New initiative will bolster infrastructure for hydrogen vehicles

Livermore Valley Open Campus will facilitate successful operation of CIRI

By Mike Janes

The broad public and government interest in renewable energy and the hope for a zero-emission transportation future seem to be at an all-time high. So what is the remaining hurdle to overcome before we see widespread adoption of clean, hydrogen-powered vehicles on the road?

In a word: infrastructure. For hydrogen-based vehicles, very little infrastructure currently exists. But that could change soon, and Sandia's Center for Infrastructure Research and Innovation (CIRI) on the Livermore Valley Open Campus (LVOC) hopes to contribute in a big way.

Daniel Dedrick (8367), the Labs' hydrogen program manager, calls CIRI a "collaboration facility" modeled on the success of the Combustion Research Facility (CRF). For years, the CRF has played a critical role in partnering with industry to provide a science base for fine-tuning the internal combustion engine and making it cleaner and more efficient.

"CIRI is a partnership-based RD&D facility focused on hydrogen infrastructure," Daniel says. "More specifically, it will be a coordination of critical materials, science, and engineering research capabilities at Sandia that are needed to improve performance and reduce costs associated with hydrogen infrastructure."

CIRI will incorporate new resources, including a full-scale test facility where equipment manufacturers can test their hardware, and existing capabilities such as a material mechanics lab that analyzes, characterizes, and predicts the behavior of various materials. It will also include a testbed refueling station where industry and research partners can run experiments to better understand refueling dynamics.

CIRI's partners, Daniel says, will include industry members up and down the supply chain and include companies who sell gases and chemicals, as well as those companies who manufacture important components like compressors, tanks, and tubing. Testing and optimizing those components in a systems environment — another feature in the works for CIRI — will be critical in developing hydrogen refueling stations and making them more economically and technically feasible for consumers, fuel providers, and station operators.

Industry, of course, will be key to CIRI's success, and Daniel points out that the nearby CRF already has a long history of partnerships with all of the US automakers. He hints that "significant support" for CIRI has already been assured from a number of critical companies.

The long-term vision for CIRI also includes research of vehicle systems integration with the electrical grid to understanding how hydrogen can help address issues associated with renewables integration, energy storage, and distributed generation.

Hydrogen on the upswing

Since the introduction more than 100 years ago of the modern, now-ubiquitous internal combustion engine that operates on gasoline, the nation has developed, honed, and successfully deployed tens of thou-

(Continued on page 3)

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Sandia National Laboratories

LRSO Sandia plays key role in Long-Range Stand-off warhead

By Mike Janes

LEE DRUXMAN, Bryn Miyahara, and Andrew Van Blarigan (all 8248) assemble a 3-D, model used to illustrate high-level LRSO concepts, in the Test Assembly Group's High Bay.
(Photo by Dino Vournas)

Sandia weapons experts say they are inspired to play a key role in the effort by the National Nuclear Security Administration to select a nuclear warhead for the Long-Range Stand-off missile program.

(Continued on page 3)

Size matters when monitoring reactors from a distance

By Patti Koning

At a mine in Virginia, researchers from Sandia and Lawrence Livermore National Laboratory (LLNL) are hard at work helping NNSA meet a goal set in its 2011 Strategic Plan: to demonstrate remote monitoring capabilities for reactor operations by 2016.

"This is a really hard problem to solve," says Peter Marleau (8132), the project lead for Sandia's part of the project. "Our ultimate goal is to create a detector that can find or exclude hidden 10-megawatt reactors at distances up to hundreds of kilometers."

This is a research reactor size that could potentially be hidden from other detection methods while still breeding plutonium in quantities that could be of concern for nuclear weapon proliferation.

About five years ago, a collaboration between Sandia and LLNL proved the effectiveness of an antineutrino detector for reactor monitoring. Nuclear decay produces large quantities of antineutrinos — the antiparticles of neutrinos, fast-moving elementary particles with minuscule mass that pass through ordinary matter undisturbed. An antineutrino detector tracks the particles as they emanate from a reactor to measure operational status and thermal power. (See the Aug. 29, 2008 issue of *Sandia Lab News* for more information on antineutrinos.)

But that technology is limited by range; to pick up antineutrino signatures, the detector must be very close to the core of the reactor. To monitor from further away — tens to hundreds of kilometers — you need a really big detector, Peter says. And by really big, he means millions of kilograms of detector material.

One of the most viable options for scaling to these sizes is water lightly doped with gadolinium. "This is a path that science hasn't gone down yet," says Peter. "It's pretty exciting research. We're pushing technology that could be very useful for physics detectors in the future."

(Continued on page 8)

Steve Rottler

recently sat down with writers Mike Janes and Patti Koning to reflect on his new role as Div. 8000 VP and share his insights about the status and prospects for the California site. Read the interview on **pages 6-7.**

Inside . . .

Cold War relics

Renovations on Bldg. 912's foundation led to the discovery of a treasure trove of Civil Defense emergency fallout shelter supplies lining the dugout earthen walkways below the building. See the story on **page 11.**

That's that

Note: This guest column was written for the special California edition of the Sandia Lab News *by Div. 8000 VP Steve Rottler.*

When I was asked to pen this issue's That's That column with a theme of diversity and inclusion, I was delighted. D&I is clearly an important initiative for Division 8000 and, indeed, for the entire laboratory. So I'm pleased to offer some thoughts and anecdotes that I hope will give *Lab News* readers a sense of my personal commitment to these issues.

My earliest understanding of diversity and inclusion came courtesy of two wonderful parents, though I never recall Mom and Dad using the words "diversity" and "inclusion." Rather, they taught these concepts through the values and life lessons they shared with me.

As I started elementary school, I recall Mom explaining I would meet children who did not look or talk like I did, and stressing the importance of accepting them as individuals, rather than judging them by the color of their skin, their gender, or their religious beliefs. I recall the experience of living overseas for three years, and finding myself, almost overnight, in a place with a language I could not speak or translate, with customs I did not understand, and where I was looked upon as someone strange and different.

I recall living in a small northeastern Texas town in the early and mid-1970s. The public schools had been racially integrated for three years, but the attitudes of many in the community remained much as they had been for the better part of a century. I experienced, in ways that were often physically painful, the challenges of trying to "straddle the line" in a racially divided community. And I recall the emotional pain of watching one of my closest friends reject forevermore another very close friend because the other friend could no longer live comfortably with us not knowing he was gay. These and other similar experiences affected me profoundly, and formed the foundation upon which I built my views about diversity and inclusion as an adult and a professional.

Three years ago, I was introduced to the concept of unconscious privilege – a special advantage enjoyed by an individual solely by virtue of some characteristic, such as skin color, gender, or religious belief. I benefit from such privileges because I am a white male. I cannot "give back" these privileges, and I receive them even though I have never sought nor affirmatively accepted them. I have learned to embrace the uncomfortable ambiguities one experiences when you are a beneficiary of unconscious privilege. These ambiguities often appear as paradoxes.

Two such paradoxes that have deep meaning for me are "it is not my fault, but I am responsible," and "I am blind to our differences, but will also be conscious of them." I am now able accept both sides of these paradoxes while not negating either side. This experience has opened my eyes to new, more deeply meaningful, dimensions of diversity and inclusion, and helped me better understand my responsibilities as a leader.

A commitment to diversity and inclusion requires a concomitant commitment to lifelong learning – learning about yourself and others, constantly challenging the way you think and the biases you hold. At this stage of my journey, I have a personal need to create conditions that permit others to bring the full measure of who they are to every situation and interaction. I experience emotional pain when I discover that others are unable to contribute fully because they feel the need to suppress or hide something that defines them as an individual. One of my daily objectives is to create an environment in which each of us can be true to who we are as individuals, bringing the full measure of ourselves to every interaction. When such conditions exist, we benefit individually and collectively.

Some refer to this as a "business case" for diversity and inclusion, but I prefer to think of it as a humanist case. To feel and be included is a basic human need, and we acknowledge and honor our humanity when we dedicate ourselves to the achievement of greater diversity and inclusion at home, in the workplace, and in society.

Thank you for reading. I hope you enjoy our annual "all-California" edition of the *Sandia Lab News*.

– Steve Rottler, Div. 8000 VP

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LOCKHEED MARTIN

CRF research shows wide appeal

By Holly Larsen

Adding to the numerous citings of Combustion Research Facility (CRF) papers in the past, three new examples confirm the value that others place on the laboratory's work.

While visiting the website of the *Proceedings of the Combustion Institute* (http://www.journals.elsevier.com/proceedings-of-the-combustion-institute/), a biennial publication at the forefront of combustion science, Sandia senior scientist John Dec (8300) of the Transportation Energy Center discovered that a paper he had written in 2008 is the most cited of all the papers in the Proceedings. Since publication, "Advanced Compression Ignition Engines — Understanding the In-Cylinder Processes" has been cited 128 times, most recently in two 2013 articles in *Combustion and Flame*, the journal of the Combustion Institute. For perspective, the Proceedings' two next most cited papers have been cited 88 and 89 times.

John has a simple explanation for the article's wide appeal.

"It's a review article that gives a good summary of work in this area that probably isn't available elsewhere," he says. What is somewhat surprising is the paper's continued influence over five years. "At some point, an updated paper will appear, and this one will drop out of sight."

