BUILDING A BETTER LANDMINE DETECTOR

by Marian Bechtel

Imagine that every time you stepped out your front door or strayed from the road during a walk, you felt a sudden fear of having your leg blown off by a landmine. My cousins in Mozambique—one of many countries worldwide that are heavily infested with mines—live with this fear every day. Landmines may be buried during wartime, but they remain active even after a war has ended, claiming victims for decades. There are over 70 million landmines buried around the world, and they kill or maim someone every 22 minutes. Most of these victims are innocent farmers, women, and children.

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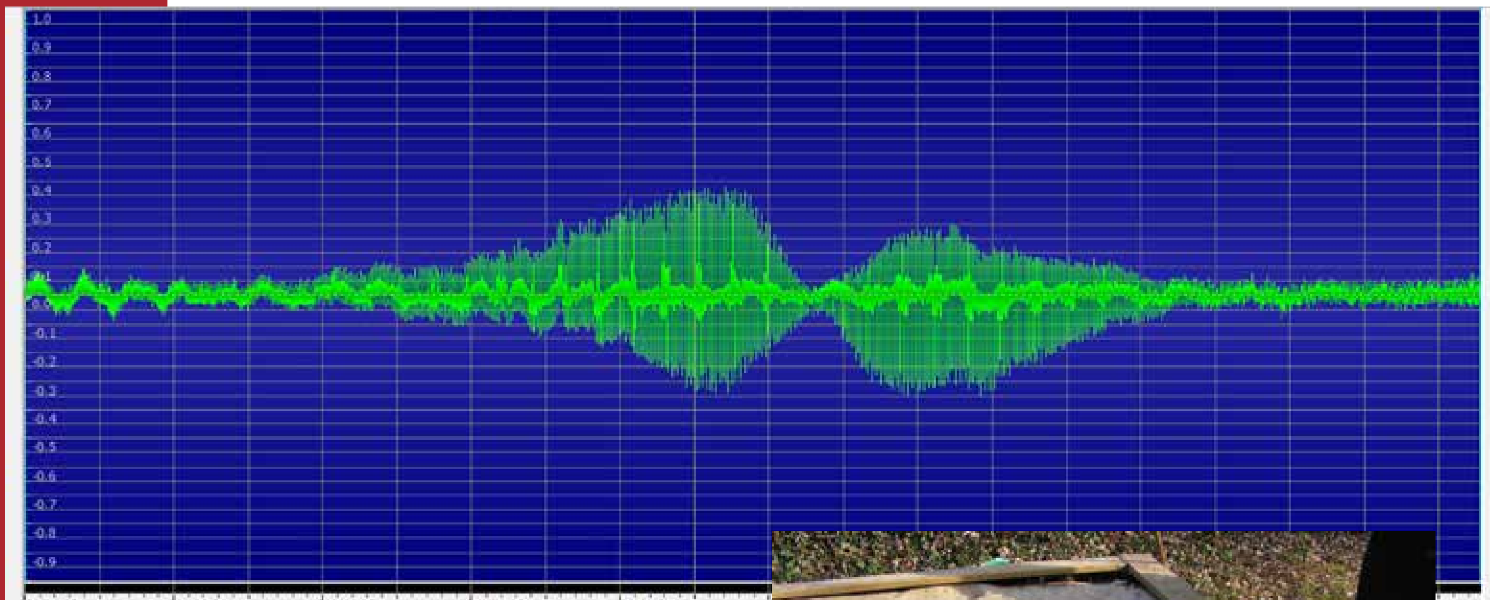

Top: In the landmine detector Marian developed, two microphones pick up sounds as the operator sweeps it across a minefield. A characteristic "swell-dip-swell" pattern indicates the presence of a mine. **Bottom:** Marian built a test bed in which she buried mock landmines made of candy tins and silicone rubber.

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In the Buzz of a String

In the summer before eighth grade, I met a group of international scientists doing research on humanitarian demining methods. My parents are both geophysicists, and they had connected with this group many years ago and worked with them to develop a holographic radar system, called RASCAN, for detecting buried landmines. They all came to our house that summer, and I had the chance to meet these brilliant people from places like Russia, Japan, Italy, and Great Britain.

Right now, the most common methods for finding landmines are simple metal detectors or probing rods called sapper spikes, which a deminer pokes into the ground, feeling around for a mine—an extremely dangerous and tedious job. The scientists explained to me how important it was to find a more efficient method, but how difficult that can be: the countries affected by landmines are mostly impoverished, and the people who must remove the mines are often untrained farmers and other civilians. After hearing all this, I wanted to get involved and contribute to this important work.

A few weeks later, playing the piano at home one day, I happened to notice that when I played certain low notes on the piano, the strings on a nearby banjo would resonate loudly. At first I thought nothing of it, but as I continued playing, a thought struck me: would it be possible to play a musical tone and make landmines resonate like the banjo strings? I remembered hearing that one of RASCAN's weaknesses was detecting landmines in wet soil. Sound travels beautifully through water, I thought, so maybe my idea would work in wet soil.

Proof of Concept

I contacted one of the scientists I had met, Lorenzo Capineri, a professor of acoustics in Italy, who had done some research on detecting landmines using acoustics. He thought my idea was good, so I spent hours upon hours reading papers on acoustics and landmines and making sketches of my detection ideas. I eventually decided to do a project that mainly involved doing proof-of-concept testing to show that landmines would in fact resonate in response to low tones.

