

Four Fellows

Sandia Fellows share insights, research thrusts in tech talks to mark National Engineers Week

By Neal Singer and Sue Major Holmes

The qualities Sandia Fellows are expected to demonstrate are not for the faint-hearted, as acting Div. 7000 VP and Chief

Technology Officer Julia Phillips made clear when she opened a celebration of Sandia's four extraordinary research-leaders honored as Fellows during a National Engineers Week forum, "Advancing the Frontiers of Science and Engineering."

And yet it seemed that as each Fellow — Ed Cole, John Rowe, Jerry Simmons, and Jeff Brinker —

described his research, each relished the challenge.

Among the formidable requirements listed by Julia were that Fellows should "measurably shape the face of Sandia through research, influence, and model behavior, showing leadership at all levels, and strategies in key technical areas." Fellows are expected "to speak truth to power — speaking their minds respectfully of course, but firmly and with conviction" to Sandia management. They should bring in other researchers, mentor the next generation of Sandians, enhance Sandia's visibility and prestige on a high level, and have significant impact on national policy and national dialogue on matters important to Sandia.

Sandia has named only nine Fellows in its history. Five are retired: Jim Gosler, Gordon Osbourn, Gus Simmons, Wendell Weart, and Walt Herrmann.

To read about each Fellow's talk see the stories and photos on pages 5-8.

NASA Jet Propulsion Laboratory Director Charles Elachi, visiting Sandia as part of the Labs' National Engineers Week celebration, talks about the engineering challenges and triumphs of the Mars *Curiosity* mission. See the story on page 11.



SANDIA FELLOWS, from left, Ed Cole, Jeff Brinker, Jerry Simmons, and John Rowe answer questions during a Q&A session following their individual talks about their research interests. For more about their talks see pages 5-8. (Photo by Randy Montoya)

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Goal busters

United Way donations top \$6 million and raise the bar



DEPUTY LABS DIRECTOR and Executive VP for National Security Programs Jerry McDowell visits the greenhouse at Cornucopia Adult Day Services in Albuquerque's South Valley, a program supported in part by the United Way of Central New Mexico. Sandia has been the single largest supporter of the organization's annual campaign, contributing more than \$82 million since the Labs' Employee Caring Program was launched in 1957.

By Nancy Salem

Sandia employees and retirees in 2013 increased donations to the United Way of Central New Mexico (UWCNM) by 8.2 percent over the previous year, giving \$6,050,426 to the charitable organization. The total eclipsed the goal of \$5.75 million and set a record.

"This level of generosity is astounding," says

Kelly Westlake, manager of Business Operations Support Dept. 10623 and 2013 Employee Caring Program (ECP) campaign chair. "Sandians faced the prospect of a lab shutdown due to the federal budget crisis early in the campaign and still came through, setting new records. Everyone at Sandia should be extremely proud."

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Protecting Sandia's personally identifiable information

An interview with Sandia Chief Privacy Officer Rusty Elliott

You saw the news; you may have been affected by it: Computer criminals, using software likely written by a lone wolf 17-year-old Russian whiz kid, hacked into the Target Stores' computer systems and hijacked credit card information and other personal data, including emails and passwords, from millions of the company's customers. The attack happened at the peak of the holiday shopping season and cost Target untold millions in lost sales. And credit card-issuing banks and credit unions have spent upwards of \$200 million replacing the compromised cards and otherwise shoring up their own security systems. All traced back to one malicious individual.



CHIEF PRIVACY OFFICER RUSTY ELLIOTT

That Target incident was the exclamation point at the end of a year in which privacy concerns, sparked in no small part by the revelations about NSA's electronic monitoring practices, seemed to generate new headlines every week. Americans are engaged in robust public debate about the issue: What are my reasonable expectations as a US citizen regarding my own privacy?

That debate will go on as the nation seeks to reconcile long-held ideas about privacy with the reality of a wired, interconnected world in which citizens voluntarily offer up detailed personal information on social media sites, in online gaming venues, and online sales transactions.

Privacy rights are not a new concern, but new technologies add a sense of urgency to the matter.