COMBUSTION RESEARCH FACILITY

An article by Oliver Welz, Judit Zádor, John D. Savee, Leonid Sheps, David L. Osborn, and Craig A. Taatjes (all 8353), "Low-Temperature Combustion Chemistry of n-Butanol: Principal Oxidation Pathways of Hydroxybutyl Radicals," was among the top 20 most-cited articles for the *Journal of Physical Chemistry A* for the month of July. In this paper, the CRF researchers revealed important product pathways in the low-temperature oxidation of n-butanol using synchrotron photoionization mass spectrometry experiments combined with quantum chemical calculations.

"n-Butanol is a promising next-generation biofuel, and this study is fundamental to the development of accurate and predictive n-butanol combustion models. Combined with CFD calculations, these chemical models form the basis of optimizing the performance of n-butanol in existing and advanced engine designs toward clean and efficient combustion," says Judit.

A third article, "Two-Dimensional Gas-Phase Coherent Anti-Stokes Raman Spectroscopy (2D-CARS): Simultaneous Planar Imaging and Multiplex Spectroscopy in a Single Laser Shot," has also garnered a significant audience since going online on June 12. Written by CRF researchers Alexis Bohlin, a postdoc appointee, and Chris Kliewer (both 8353), the project's principal investigator, the article placed 11th in Top 20 Most Read Articles of the *Journal of Chemical Physics* in June 2013 (http://jcp.aip.org/features/most_downloaded?month=6&year=2013).

Asked about the article's popularity, Chris says, "It describes a new multidimensional technique, enabled by recent developments and discoveries from our lab, that has been a goal of laser diagnostics for more than 30 years. Researchers in many fields of science may find the concept interesting and potentially useful."

In a letter, the journal editor congratulated the researchers on their impressive accomplishment, and noted that the *Journal of Chemical Physics* ranks number one in total citations in the category of Atomic, Molecular, and Chemical Physics by Thomson Reuters (formerly ISI).

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Sandia CaliforniaNews

Patti Koning and Mike Janes (both 8521), seen here during a recent emergency response exercise at Sandia's Livermore, Calif., site, once again took over the helm of *Sandia Lab News* as guest editors for the 7th annual California issue, featuring the site's research, people, and happenings.

(Photo by Randy Wong)

WORK ON THE NEW CIRI INITIATIVE commenced at the California site with some initial construction work in May by Division 8000's facilities planning group. Here, ground on the Livermore Valley Open Campus is moved in preparation for a concrete foundation that could eventually house a CIRI refueling station or other equipment. (Photo by Dino Vournas)

CIRI

(Continued from page 1)

sands of fueling stations to power our vehicles. The driving lifestyles Americans have been accustomed to over the decades wouldn't be possible without that network of fueling stations.

A hydrogen fuel cell-based infrastructure, however, is limited, largely because the technology is relatively immature in the consumer environment and requires a different approach compared to the existing liquid-based fueling infrastructure.

Still, despite the technical challenges, inconsistent government investments, and competing technologies, the automotive industry has stayed the course, says Daniel.

"The automakers have stayed very consistent with their business models these past few years," he says. "They understand the benefits of hydrogen fuel cell vehicles and have continued to move the technology forward." Hydrogen fuel cell vehicles, Daniel asserts, compare favorably to electric battery vehicles, mainly because fewer high-cost materials are necessary with fuel cell vehicles.

Recent news reports would appear to confirm the notion that automakers remain bullish on hydrogen fuel cell vehicles.

According to a July report from Bloomberg, General Motors and Honda Motor Co. are now partnering to bring hydrogen fuel cell vehicles into the marketplace.

In November, Toyota Motor Corp. is expected to unveil its own fuel cell sedan, one that is expected to go on the market in 2015. Hyundai Motor Co. and Mercedes-Benz are also planning commercial availability of hydrogen vehicles in 2015.

In fact, virtually every major automobile manufacturer has designed and produced hydrogen fuel cell vehicles. In May, DOE Undersecretary Dave Danielson announced a public/private partnership known as H2USA focused on hydrogen infrastructure that is designed to help coordinate the nation-wide rollout of hydrogen fuelling stations. Sandia became a member of H2USA this month.

Daniel and Sandia's transportation energy experts, along with their federal sponsors, understand the role that fuel cell electric vehicles can play in a zero-emission transportation future. The Labs' vision, Daniel says, is for CIRI to help industry with the all-important hydrogen infrastructure part of the equation.

Reducing cost, improving performance of hydrogen systems

Sandia's own hydrogen and fuel cells program has significantly informed and influenced the hydrogen transportation community already on key technical issues, and Daniel says researchers now have data that demonstrates the need for further R&D on infrastructure.

And what are the specific infrastructure issues that need to be addressed? Daniel points to three areas: high-pressure compression, storage, and delivery.

Compressed hydrogen is stored at high pressures (10,000 psi) in hydrogen vehicles, and the hardware used with that technology is relatively immature in the consumer environment. This leads to deficiencies in reliability and efficiency that need to be addressed. More research into how hydrogen is compressed, stored, and dispensed is required to make the infrastructure components more robust and dependable.

Secondly, Daniel says, the current capital costs of a hydrogen fueling station are higher than traditional gasoline stations and must be lowered significantly. A typical hydrogen station currently costs roughly $1-2 million from start to finish, while the cost of a gasoline station today runs around $200,000 to $300,000.

"A main reason for this is the high cost of materials used for a hydrogen station," Daniel explains. High-nickel steels, in particular, are expensive, so new research is needed to find lower-cost classes of materials that will perform well and last long. "We also need to understand how the entire [hydrogen fueling station] system behaves so that we can refine it, introduce new technologies as needed, and shrink the system's footprint," Daniel adds.

For now, Daniel's focus is on finalizing partnerships with industry and other national laboratories, with a grand opening of CIRI tentatively planned for early next year.

"If we're successful with CIRI, we'll be able to say that we enabled industry by providing them with a technical, scientific basis for producing cost-competitive hydrogen fueling stations that can be deployed anywhere, whether it's downtown San Francisco, Washington, D.C., Livermore, or Albuquerque," says Daniel.

LRSO

(Continued from page 1)

The LRSO is a nuclear-capable cruise missile that will replace the US Air Force's aging Air Launched Cruise Missile (ALCM), which rolled off the assembly line in 1985 and needs a comprehensive service life extension program (SLEP). The LRSO will be compatible with the B-52 and B-2 aircraft.

NNSA and the USAF asked Sandia, along with Los Alamos and Lawrence Livermore national laboratories, to examine three families of warheads — the B61-12, the W84, and W80, which is the current system — to help determine which would best meet the requirements of the LRSO system. The job fits neatly within Sandia's traditional role as the systems integrator for the nation's nuclear weapons stockpile.

"We looked at the three warhead families to see which — if any — would work best with LRSO, and which modifications and upgrades would make the most sense," says Bryn Miyahara (8248), a systems engineer with Sandia's Advanced and Exploratory Systems Department. "We asked ourselves a number of questions," says Bryn. "Given the draft requirements and design space available, what do we want this system to look like? What modifications need to be made? What technologies are now available to upgrade what was there in the system previously? Those were all considerations."

Sandia first studied the W80 and W84 and examined high-level options for using those systems. Later, engineers conducted a lengthier study that proposed more detailed design options for all three warhead families, including the B61-12 now under development. Miyahara, Lee Druxman (8248) and several others at the Sandia's California site led the W80 and W84 portion of the work, while Maria Rosado (2141) and others at Sandia/New Mexico focused on the B61-12 options.

The Sandia team looked at the draft requirements, including the available mass and volume. Along with Sandia's Design Definition Team, the group laid out multiple design iterations to help better understand and define the upper and lower design limits. Where possible, they examined how best to use components under development for ongoing weapons alterations (ALTs) and LEPs.

"It was a challenge for us," Lee says. "Traditionally, there is an existing, designed missile with an established payload and interfaces, and our job is to identify the right warhead to interface with it. Here, the missile and warhead are being designed concurrently, which poses a chicken-or-the-egg challenge."

"Plus, there are certain size constraints associated with a cruise missile system," Bryn adds. "That poses difficulties in fitting anything into a compact package."

Working with Air Force new, challenging

Working closely with the US Air Force and NNSA has been a fascinating experience, Lee says.

"It's been a different dynamic than I've been used to," Bryn says. "Balancing Air Force requirements with NNSA resources has been a new challenge."

Lee, who has previous experience working with the Air Force, says a project like LRSO allows the team to use system engineering skills that can't be learned in formal educational settings.

"Skills for this type of system engineering just aren't taught in school," he says. "Engineering courses can't teach you how to design a weapons system from the ground up, how to get it implemented, fielded and tested. So this kind of work is exciting."

Something is inherently thrilling about working on the kind of project that hasn't been tackled in decades, says Lee.

"The last time a missile and warhead were concurrently designed and fielded was in the late 1980s, when the W87 and W88 were fielded," he points out.

Decision lies in hands of customers

Which of the three families will be selected as the warhead for the LRSO program depends on factors that are not part of Sandia's technical studies, says Bryn.

"Both NNSA and the Air Force will consider which features they value most and go from there," she says. "Each of the three warhead families offers something the others can't, but they also sacrifice different features." One warhead, for instance, might have unique safety or security features compared to the other two, yet may offer the lightest weight.

One thing that is for certain is that Sandia will be the systems integrator for the warhead, as it is for the entire stockpile. Working closely with the Air Force, Sandia will continue down its traditional path: creating components, developing subsystems, doing detailed design, considering dimensions, packaging the electronics and managing qualifications testing for the system.

