invested more than \$ 1.0 M over a year for Silicon Audio to adapt its Phase II prototype to the specifications required to interface the optical seismometer to an existent survey system. Silicon Audio was able to meet the expectations and delivered 100 seismic sensors to customers. As a result of this success, Silicon Audio started planning for an 8-fold increase in production in order to honor impending larger purchase orders. The latter never materialized due to the fall in gas prices in 2014 and in the following years. At this point the Silicon Audio team resumed its search for new markets, attending this time geoscience-oriented conferences and trade shows. Soon thereafter, Silicon Audio's sensor was approved by the U.S. geological survey (USGS) and made the USGS's approved vendor list. The stamp of approval from USGS was key to persuade the scientific community of the exceptional performance of Silicon Audio's product, and sales to Universities, National Laboratories, and other scientific institutions soon followed. Silicon Audio's sensor sale revenues into this market have doubled each year since 2015. Plans for the near future include scaling up the original manufacturing cell designed to produce 500 sensors per year to meet a projected request of 4000 sensors per year.

Working with the scientific community was a great opportunity to further improve Silicon Audio's sensor performance, as the sensor's reliability was tested in environments harsher than originally envisioned. "We learned a lot more about our sensors because they were deployed to cold and wet places such as Alaska and we had to figure out how to make them work in these environments, which ultimately led to new capabilities and deployment opportunities". As an example, sensor reliability for extended time in low-temperature and icy environments opened the doors for Silicon Audio to join a team of Universities working on an exciting NASA project involving the exploration on Jupiter's moon Europa. The project is in the earth-based testing phase with a successful test recently completed on an [Alaskan glacier](#), and future deployments scheduled in Greenland in 2018.

Written By Claudia Cantoni, Commercialization Program Manager, DOE SBIR/STTR, January 2018.

* The photo was published in the article "A glacier in Interior Alaska is a testing ground for equipment intended for use in space" by Yereth Rosen, Anchorage Daily News, Sept. 17, 2017.