While the nation works its way through the complex terrain of privacy in the 21st century, Sandia is already proactive in protecting the privacy of its

(Continued on page 4)



Willis Whitfield

The inventor of the modern cleanroom, Willis Whitfield, will be honored posthumously by the National Inventors Hall of Fame for his development of the cleanroom, which has been a key enabling technology for the modern computer era. Read about it on page 12.

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That's that

Willis Whitfield, the most unassuming man you'd ever want to meet, was a titan who laid the groundwork for the modern computer era. On page 12 we have a story about Willis, inventor of the laminar airflow cleanroom, being inducted posthumously into the National Inventors Hall of Fame. His invention is credited with being one of the enabling technologies that made possible the modern computer, among many, many other things that define the 21st century. Willis' recognition got me thinking about another inventor, Raymond Kurzweil, who's been in the news again recently.

The danger with writing a column like this is that you risk exposing yourself as not knowing what you're talking about. Having said that, here goes:

There's no question Ray Kurzweil is a brilliant man. A controversial and provocative one, but brilliant, certainly. Kurzweil, whom I've written about before in this space, is, like Willis, an inductee of the Inventors Hall of Fame, recognized for, among many other things, his contributions to the development of the flatbed scanner, optical character recognition, speech-to-text systems, and music synthesizers. It's not for his long-as-your-arm list of inventions that Kurzweil is controversial, though. He's also a futurist and a thought-leader in the so-called transhumanist movement, which holds – I simplify here – that the exponential growth of computing capabilities will inevitably transform human nature itself and perhaps the very meaning of being human. He says “the pace of change will be so astonishingly quick that we won't be able to keep up, unless we enhance our own intelligence by merging with the intelligent machines we are creating . . . over the next few decades our human-machine civilization will become increasingly dominated by its non-biological component.”

Kurzweil, who now works for Google, predicts that within 15 years, computers will overtake humans by every meaningful measure of intelligence. By that point, he says, computers will easily pass the “Turing Test,” named after computing pioneer Alan Turing, in which a human being, no matter how clever, will not be able to tell whether he's talking to a fellow human or a computer.

Google's motive in luring the famously autonomous Kurzweil onboard is a practical one: The search giant has been hiring the best AI and neural networking talent in the world, promising them almost limitless resources, to advance its quest to create the perfect search engine. The ideal is that you could ask Google virtually anything – in your native tongue – and it would provide exactly the answer you need.

I can see this happening. I can see cognitive functions being replicated and then superseded by computers. But here's what I wonder: Can our humanness be defined in purely cognitive terms? If we were able to pour the entire contents of our brains into a computer, would that be a path to immortality? Kurzweil says the answer is an emphatic and enthusiastic yes! And he's a genius.

But I don't think so. It seems to me (for example) that when he composed the Brandenburg concertos there was something going on in Johann Sebastian Bach's psyche that was greater than the sum of its cognitive parts. Something more than “mere” thinking.

The Kurzweil quote above – perhaps ironically – steers me toward something I'm groping to understand. He says the “non-biological” component will increasingly dominate our human-machine civilization. But the point is, we are biological creatures, not “just” thinking machines. We think the way we do precisely because we are composed of carbon compounds and not silicon ones.

Maybe this example will help explain what I'm driving at: A German robotics company will soon conduct a contest between one of its robots and a world-class table tennis player. I have no idea “who” is going to win, and that hardly matters, because at some point soon a robot will beat a human. Easily. No contest. But when that happens, will the robot do a victory dance, a spontaneous eruption, starting not in the brain but somewhere deep in the body core, of sheer joy, triumph, and elation, mixed with a little dose of unseemly satisfaction at having humiliated your opponent? Want to see what I'm talking about? On your own time, search “ping pong victory dance,” watch the first hit that pops up on YouTube, and then tell me: Will a robot do *that*?

I long ago embraced the digital age. I'm in awe of what computers have done and will do for the benefit of humanity. I'm excited to see where all this is going, which I think will be mostly for the good. But I like my biological component, which I took skiing several times this winter and plan to take sailing this summer. It's really my favorite part of me.

See you next time.

– Bill Murphy (505-845-0845, MS1468, wtmurph@sandia.gov)

Retired?