Bryn and Lee travel to Washington, D.C., regularly to present their studies and to help agency decision-makers make the best use of their conclusions.

"It's been rewarding to exercise skills that we haven't used before, and do something that will have such a meaningful impact on the nation's security," Bryn says.

Data center modernization, consolidation will enable more efficient use of resources

By Mike Janes

Sandia's California site prides itself on being innovative, contemporary, and nimble, able to take on mission problems with the efficiency and pioneering spirit of its Silicon Valley neighbors.

That may all be true, but when it comes to the site's essential computing infrastructure — and a facility to house it all — Division 8000 has been somewhat static and unable to do what it takes to maintain a world-class operation.

"We need to modernize the Sandia/California data center not only because it's deteriorated, but more importantly to help us to build, adopt, and implement the core of the Labs' internal cloud," says Steve Carpenter (8945), who manages the information systems and services group at the California site. A successful modernization effort, Steve says, will also provide the opportunity for consolidation of redundant services and applications corporate-wide, and will provide agility and on-demand elasticity.

HARD-WIRED — Matt Schrager and Mike Kurtzer work with cables below the floor tiles in the Bldg. 912 data center. The amount of piping, both active and inactive, makes it difficult for maintenance personnel to work under the floor. (Photos by Jeff McMillan)

The problem of "sprawl" of distributed resources, Steve says, is reflected in too-high costs, elevated energy consumption, and risk of IT-related security incidents or data loss. The benefits of successful modernization and consolidation, he says, include disaster recovery and business continuity, more effective maintenance planning and operations, and integrated services that help improve mission delivery.

Into the 21st century

So change is coming. For its part in a five-year, Laboratories-wide data center consolidation (DCC) effort, the California site is aiming to complete a modernization and consolidation strategy that will bring the site's data center well into the 21st century. Matt Schrager (8945) and Mike Kurtzer (8945-1) are leading the project for Division 8000.

"When people think about where their Sandia information and data are stored in the future," adds Steve, "they won't have to care about which one it is or where it's located, it will simply be 'the data center,' consistent with how we think about the cloud services we're all becoming accustomed to now."

Before the site can effectively consolidate, it needs to modernize, the team asserts. So the first order of business has been the development and execution of a modernization plan.

The modernization study began with a needs assessment that sought to determine the site's entire customer IT needs and requirements, both present and future, to fulfill mission and programmatic goals. Based on the study's findings, several conceptual options for a modern data center were developed. The options include modernizing the existing data center (which currently resides in the basement of Bldg. 912), renovating an existing building, purchasing or leasing a modular/POD type structure, or raising a new building.

CHILL OUT — Casey Collins (8515-2), a member of the facilities maintenance team, inspects a leak from a chilled water supply line. Obstructions such as the density of pipes seen here can interfere with proper airflow.

For years, says Mike, the California site's main data center has experienced deterioration with infrastructure issues such as cooling and power. Consequently, upgrades to air handlers and air delivery, power distribution, flooring systems, and other hardware would be needed for the facility's successful modernization.

Another key feature that has previously been missing in the Sandia/California data center is redundant power and cooling capabilities. Redundancy would ensure that the data center could still operate without interruption if a power source went down or if there was a mechanical failure in a cooling system unit. Cooling impacts can be avoided by ensuring a sufficient number of air handlers are available to support the environment in the event of a cooling unit failure, says Mike.

Currently, the majority of equipment in Sandia/California's data center is powered by a single source. Most modern data centers, Matt says, have redundant power and cooling.

"Some of our more critical programs need power 24/7 no matter what. They simply can't afford to have even a moment of down time," Matt says. "They must have redundant and unlimited power supply from multiple sources to draw upon for failover."

As part of the current study, Matt says this component will be examined closely so that a solution can be devised to support all customers and ensure they have the power they need in all circumstances.

Cutting down on IT 'sprawl'

The consolidation piece of the project is largely being driven by DOE requirements, though Mike and Matt both say consolidation has been needed at the California site for years.

"They [DOE] want their facilities to reduce power consumed at all external data centers and server rooms, and consolidation is a good way to leverage those areas for efficiency," Mike says. "Power and cooling are the two biggest consumers of electricity and thus the two areas where consolidation can have the most impact." An important side benefit of the consolidation effort, Mike says, is that moving some servers into the primary data center may open up much-needed space for potential office use.

Even without DOE's directive, Matt says, consolidation at Sandia/California has become a necessity.

"Some members of the workforce have developed their own storage, computational, or web servers and manage these themselves," Matt says. The assumption, he says, was that there would be cost savings and improved efficiency, but the result has been an infrastructure spread out throughout the site that's been decidedly inefficient and difficult to manage.

Fortunately, Matt says, owners and administrators of those "rogue" servers have largely been understanding of the site's consolidation needs and willing to consider relocation of their resources into the primary data center.

"Most of the people we interviewed are open to a shared, centralized data center," says Matt. "It's been a pleasant surprise, as we expected more resistance."

Some programs will continue to require their own servers and resources, however. The site's Emergency Operations Center has unique needs that can't be met in a shared environment, and the same can be said for other special programs. Eventually, Mike and Matt hope that a shared — yet secured — environment can replace the vast majority of independent servers around the site.

Laboratories-wide benefits

Mike and Matt say that, although tangible benefits to the workforce are expected, the end result of the modernization/consolidation effort will be largely invisible if the work is done correctly. "It should be a seamless transition, though energy efficiencies, less noise, and more available space for other uses will certainly have a positive impact on members of the workforce," says Matt.

Perhaps most importantly, they say, the Labs-wide consolidation effort of which Division 8000 is a part will have far-reaching impact for all members of the workforce at Sandia.

"The California site is playing an important role in a key strategic effort for the enterprise," says Steve. "Modernized data centers today are actually the sum of multiple ones in geographically separate locations carefully integrated to deliver important resources to the workforce. Without a California component, Sandia's data center will be incomplete."

Acting NNSA chief visits California lab

NNSA ACTING ADMINISTRATOR Bruce Held paid a visit to Sandia/California on Aug. 1 to learn about the site's unique capabilities in weapons systems, information operations, combustion research, and biosciences, and the Livermore Valley Open Campus. On a tour of the Combustion Research Facility, Held learned about engine research from Mark Musculus, left. Also in the photo above are, left to right, senior manager Art Pontau; Capt. Geoffrey deBeauclaire, military assistant to the NNSA acting administrator; Div. 8000 VP Steve Rottler; and Held. (Photo by Dino Vournas)

Uncovering the mechanisms of virulence in pathogens

ZACH BENT, in the foreground with Steve Branda, manipulates a pathogen capture reaction under high temperature to maintain stringent hybridization conditions so that binding specificity remains high, thus enhancing efficiency of the capture. (Photo by Dino Vournas)

By Patti Koning

The original aim of the RapTOR (Rapid Threat Organism Recognition) Grand Challenge was to identify "unknown unknowns" — dangerous, virulent pathogens of unknown origin. Zach Bent (8623) and Steve Branda (8621) have now applied molecular biology capture approaches developed by the RapTOR team to a different problem, understanding how known pathogens become virulent. Until recently, determining what made pathogens dangerous was too expensive and time-consuming, but the capture methods overcome that barrier and could help researchers develop diagnostics and therapeutics to better combat drug resistant pathogens.

Analyzing pathogens' gene expression during infection has been difficult because pathogen RNA molecules ("signal") are generally outnumbered by host-derived RNA ("background") in the sample (e.g., infected blood) by about 100-fold. RapTOR began to address this signal-to-background ratio problem with a negative capture method that uses affinity probes to capture and discard nucleic acids not of interest (e.g., host-derived) prior to sample analysis via Second Generation Sequencing (SGS). To amplify the pathogen signal, Zach turned to capture probes that selectively bind and recover pathogen nucleic acids for sequencing, a strategy referred to as pathogen capture.

"Our approach is very minimalist. It's fast and cheap, which is important because it requires a large excess of probe, about 100 times more probe than sample," says Steve. "We finely chop and tag pathogen nucleic acids to generate the probes. It's crude, but it gets the job done. This method uses the entire genome, so every possible transcript can be captured and sequenced."

A simple concept

The concept is simple: Saturate your sample with pathogen-specific probes; give the probes every opportunity to find their complementary nucleic acid partners; recover the hybridized probes on a column; wash extensively to disrupt non-specific interactions; and release the pathogen nucleic acids from the column for sequence analysis.

"It sounds straightforward, but carrying it out is tricky because the conditions have to be exact for the probe to find the target, grab it, and remain stable enough to isolate it from the sample," says Steve. "Efficiently separating the target from the probe is key as well. You don't want to waste time and money inadvertently sequencing the probe."

Another challenge is making the probe discriminating enough to grab only nucleic acids from the pathogen, avoiding those from the host. This increases the degree of pathogen enrichment, which is critical to getting sufficient sequence coverage of the pathogen's entire transcriptome at a reasonable cost. Zach and Steve's goal was at least 100-fold enrichment.

Getting it right took about two years of painstaking research; Zach and Steve are grateful to the many interns and technologists who have helped on the project. Most improvements were incremental, but their breakthrough came with precise definition of the column washing conditions.

"We significantly raised the ionic strength of the washing buffer to increase the stringency of the wash. Suddenly almost all of the nonspecific binding we were getting went away. That brought our enrichment up from 10-fold to over 100-fold in a single step," says Zach.