The first step in this testing was to acquire landmines. As real landmines were obviously too dangerous to have in the house, I created mock landmines out of small candy tins and silicone rubber, simulating the size and physical properties of real landmines. After burying them in a sand test bed I had assembled in my basement, I played a computer-simulated tuba tone through a suspended subwoofer at the test bed. Using basic geophones connected to a seismograph, I measured the difference in the vibrations of the sand around the landmine, versus the sand over the landmine. This is called a "seismo-acoustic" approach, because it uses both ground vibrations and sound waves.

This being my first experience with real science, I was not expecting the obstacles I encountered. I became easily frustrated when something didn't work, or a test didn't appear the way I expected. Sometimes the geophones would not respond properly, or a graph displaying the frequency content of the vibrations seemed off. But I persisted, and eventually I ended up with very promising results that displayed the ability of seismo-acoustics to detect landmines. I took my project to the local North Museum Science and Engineering Fair—my first science fair.

I loved talking to judges and other people about my work, but I wasn't expecting anything more than a great time. To my surprise, I was named the Junior Reserve Champion! This led to my nomination for the International Sustainable World Project Olympiad (I-SWEEEP) in Houston, Texas, later that spring. There, I talked to people who had actually demined in various countries or lived in mine-infested countries. I even met two girls from Egypt who had landmines around their homes and were researching ways to detect these landmines using a genetically modified plant, thalecress. The whole experience opened my eyes to the amazing world of science and transformed me from a timid, awkward teenager into an outgoing, excited, and confident young scientist. I came home not only with a silver medal, but also with motivation to start another project.

Mapping the Mines

The next year I did something a little different. In my first project, I showed that landmines resonated in response to a tone; this time, I created a method of seismo-acoustic imaging. My idea was to create an image that would show the location of the mine.

When I first started doing the tests and creating the images, I could see absolutely nothing. After making adjustments to settings on the seismograph and on the computer analysis, I worked my way through and eventually produced dramatic images of landmines in various locations in the sand. I ended up with an interesting project on a very different approach to demining, and was once again honored to travel across the country, presenting at various local, state, national, and international science fairs.

While I had learned some interesting things during these two projects, one big, looming issue remained: the method I had designed was not very practical in the real world. It would involve lugging a large subwoofer out to a mine field, suspending it above the ground, and measuring the vibrations with ground-contact devices that would have to be moved manually around the ground. I wanted to develop something that could really work in a mine field—a simple, inexpensive, and efficient method that could replace the sapper spikes that are used now. I drew sketch after sketch until I finally came up with an idea that seemed plausible.

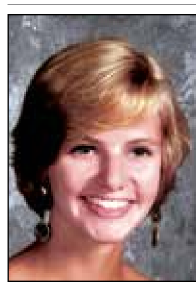
Signature Sounds

For my third project, I turned my previous method inside-out. I shook the ground with a tool normally used to get bubbles out of drying concrete, and used simple microphones to pick up the sound of the vibrating landmines. The method is actually very simple: the shaker sends seismic waves through the ground, causing any buried landmines nearby to resonate. The deminer then sweeps two microphones horizontally above the ground, each recording the sound separately. As they pass over a resonating landmine, each of the microphones picks up the same sound, but at off-set time intervals. Thus, when "noise-cancellation" is performed, or when one recording is subtracted from the other, much of the background noise is cancelled, and a characteristic swell-dip-swell pattern appears in the sound wave, indicating the presence of a mine.

Of course, it did not work like this right away. The first time I tried, the results showed nothing at all, so I made lists of variables and issues to explore, such as the height of the microphones, position of the concrete vibrator, and settings on the microphones. After testing the effects of these variables, I finally found a few that changed everything. Suddenly, I began seeing results, even better than I expected! The noise-cancelled sound waves showed the swell-dip-swell pattern clearly, and the pattern was even audible when I played the noise back. I tested both metal and plastic mock landmines in dry and wet soils, and spent hours going through the noise-cancelled records, examining the results. I performed statistical tests as well, and they showed overwhelmingly strong statistical support confirming the significance of the data.

Then, taking my project one step further, I built a prototype out of a metal detector I rescued from a dumpster. I put the whole thing together in my basement with off-the-shelf materials, and then took it to the test bed. The prototype showed great promise, as I could hear the swell-dip-swell pattern in the sound through a set of headphones. Although there is still much modification needed to improve the efficiency and amplify the sound, it is an exciting first step on a path that could lead to a better, safer way of finding mines.

This research took me on adventures across the country, and even around the globe, where I met some of the brightest, most inspiring young scientists in the world. I met rock star scientists like Dean Kamen, Brian Greene, and Bill Nye the Science Guy, and I even shook hands with President Obama! But most important, this experience fueled my passion for science. I have learned that science can transform even the most ordinary things—like piano keys and banjo strings—into projects that can change the world. i



Marian Bechtel is a junior at Hempfield High School in Pennsylvania, where she plays in the orchestra and marching, symphonic, and jazz bands, and sings in the choir. In addition to winning awards at ISEF and I-SWEEEP, Marian was a finalist at the 2012 Intel Science Talent Search and was named a Davidson Fellow for her research on humanitarian demining methods.

See a short YouTube video of Marian describing her project at the 2012 Intel Science TalentSearch at http://bit.ly/KenE4k.