Project Neptune: Specialized gas detection for nonproliferation

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Sandia National Laboratories' Todd Embree inspects one of the Neptune sensor's two liquid-nitrogen-cooled cameras before field installation. Neptune underwent field testing in Nevada in December 2012. Credit: David Karelitz)

Trying to sniff out traces of hard-to-detect gases can be like trying to hear a whisper at the other end of a very large, very crowded, very noisy room.

Sandia National Laboratories' Project Neptune aims to design a system capable of sensing, from among the loud signals of a lot of gases, the weak signals from specific gases that are signs of nuclear proliferation. The researchers believe their gas correlation technique will prove ideal for a simple, inexpensive sensor to monitor those few illusive gases.

"The hope is to detect gas early so there's evidence before a nation gets too far along in a proliferation program," said Jeff Mercier, a manager in Sandia's Mission Science and Analysis Department and Neptune's principal investigator.

With about one photon out of every million coming from the signal the Neptune sensor is seeking, "it's a very, very hard problem," he said.

The goal is an imaging technique that could be used in airborne- or space-based systems, said Steve Vigil, project team lead. The three-year project has wrapped up but was continuing to analyze data from a December test of the prototype Neptune gas correlation imaging system.

Field test gathers data

The field test at the Nevada National Security Site piggybacked on a larger, separate test. The test was calibrated, "so we knew where they were releasing things, what they were releasing and when they were releasing it," Vigil said.

While the sensor and software worked well, the test conditions were different from those the instrument was designed for. The team planned to capture an image of something about the size of a meter from half a kilometer away, but ended up trying to image something that was only about a centimeter in size, Vigil said.

Neptune was funded under the Nuclear Fuel Cycle Remote Sensing

portfolio of the National Nuclear Security Administration's Office of Proliferation Detection. A small Albuquerque business, CIC Photonics, which designs and produces analytical and industrial instrumentation and sampling systems, worked with Sandia to design and build Neptune's gas cells and did calibrated measurements of the cells.

The gas cells are the key. Sandia's instrument contains two, each weighing around 20 pounds, in a stainless steel box about 3 feet square by 16 inches high. A beam splitter separates sunlight coming in the sensor's window into two paths—one going to a cell filled with the gas sought and the second to a cell with a different gas.

Researchers are not saying what gases they want to detect, but Mercier said operators can identify whether the gas they seek is present by comparing signals on the two paths.

New twist on old technology

He called the work "a newer, more capable twist on a proven scientific concept."

Gas correlation technology has been around for decades, but modern focal plane arrays, optical design, computer codes and new materials made it practical for an imaging system, said Remote Sensing Portfolio manager Prabal Nandy.

The team uses sunlight to calibrate the instrument, which must operate in the daytime since it measures absorption of specific wavelengths of sunlight.

The basement Opto-Mechanical Research Lab where the prototype was built and tested is equipped with a periscope-like mirror system called a heliostat. A 40-inch sun-tracking mirror mounted on a post outside the

building directs sunlight down a concrete-lined shaft, and a mirror at the bottom of the shaft directs the sunlight into the lab.

Neptune detects signals in infrared rather than visual colors humans can see. An operator watches for indications of the selected gas on a computer screen that displays a processed image from the sensitive focal plane arrays.

Take, for example, emissions from a smokestack.

"If our gas is not coming out the smokestack, we just see the smokestack. If our gas comes out, it looks like steam," Vigil said. An operator also can gauge gas concentration, he said.

Neptune differs from other detection systems

Greenhouse gas monitoring uses similar technology, the researchers said. Vigil said Neptune is different because it's ultimately aimed at detecting certain gases with a space-based system, "and that's not something that's commonly done."

Mercier said technologies that detect more common gases are not sensitive enough for the gases the team wants to find.

The portable prototype operates from the Mission Science and Analysis Department's Mobile Remote Sensing Laboratory, a 16-foot-long trailer modified for field testing operations. The front two-thirds houses a computer room; the back third houses remote sensing instruments the department deploys, including Neptune. Operators simply lower the 8-foot-high rear trailer door to use the sensor.

Since gas correlation can detect extremely low gas concentrations, Nandy suggests it also could fill an important niche: finding suspected

leaks in large industrial facilities. Industrial inspection teams could easily use an imaging gas correlation sensor since it has no moving mechanical parts, operates like a video camera, doesn't require costly computer post-processing and is small enough to be driven around a factory in a truck. It's designed to locate where specific gases originate, even if they're not present all the time, Nandy said.

A new way of monitoring

That could change how the nation thinks about monitoring, Nandy said. Instead of single-point measurements taken with expensive sensors deployed after someone suspects a problem, continuous monitoring could find leaks early, he said.

"Why not have 24/7 monitoring when the data is simple to interpret? You don't have to wait years for health effects or environmental damage before the source of a leak or release is known," he said. "Catching leaks in real time means that we can move away from a mode of punishing industry for accidents after the damage is done, and instead work with them to catch issues before they become problems. This means less damage to the environment, more efficient and profitable operations for the company and a healthier environment for all.

"New forms of monitoring technology developed here at Sandia allow manufacturing operations to become more efficient, clean and cost-effective, which will enable the next renaissance of American industry."

Sandia can take on such complex problems because of its ability to turn ideas into prototypes—in this case, from a scientific concept to a field demonstration in three years, Nandy said.

"That's what we bring to the table that's unique," he said. "The niche is not just in gas correlation, but in things that have never been done, ideas

that have never been looked at this way, applications that have never used this technology."

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