Seeing pathogens in high fidelity

Zach and Steve use pathogen capture in tandem with other molecular biology methods developed for the RapTOR project, and the results are quite amazing — the ability to see details of what the pathogen is doing, due to the sheer number and variety of pathogen gene transcripts that can be sequenced.

Zach puts the advance in perspective. "I spent all of my time in graduate school looking at the in vivo expression of four different genes. This required an intense amount of work to get results of any significance," he says. "With our new technique, instead of looking at a few genes, I can look at expression of all of the pathogen's genes, several thousand of them, at once."

This technique mitigates a significant barrier to research — the cost of sequencing. While sequencing remains a fixed cost, the cost of prepping the sample is small (about $20 to prepare and capture a sample), and the sample itself is rich in genetic material. By enriching the sample for transcripts of interest, the researchers can load multiple samples on the sequencer and still get appropriate coverage depth. This yields better bang for the buck, in terms of sequencing costs, and also saves time because multiple samples are analyzed in a single sequencing run.

Zach and Steve tested the efficacy of their pathogen capture technique by analyzing in vitro infections. In a paper titled "Enriching pathogen transcripts from infected samples: A capture-based approach to enhanced host-pathogen RNA sequencing", published in *Analytical Biochemistry* in March 2013, they reported 10- to 100-fold enrichment of reads mapping to the pathogen's transcriptome, relative to untreated controls. This enrichment greatly increased the diversity of pathogen transcripts sequenced, as well as the coverage depth at which each transcript was sequenced.

They then closely studied *F. tularensis* at two critical transitions during infection: when the pathogen escapes from an internal membrane-bound compartment within the host cell, and when the pathogen begins replicating within the cytosol of the host cell.

"We saw what we expected: Two distinct gene expression profiles at those two transitions," says Steve. Their work also revealed several hundred transcripts of unknown function, many of which are up-regulated (switched on) and therefore potentially important for pathogen survival and proliferation within the host cell. These results will be reported in a *PLoS ONE* article that is currently in press.

"We don't have the resources right now to study those particular unknown genes," says Zach. "Just the number of unknown genes we found is quite interesting, because *Francisella* has been studied extensively for two decades. The number of unknown, up-regulated genes we found in just this initial experiment shows that we really haven't been seeing the whole picture."

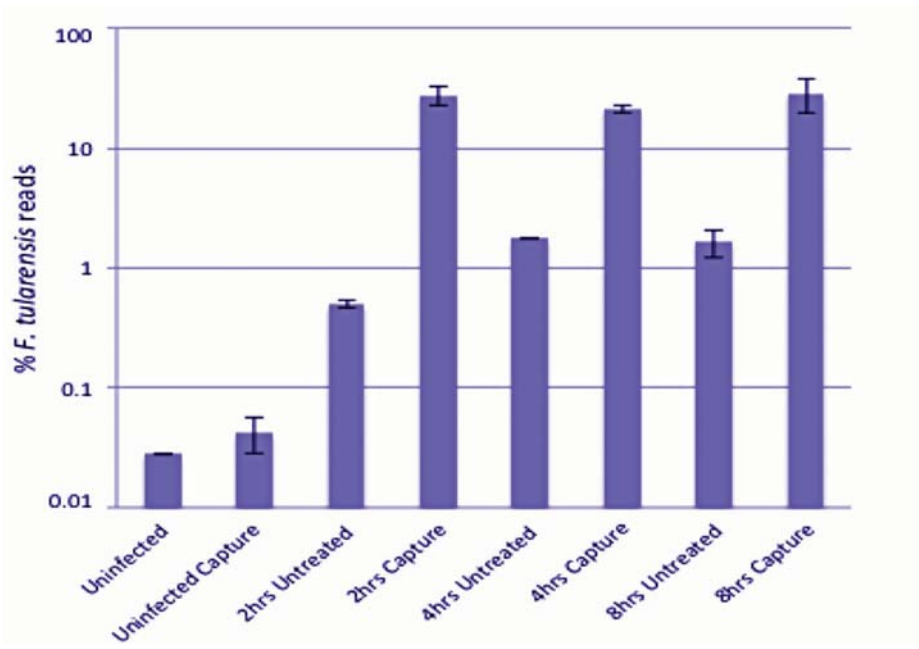
Understanding host/pathogen wargames

Moving forward, the researchers would like to study infections in even greater detail. Zach likens host/pathogen interactions to an arms race on a microscopic level. "The pathogen invades, the host responds, the pathogen counterattacks, and this goes on until one side wins," he says. "Being able to look so closely at expression of all of the host and pathogen genes will let us figure out those key critical moments when the host is overpowered and an infection spreads."

They want to expand their research to include animal studies to track the dynamics of infection at different physical locations, a particularly under-studied dimension of infection. The speed and low cost of the pathogen capture-based technique would enable tracking of an infection as it spreads to different parts of the body.

"By being able to sample many different physical locations, you can see how different body defenses are mounting a reaction, and what the pathogen is doing to survive," says Steve. "Those have been really difficult experiments to carry out, and we don't at all understand what it means for bacteria to survive in the liver versus a lung, for example. This is a completely different facet on the whole interaction between a pathogen and a host."

In the future, pathogen capture could enable researchers to study bacterial gene function during infection with such precision that they can develop new counter-measures that are effective against drug-resistant strains. Therapeutics could be made to target specific bacterial pathways and infection mechanisms entirely separate from those targeted by broad-spectrum antibiotics. By hitting multiple pathways at once, says Steve, a therapeutic could conceivably stop a pathogen in its tracks, preventing it from developing resistance to the new drugs.



PERCENTAGE OF READS MAPPING to *Francisella tularensis* at three different post-infection time points and an uninfected control sample presented on a log scale. In all cases, pathogen capture is able to increase the percentage of reads mapping to the pathogen by 25-50 fold.

Zach is also the principal investigator of an Exploratory Express LDRD to analyze the *Yersinia enterocolitica* transcriptome at very early time points in infection using pathogen capture technology. "We aren't quite finished analyzing all of the data, but we have already made several exciting discoveries that shed light on the roles of its various virulence mechanisms," says Zach.

In October, Zach and Steve will begin working on an LDRD-funded project led by Robert Meagher (8621) to build an automated device to perform pathogen capture on 96 samples simultaneously. "Right now, we have a very specialized setup and it still relies on a lot of manual labor," says Zach. "We want this to be accessible and compatible with a typical lab setup, so that other groups can take advantage of our technique."

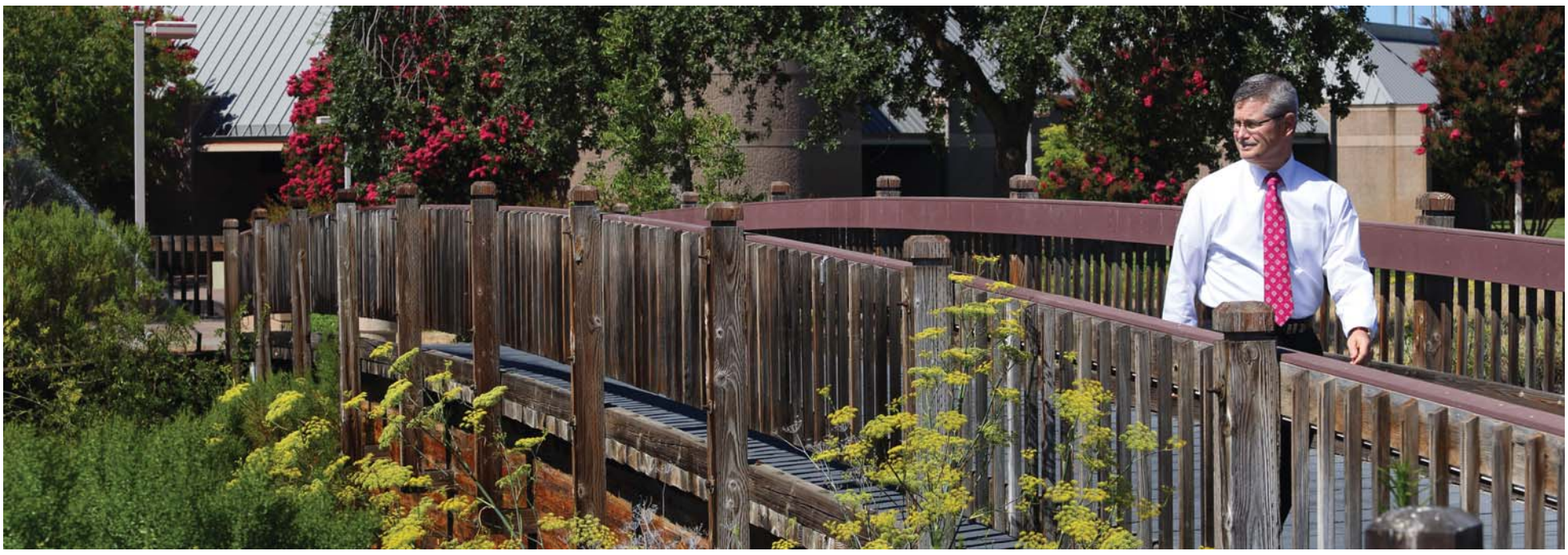
Developing the automated device will take a year or so, but during that time Zach and Steve will conduct more studies to prove the technology. "With each new development, you can do more experiments than you could in the past, and different types of experiments as well," says Steve. "It's been a long time in the making, and there's still much more work to be done, but we'll continue to get exciting results along the way."

What's not to love about California?

Steve Rottler reflects on his new role as Division 8000 VP

Lab News ***interview by Mike Janes and Patti Koning***

Photos by Dino Vournas (Except where noted)



"I FEEL PRIVILEGED to be part of Division 8000," says California site VP Steve Rottler.

Photo by Jeff McMillan

Lab News: *You lived in Albuquerque for 28 years and are still a resident. How did you feel about moving to California?*

Steve Rottler: I was very excited. In fact, much earlier in my career I had hoped to go to California for an assignment. However, before anything could be arranged I was promoted to center director. My career took a slightly different turn, the opportunities became much narrower, and when I became an executive in 2005, I pretty much gave up any hope of ever coming to California.

When Paul [Hommert] called me about this opportunity on Thanksgiving last year, the only negative I could see was living apart from my wife for several years or more because of the need for one of us to remain in close proximity to our aging parents who live in north Texas.

Everything else is positive: the site, the people who work here, the work that goes on in the division, the number of interfaces and opportunities that the lab has here in the Bay Area, and this fantastic place in which we live. What is there not to like, about living and working in the Bay Area? Nothing. It's fantastic.

LN: *You have a very strong background in nuclear weapons. Do you think that background is important at this particular time in leading this site? If so, why and how is it important?*

SR: I don't know that it so much has to do with a particular moment in time. We have Bruce [Walker] and Jerry [McDowell] in New Mexico and the directors who have the primary responsibilities for the nuclear weapons program, and so we are blessed with much talent in this area. In the role I have out here, I believe my experience and background in nuclear weapons and the programmatic role that I've retained are valuable assets for this division and for the site.

One of our most important relationships is with our colleagues across the street at Lawrence Livermore. I know their key leaders, and feel I'm well known to most of them. I think that will be very helpful to the division and the lab. I think the experience and background that I bring and those established relationships will make it easier to maintain the trust-based relationship that underpins our very important strategic partnership with LLNL.

Understanding the context in which the NW program exists nationally and the forces that shape it are both important parts of developing strategy and engagement for our division in the rest of the work in the Laboratories. I think I bring that perspective, too, and it's a useful tool to help our leadership team plan and move into the future.

LN: *Do you have additional thoughts on the relationship between Sandia and Lawrence Livermore National Laboratory?*

SR: Our most important relationship is the 60-year strategic partnership with our colleagues across the street (LLNL). That relationship is even more important during this time of rapid change and adjustment in programs based here in California. These changes can create tensions in our relationship, but they also present opportunities and

CENTER FOR CYBER DEFENDERS interns Joan Hong, Natalie Roe, and Steven Barker (all 8965) share their research project with Steve.

AN IMPROMPTU ENCOUNTER with Patrick Doty (8131).

DISCUSSING THE DAY AHEAD with Deputy Carole Le Gall (8005).

we should exploit them. In any event, we should not allow the changes going on around us to alter our focus on continuing to strengthen this important relationship.

LN: *What is your vision for the site? What is your process for creating this vision?*

SR: In terms of a process for developing a division vision, I have to say that I don't really have one. I'm really primarily focused on achieving our laboratory vision, and on defining the role of our division in making the vision of the laboratory a reality. So when I think about Division 8000, I think about strategy and how to maximize our division's impact on helping the laboratory realize its strategic plan.

Regarding high priorities, I would put at the top of the list our joint plan with LLNL for the development of the Livermore Valley Open Campus. It's not only differentiating for this division and for this site, but I also think it's critical for both LLNL and our laboratory. We talk often about the benefits to Sandia from having a presence here in California, and in my mind, the Livermore Valley Open Campus provides a means by which we can more fully realize these benefits.

The nuclear weapons program is an obvious priority. There is still some uncertainty about what the workload will be for California, but there's no question in my mind that the modernization programs are going to proceed, and our division will play a very important role in the program. I also see very exciting opportunities for this division in areas of emerging importance from a national security perspective, our work in biosciences, energy, transportation through the Combustion Research Facility, and cybersecurity. Those are areas of emerging importance, and for some, the funding opportunities exceed our ability to provide the resources necessary to do the work. They represent potential growth areas and areas for our division to have a very high impact on national security.

CHATTING with Patrice Sanchez (8353), manager of Site Mission Partners California, outside Bldg. 929.

LN: *What are the challenges facing the California site?*

SR: A big challenge for the California site is the implications and reality of the 1,000 miles that separate us from Albuquerque. We're an integral part of the lab, and that's well understood in New Mexico. However, if you don't work here or spend a lot of time here, it can be difficult to understand the often subtle differences between the two sites, and what's necessary to be successful here versus in New Mexico. This disparity does drive decisions that, while optimal for the lab, are often not optimal for our presence here in California. So an ongoing challenge for me is continuing to drive connectivity and interaction between California and New Mexico.

I'm also a bit concerned about the weapons program at the site. While the modernization program appears to be somewhat stable, the workload and programs associated with our responsibilities here in California have a bit more instability than the programs that are centered in New Mexico. That is introducing some uncertainty with regard to workforce planning, and it has an impact on the morale of the organizations that are heavily dependent on that part of the program. There have been unexpected budget changes that have affected the weapons programs in California. We've worked out much of that, but those actions still create uncertainty and doubt.

LN: *What do you find exciting about working at the California site?*

SR: I truly love being here in California. This is something I've always wanted to do. I have been impressed with everything that I've seen; this division is on the cutting edge of many things at the Laboratories. I feel privileged to be a part of Division 8000.

There is a very different feel to being a leader in California. In my prior job as CTO, I thought I had a large number of interfaces. It pales in comparison to the number of interfaces I have or could have here in California. Some of that is simply by virtue of being in this part of the country. We are situated in the Bay Area with millions of people, thousands of companies, hundreds of educational institutions, and many different government entities. Our employees come from about a dozen congressional districts. The many interfaces and the number of people that are interested in what we are doing here at the lab are huge.

STEVE REFLECTS on the evolution of Sandia's microfluidic devices.

Before I came out here, I saw the LVOC as a very important asset to the laboratory, but something that anchored our California site. While that's true, I think the greater value may be in how the LVOC draws more of the lab into California. . . . LVOC positions us to use our California site location more strategically as a lab. A key part of my role as the site VP is to help communicate and drive this vision. he future of LVOC is exciting and I've told our LVOC team I want us to do everything we can to accelerate the realization of our vision."

Photo by Jeff McMillan

LN: *What are your thoughts on the Livermore Valley Open Campus (LVOC)?*

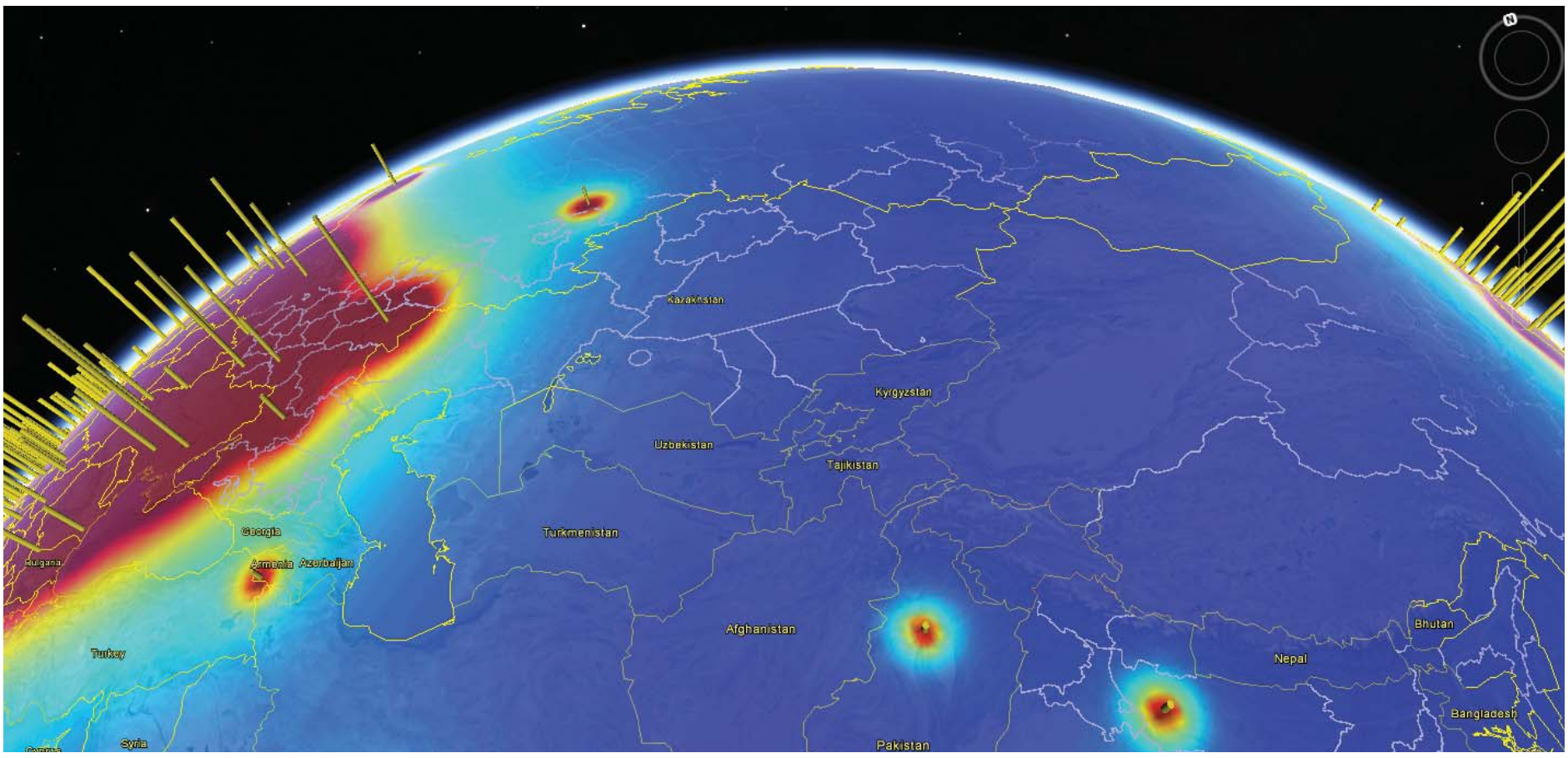
SR: After I'd been here for a few months, I had a personal epiphany about the potential for the LVOC to create greater connectivity for the lab here in California. Before I came out here, I saw the LVOC as a very important asset to the laboratory, but something that anchored our California site. While that's true, I think the greater value may be in how the LVOC draws more of the lab into California. The opportunities created by the LVOC can give lab program managers a gateway to the Bay Area and a reason to see value in exploiting our presence here to strengthen our capabilities and programs. This was probably well understood to others, but was something I realized only after being here for a few months. LVOC positions us to use our California site location more strategically as a lab. A key part of my role as the site VP is to help communicate and drive this vision. The future of LVOC is exciting and I've told our LVOC team I want us to do everything we can to accelerate the realization of our vision.

LN: *You've talked about genealogy as one of your hobbies. How did you get started and what have you learned?*

SR: I began researching my family history after losing my mother about five years ago. It happened very suddenly and we did not have much time to prepare. When my sister and I were helping our father organize her things, we came across several large boxes of pictures. My mother shared everything with us, but neither of us had ever seen these pictures before. We guessed that the pictures, which were not stored well or labeled, came from the homes of our two grandmothers. This was clearly a project my mom had in mind but never got around to before she passed away.

My sister and I decided that if we didn't do everything we could to document our family history, we would have nothing to leave our children, and it would be the end of the knowledge of our families. It began as just archiving and labeling pictures, but after a month I wanted to do more — reconstruct the family tree. It has become almost an obsession for me; I spend much of my time outside of work researching and documenting my family history. Lately, I have begun using DNA testing as a tool for genealogical research. This has introduced another new dimension in my research.

I've discovered that this is really good therapy for me. I still find the loss of my mother to be quite painful. I was very close to her and she was a big influence on my life. When I'm working on our family history, it's like she's there with me. I feel closer to her and other members of my family who are no longer around.



FLUX CAPACITOR? — No, but as shown in this image of antineutrino fluxes around the world, WATCHMAN will have plenty to watch.
(Image courtesy of Glenn Jocher and John Learned, University of Hawaii)

WATCHMAN

(Continued from page 1)

Sandia and LLNL are teaming with six universities — University of Hawaii, Hawaii Pacific University, Virginia Tech, and the University of California, Berkeley, UC Davis, and UC Irvine — on a project funded by NNSA's Office of Defense Nuclear Nonproliferation Research and Development. The project is called WATCHMAN, or WATer CHerenkov Monitoring of Anti Neutrinos.

There is some precedent for a detector of this scale. Japan's Super-Kamioka Detector, or Super-K, has a massive 50-kiloton tank that stands 136 feet high. But as a neutrino observatory searching for proton decay, neutrinos, and cosmic rays, Super-K is not sensitive to reactor antineutrinos. Super-K uses ultra-clean water, not the doped water proposed for the WATCHMAN detector.

Because the WATCHMAN detector will break so much new ground, the team is starting with basic research to optimize the design and location of the demonstration site of a smaller kiloton-scale gadolinium-doped water detector. They are about halfway through a two-year scoping study.

Understanding background at shallow depths

One challenge for a detector of this size is background radiation. The bigger the detector, the more background radiation it is going to pick up. One solution to this, says Peter, is to place the detector underground.

"At a certain depth, cosmic radiation disappears," he explains. "But that kind of excavation would be very costly and time-consuming for a detector of this scale. We're looking at what happens at shallow depths. Is there a more reasonable depth of a few hundred feet where background radiation drops off to a more manageable level? That's something we don't know because there just isn't much research on background radiation at shallow depths, especially with a water-based detector. We are after a low signal-to-noise regime to optimize the detector's effectiveness, so understanding background is huge."

In particular, the study is looking at background radiation created by muons that can mimic antineutrinos. Muons are fundamental particles created when cosmic rays collide with molecules in the upper atmosphere. Every second of the day, muons are hurtling down to earth; the rule of thumb, says Peter, is that a muon passes through your thumbnail every minute. They eventually attenuate when they are absorbed or deflected by other atoms.

"Muons are very high energy particles that are not easily stopped. When they interact with rock, they basically rip apart the nuclei in the rock and create a shower of particles that can look like an antineutrino signal in the detector," says Peter. A muon can also pass through a water-based detector and create radionuclides with decay particles that look like antineutrinos.

To understand how these phenomena affect background radiation at shallow depths, the WATCHMAN team is conducting a series of fast neutron measurements at the Kimballton Underground Research Facility (KURF), a science facility operated by the Virginia Tech Neutrino Science Center.

Splitting the problem

Early into the project, it became clear to the WATCHMAN team that a single detector could not encompass all of the muon interactions, so they split the problem. LLNL took on radionuclides while Sandia focused on the neutron spectrum, specifically muon-induced fast neutrons with energies between 100 and 200 MeV.

THE MARS TEAM — Kevin Hulin (8136), Caleb Roecker (UC Berkeley), Peter Marleau (8132), Jim Brennan (8125), Mark Gerling (8132), and John Steele (8132). Not pictured is Dan Throckmorton (8125).

LLNL's radionuclide detector, still in development, will be similar to the kiloton detector on a much smaller scale, about 3 meters across, with a tank that will hold gadolinium-doped water. "There has been no measurement of the production of radionuclides from muons interacting with water, so it's not a well bounded problem," says Peter.

Over the past year, the Sandia team members designed and constructed a one-of-a-kind detector that was delivered to the KURF site in early June. That detector, which the team dubbed MARS for Multiplicity and Recoil Spectrometer, combines two established modes of neutron detection to cover the entire energy spectrum of interest.

Think of it as a detector within a detector within many more smaller detectors. MARS consists of a 20-centimeter-thick pile of lead sandwiched between plastic scintillator wrapped in photo multiplier tubes to read out the scintillation light. The entire package is wrapped in paddle detectors to tag muons that enter MARS.

"We want to measure what is coming out of the walls of the cavern, not neutrons that are created within our detector by muon interaction," explains Peter.

The lead acts as a multiplier for high energy neutrons, so there are two modes of detecting neutrons. A high energy neutron can interact directly with the scintillator, which causes a large pulse of light that is captured by the photo multiplier tubes — this is the recoil. Neutrons at even higher energy levels interact with the lead, producing many more low energy neutrons — the multiplicity. The number of low energy neutrons produced is correlated to the energy of the neutron.

The antineutrino detector developed by Sandia and LLNL in 2008 found new life in MARS. "We were able to reuse the plastic scintillators with layers of neutron capture gadolinium from two detectors that were deployed at the San Onofre nuclear power plant," says Peter. "We added more photo multiplier tubes to increase light collection."

MARS was then placed in a trailer so it can be moved to three different locations within the mine to collect data at different depths. It is currently sitting at 600 feet; in a few months it will be moved to 350 feet and will finish the year of testing at 150 feet. This project is the first-ever continuous measurement as a function of depth.

Peter expects many in the scientific community to pay close attention to the WATCHMAN project as it develops. He describes the project as a good testbed for basic scientific research with the potential to make measurements of great interest to the scientific community.

"The idea of creating a detector based on gadolinium-doped water has been kicked around for some time, but no one has pursued it. We don't have a choice — for long-range detection we need a large detector and gadolinium-doped water is possibly the only feasible option for a detector of that size," says Peter.

"In addition, there is no antineutrino detector in North America today. It's good to have several well-separated independent detectors with different systematic uncertainties observing the same phenomena as a cross check. WATCHMAN could be America's contribution to neutrino astrophysics."

Detecting Supernovas

There is another benefit to WATCHMAN — when complete, it will be among the best supernova detectors in the world. A core collapse supernova produces an enormous burst of neutrinos. Knowledge gathered by measuring the type, time, and energy structure of those neutrinos can help answer many physics and astrophysics questions.

With gadolinium-doped water, WATCHMAN will be able to distinguish between neutrinos and antineutrinos. The number of neutrinos and antineutrinos as a function of time will be useful data for supernova physics models.

WATCHMAN will be smaller than Super-K, but that size could prove an advantage with a nearby supernova. The signal of Supernova 1987A, which occurred 168,000 light-years from Earth and was observable by the naked eye, overwhelmed Super-K.

LVOC academic alliances soar with UC Davis, others

By Mike Janes

It's only natural that Sandia would seek strong academic alliances. The cultivation of ongoing partnerships with key universities and colleges, the Labs has demonstrated time and time again, can lead to funding opportunities, innovation, and entrepreneurship. They can also provide a pipeline to recruitment of future generations of engineers and researchers.

There is no exception to this rule at Sandia/California, but the site's Livermore Valley Open Campus (LVOC) initiative has energized the potential for enhanced academic alliances even more than before. In fact, says Andy McIlroy (8310), academic alliances are vital to the future success of the open campus.

"The LVOC exists to enhance Sandia's national security mission impact by strengthening Sandia's science and technology base through world-class collaborations," says Andy, who serves as the site's senior manager for LVOC development. "Combined with key industrial partnerships, the LVOC academic alliance provides Sandia with a platform for building collaborative programs that build our core competencies and create lasting partnerships whose value extends beyond a single project."

AS PART OF THE ACADEMIC ALLIANCE with UC Davis, Sandia sponsored the 2013 UC Davis C-STEM Scholarship for northern California college-bound seniors pursuing computing-related post-secondary study in a university. Shown here are Harry H. Cheng, Director of the C-STEM Center at UC Davis; scholarship recipient Kevin Chen, a graduate of Amador Valley High School in Pleasanton; and Mike Hardwick.

'Strategic roadmap' with UC Davis strengthened by LVOC presence

Last winter, the first significant LVOC-based industry partnership — a 5-year Cooperative Research & Development Agreement (CRADA) with local solar startup Cool Earth Solar — was announced. Now, as the shining example for LVOC academic partnerships and perhaps a model for how others might work, Sandia/California is in the midst of a 5-year "strategic partnership roadmap" with the University of California, Davis (UC Davis), a collaboration that Mike Hardwick (8240) and Chris Moen (8256) say will only be stronger because of the new and growing presence of the LVOC.

"When UC Davis executives arrived here [for a kickoff meeting], their reaction was pretty amazing," Mike says. "Before, there were always barriers and they had to go through multiple layers of security to get here. This time, they immediately recognized the open campus as a lowering of the barriers, and they were clearly energized."

Chris co-leads the science and engineering education thrust area of the UC Davis roadmap. The other thrust areas, each co-led by a Sandian who shares leadership duties in his or her area with a UC Davis counterpart, include sustainable energy systems (Dawn Manley, 8350), cybersecurity (Karim Mahrous, 8958), and systems engineering and manufacturing (Mike). Mike also serves as the partnership's steering committee chair along with Enrique Lavernia, a longtime champion of Sandia who now serves as the dean at UC Davis's College of Engineering.

"The program gave them a rare and valuable opportunity to spend time with real engineering professionals and immerse themselves in an actual development environment."

— Sandia researcher Mike Hardwick

Sandia's relationship with UC Davis predated the LVOC initiative, but Chris and Mike say the open campus was a clear motivation for both formalizing and broadening the partnership. Former Div. 8000 VP Rick Stulen and UC Davis chancellor Linda Katehi, Mike explains, tasked managers with both organizations to draft a roadmap that would focus existing technical and programmatic synergies, and the end result was a memorandum of understanding and the strategic roadmap.

Education thrust area off and running

"Our connection with UC Davis always seemed like a natural in terms of doing something big together instead of mere project-by-project collaborations," says Mike. "Rick and Linda's leadership was a driving force, and Enrique's move from UC Irvine to UC Davis really made a big difference since we'd had a good relationship with him for years. The launch of the LVOC was the final piece of the puzzle and sealed things for us."

The strategic roadmap's science and engineering education thrust area has been active from the very beginning, says Chris.

Sandia has started sponsoring an annual Engineering Design Award competition at UC Davis, which recognizes innovation in engineering design related to a national security mission such as defense, natural resources, or the economy. At the university's 2013 Engineering Design Showcase in May, a team of students was recognized by Sandia for its project, "Real-time amperometric glucose biosensor for facilitation of biofuel research."

In addition, Chris says, the lab now provides Sandia mentors for capstone design projects that most UC Davis engineering seniors are required to complete. Finally, the lab is helping to expand UC Davis's C-STEM initiative (Center for Integrated Computing and STEM Education) into the San Francisco Bay Area by introducing it to the Livermore Valley Joint Unified School District and the Oakland School District. One of the leading C-STEM outreach activities, an annual "RoboPlay" competition designed for K-12 students, will take place at Sandia's open campus in 2014.

The sustainable energy systems thrust area, Mike says, has largely been focused on proposal writing and generating opportunities to work with state leaders in Sacramento. The cyber thrust area plans to host a workshop at UC Davis on cybersecurity policy and research.

Finally, the systems engineering and manufacturing team is preparing to play a key regional role in the National Network for Manufacturing Innovation (NNMI), a federally sponsored initiative that serves to create an effective manufacturing research infrastructure for US industry and academia to solve industry-relevant problems. At the LVOC earlier this month, Sandia and UC Davis piloted the Design to Manufacturing Academy (DMA) for high school students, where participants were exposed to authentic manufacturing issues and took on a project of their own.

"They were able to work with Sandians to identify requirements for an actual design problem, design a solution, conduct a structural analysis, fabricate prototypes and test them in a laboratory," says Mike. "The program gave them a rare and valuable opportunity to spend time with real engineering professionals and immerse themselves in an actual development environment."

Others poised to join LVOC academic alliance

While the collaboration and strategic roadmap with UC Davis has perhaps been the most visible success story in regards to LVOC academic alliances, others are also emerging.

The University of Illinois Urbana-Champaign and Sandia have signed an MOU that specifically embraces the LVOC. Senior leaders from Sandia, Lawrence Livermore National Laboratory (co-partners with Sandia on the LVOC), and the university have visited each other's campuses and are examining how the partnership can most effectively move forward. A kickoff celebration to announce the new MOU is planned at the LVOC next year, with key leaders and alumni from the university expected to attend.

MATT TURKIE (second from left), principal of the School of Engineering and Sciences in Sacramento, received the C-STEM School of the Year award, sponsored this year by Sandia, for excellence in integrated learning of computing and STEM subjects. From L-R, Dr. Ralph Hexter, UC Davis Provost and Executive Vice Chancellor; Turkie; Dr. Enrique Lavernia, Dean of the UC Davis College of Engineering; and Mike Hardwick. (Photos courtesy of UC Davis)

Other schools, particularly those in the Bay Area, are likely to partner with Sandia on the LVOC in the future, according to Kelly Nykodym (8522), who is leading the overall LVOC academic alliances effort. Ongoing conversations with Las Positas College continue to take place, as do discussions with San Jose State, particularly around opportunities in the cybersecurity research domain.

Kelly, whose "day job" involves talent acquisition for the California site's HR group, says the LVOC has created a vibrant, creative, interactive learning environment that provides a new realm for recruitment.

She points to recent examples such as an LVOC-hosted event involving some 35 young women from Stanford, UC Berkeley, and UC Davis that featured lab tours, technical discussions, and lunch with hiring managers and Sandia mentors. Additionally, the LVOC hosted an event that welcomed professors from traditionally black colleges and universities, and a science and engineering networking event in mid-July specifically for UC Berkeley students.

"There are often misperceptions among university students, even those right here in our backyard, about what it means to be a DOE national security lab, or what Sandia does," says Kelly. "Perhaps they think, 'a weapons lab is not for me,' or maybe they've just never been exposed to the variety of work we do that could appeal to them. Now, with these LVOC events and a new sense of openness, they can come and learn first-hand what we're about, make a personal connection, walk around freely, and learn about career paths that they might not have considered before. From recruitment's point of view, this is very exciting."

How 'real' is the LVOC?

Since its opening in September 2010, the Livermore Valley Open Campus has moved far past the conceptual stage and is now a vibrant, active presence on the Sandia/California campus. Here are some facts and figures:

- The LVOC comprises 84 acres on the Sandia/California site and additional space at Lawrence Livermore National Laboratory.
- The open campus includes more than 100,000 square feet of office, lab, and auditorium space.
- The internationally renowned Combustion Research Facility (CRF) is the heart of the LVOC at Sandia/California, while the High Performance Computing Innovation Center is central to the LLNL LVOC component.
- The Cybersecurity Technologies Research Laboratory (CTRL) opened on the LVOC in June 2012 and regularly hosts large meetings and visits, as well as serving as a hub of cyber-related research activity at the site.
- A 5-acre Clean Energy Demonstration Field sits across the CTRL, the centerpiece of which is now a pilot project with local startup Cool Earth Solar.
- The LVOC regularly hosts a farmer's market for Sandia/California and LLNL and other "open" activities such as the annual Math and Science Awards for local high school girls.
- As an initial step in making the LVOC the "front-facing" part of Sandia/California, visitors to the site, including job candidates, will soon be directed to a renovated Post 17 (near the CRF) for check-in and processing rather than to Bldg. 911.
- Plans for a large administrative building and additional LVOC programmatic elements are underway.

Construction unearths Cold War relics

By Patti Koning

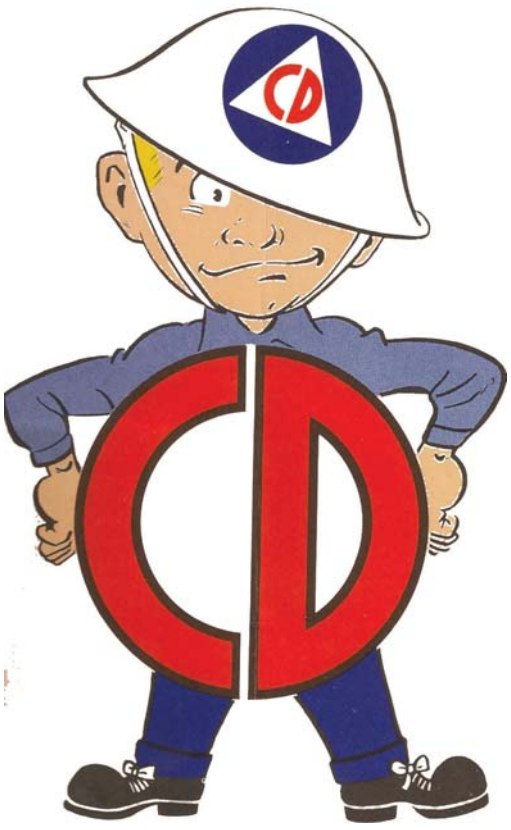
TRACY WALKER with some of the old Civil Defense fallout shelter supplies he discovered in the basement of Bldg. 912. Photo by Dino Vournas

Early in his career at Sandia, Tracy Walker (8949) heard rumors that the basement of his building, 912, had once housed a fallout shelter. More than 20 years later those rumors were confirmed true when renovations on the building's foundation led to the discovery of emergency fallout shelter supplies lining the dugout earthen walkways below the building.

"We opened one of the boxes and found Civil Defense all-purpose survival crackers from 1962," says Tracy. "We brought out some of the supplies, cleaned them up, and showcased them at Family Day that year."

He did some research and learned that the newly discovered cache of fallout shelter materials was quite unusual. Tracy described the discovery and the history of Civil Defense shelter supplies in the March 2013 issue of the *Watercooler* [http://cfo.sandia.gov/watercooler/MarchArticles/stratMar13.html]. He writes:

"Civil Defense shelter supplies, consisting of food, medical and sanitation kits, and water containers, were produced by the federal government in the 1960s as fallout survival gear. A lot of national thought and preparation went into the contents and accompanying instructions for these supplies, and Sandia procured its share.



"Some of the supplies are definitely outdated. Being packaged in May of 1962, the flour crackers just celebrated their 50th year in storage. A Civil Defense memo dated September 1976 confirms that due to rancidity, they should 'no longer be considered for human consumption.' Yet here they are still, packaged up nicely for the impending emergency 35 years after rancidity set in.

"All that is left of the wheat crackers is a single, empty metal container. Presumably, they were tastier to the denizens of the night. We've determined the medical kits are now gone, possibly due to the phenobarbital tablets determined to be a controlled substance in 1970. And the hard tack candy, which came in three flavors — red, green, and yellow — are gone, possibly because they were made with red dye #5. However, the still present sanitation kits are stuffed with interesting items, including all items necessary to turn the multitude of available water barrels into commodes.

"Some of the suppliers are listed on the containers. Of note, one of the companies that made the crackers is Sunshine Biscuits, and they are still making Krispy Saltines and Cheez-Its today. Sunshine became a subsidiary of Keebler in 1996, and Keebler was bought by Kellogg's in 2001.

"Thankfully, these materials were never needed, and they certainly have no continuing value. But they identify a time period when the nation as a whole was blanketed with a real fear of impending attack. Every community had an evacuation plan and a Civil Defense coordinator. Every school practiced 'duck and cover' nuclear attack drills learned from Bert the Turtle. The precursor to our Emergency Broadcast System (EBS) was to turn to CONELRAD radio at 640 or 1240 on the AM dial. Our outlook has changed, as have the needs in our 72-hour ready kits. I know some employees keep their own personal kit in their car or a limited-item version stashed in their offices for emergencies. Given that we spend a bunch of our time on site, I wonder why more don't."

A few individuals commented on Tracy's *Watercooler* article, including Matt Hopkins (1516) whose grandfather, Joseph Romm, was the director of Civil Defense during the 1960s. Laura Sowko (3657) recalled growing up in Los Alamos with a fallout shelter of sorts in the crawl space beneath her house. There was a large metal container with food in it and several glass 1-gallon bottles filled with water. She and her brothers were under strict instructions to leave the supplies alone.

"Sometime in the '80s, we opened the metal food tin to learn what we would have had to subsist on — mostly freeze-dried meals and other things that I can't recall. Since the danger had passed, we found it all amusing and wondered how long it would have sustained all five of us," she wrote. "Perhaps others who had these preparations occasionally had nightmares about an atomic bomb being dropped nearby — I know my mother and I both did. I think the lasting effect of this for me is attending to emergency preparedness and having an updated kit, mostly for power outages."

To get a sense of the times that Laura describes, take a look at *Nuclear War Survival Skills*, published by Oak Ridge National Laboratory in 1979. An updated and expanded version was published in 1987 by the Oregon Institute of Science and Medicine. There have been several updates to the book, the most recent in 2012.

In the foreword of the 1987 edition, Edward Teller describes civil defense as "the most peaceful and the most effective deterrent of nuclear war" because "if [the Russians] cannot count on destroying us they will probably never launch their nuclear arsenal against us."

Many of the supplies discovered below Bldg. 912 are listed in chapter 16, Minimum Pre-Crisis Preparations. The book also covers how to build six different types of expedient fallout shelters, surviving without doctors, improvised clothing, and basic needs like food and water. The 1987 edition available online for free at: http://www.oism.org/nwss/s73p904.htm.

Rep. Kaptur visits Sandia/California

ON AUGUST 6, US Rep. Marcy Kaptur (D-Ohio), the ranking member on the House Energy and Water Development subcommittee, visited Sandia/California. Sandia President and Labs Director Paul Hommert and Div. 8000 VP Steve Rottler welcomed her to the site and shared Sandia's heritage, capabilities, and evolving mission. Staff members Chung-Yan Koh (8621), shown here, Thomas Kroeger (8965), and postdoc Melinda Sweaney (8132) presented projects that support Sandia's national security mission. Kaptur ended her visit with a tour of the Combustion Research Facility led by Center 8300 Director Bob Carling. (Photo by Dino Vournas)

Giving back

Sandia/California Community Outreach Initiatives

Giving back is part of our culture at Sandia. We are passionate about serving the country, but at the same time we also feel strongly about supporting our local communities and ensuring that we are giving back. Whether we're encouraging children in their exploration of science, serving on boards of directors, volunteering to improve our community, or giving our time to support organizations and causes that move us. We are passionate about service.

At the California site, we serve our communities in a number of ways. We collect turkeys and fixings for Thanksgiving baskets for needy families, donate everyday items to support our troops overseas, volunteer our time at the DOE Science Bowl and Lego robotics tournaments, walk all night in the Relay for Life to fight cancer, help preserve the heritage of our community, and support causes close to our hearts through SHARE. We engage with the civic community, help young people explore career paths, and recognize outstanding high school and college students. The causes we support and the ways we choose to give vary greatly, reflecting the diversity of our workforce, but the goal is always the same — to strengthen the communities in which we live and work. *— Patti Koning*

MAYNARD HOLLIDAY (8118) emcees a First Tech Challenge competition hosted by Robot Garden, a robotics-themed hackerspace, at iGATE, a regional public-private partnership focused on green transportation and clean energy. Maynard is a volunteer Citizen Teacher, teaching robotics at Elmhurst Community Prep in Oakland, a recipient of the President's Volunteer Service Award and, along with Daniel Casner (8136), a founding member of Robot Garden. (Photo by Dino Vournas)

TURKEY BRIGADE — Volunteers sort turkeys for the Tri-Valley Basket Brigade, organized by Sandia/California ombuds Reese Ramos (30) and his wife Katherine Havener. On a single day last November, volunteers assembled 138 Thanksgiving baskets and 80 care packages from donated items and delivered them to needy families and the homeless. (Photo by Rich Washburn)

SHARE — Margaret Quinn (3555) talks with a representative from Children's Hospital & Research Center Oakland, one of more than 200 organizations that Sandians support through SHARE. (Photo by Randy Wong)

RELAY FOR LIFE — Cancer survivor Christy Turner (8237) proudly represents Sandia in the team captain lap at the 2013 Livermore Relay for Life. (Photo by Dino Vournas)

RESTORED SEAGRAVE — Will Bolton (8123) and Irv Stowers (retired LLNL) take a fully restored 1920 Seagrave fire engine out for a spin in the Livermore Rodeo Parade. Riding in the back are members of the Livermore City Council. Will, Irv, and other members of the "Seagrave Hard Corps" spent the last 3.5 years restoring this piece of history for the Livermore Heritage Guild. (Photo by Fred Deadrick)

INNOVATION FORUM — Division 8000 VP Steve Rottler participates on the Innovation Panel at the Livermore Valley Chamber of Commerce's Summer Luncheon Innovation Forum. (Photo by Dino Vournas)

BLUE STAR MOMS — Tim Shepodd (8220), Mary Fadhel Burton of Blue Star Moms, and her husband Carl look over the donations for Blue Star Moms collected at the Center 8200 holiday party. (Photo by Dino Vournas)

REGIONAL SCIENCE BOWL — Helena Jin (8256) keeps score in the final round of the Sandia/Los Positas regional DOE Science Bowl for middle school. Sandia/California also runs a regional DOE Science Bowl for high school with Las Positas College and supports three additional Bay Area regional science bowls. (Photo by Dino Vournas)

FAMILY SCIENCE NIGHT — A parent and child work together to build a "hoopster" (wingless airplane) from straws, scotch tape, and index cards at Family Science Night. (Photo by Randy Wong)

MANUFACTURING ACADEMY — At the first-ever Design-to-Manufacturing Academy, Bryant Morgan (82472) helps high school students design a part on the computer. In the three-day academy, area high school students explored career opportunities in manufacturing. (Photo by Dino Vournas)