Consider joining the Coronado Thunderbirds



Are you a Sandia or DOE/NNSA retiree? If so, have you considered joining the Thunderbirds?

The club is for persons 50 years or older who have retired from Sandia, DOE/NNSA, other federal agencies, or the military. Spouses and surviving spouses can also join. This is a social club offering monthly programs plus activities such as bridge and travel.

Meetings are held at the Mountain View Club (formerly the Officer's Club East) at Kirtland Air Force Base on the second Tuesday of each month. Meetings begin at noon with 30 minutes of club business followed by a one-hour program. Programs vary from entertainment to informative presentations. Many members come at 11 a.m. for a lunch of soups, salads, and sandwiches. It's a good time to get to know each other.

Since all Coronado Thunderbird meetings and activities are held at the Mountain View Club (MVC), Coronado Thunderbird members are required to be members of the MVC. Membership in the club allows Thunderbird members to be active in the monthly MVC events.

Coronado Thunderbird members also must have a DBIDS identification or military ID to have access to KAFB. DBIDS applications are handled through Coronado Thunderbird membership chairman Vicky Clark. For information on joining the Thunderbirds, MVC membership, and DBIDS passes, call Vicky at 881-3625.

For further information on the Coronado Thunderbirds, visit the website at <http://tinyurl.com/mfboasu>.



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Students from San Ramon and Fremont headed for DOE National Science Bowl

By Patti Koning • Photos by Ray Ng

Students from Dougherty Valley High School in San Ramon, Calif., and Hopkins Junior High School in Fremont, Calif., will represent California at DOE's National Science Bowl in Washington, D.C.

The Dougherty Valley High School team (photo at immediate right) of Augustine Chemparathy, Rishi Krishnan, Bibhav Poudel, Saranesh Prembabu, and Wesley Wang, coached by Cathy Huang and Rym Hannachi, won the Sandia National Laboratories Regional High School Science Bowl at Las Positas College on Saturday, Jan. 25. Fremont's Mission San Jose High School, last year's winner, finished in second place, and Pleasanton's Amador Valley High School took the third spot.

The Hopkins Junior High School team (photo below) of Sulaiman Ahmed, David Hou, Yvette Lin (captain), Allen Mao, and Ashish Ramesh, coached by Anja Crickmore won the Sandia National Laboratories Regional Middle School Science Bowl at Las Positas College on Saturday, Feb. 22. Fremont's Thornton Middle School finished second, and Walnut Creek's Dorris-Eaton School took third place. Hopkins and Thornton battled it out through two final matches, with Hopkins securing its win by answering the bonus portion of the very last question correctly.

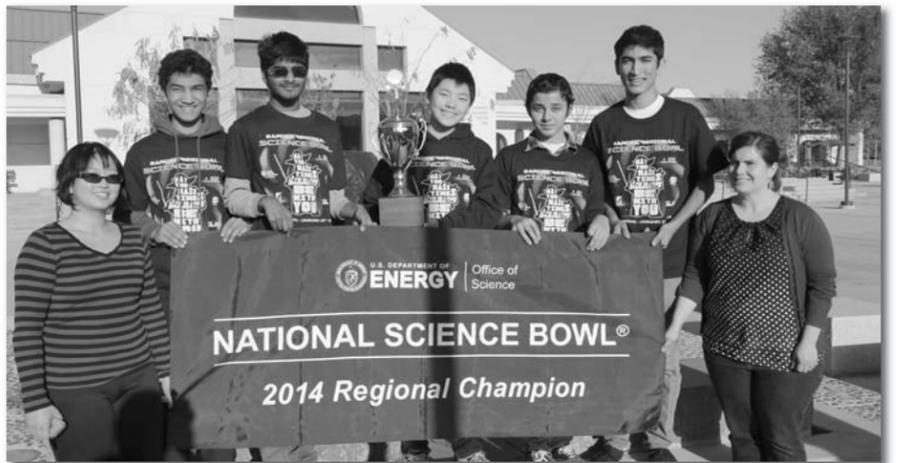
Rep. Eric Swalwell (D-15th) (photo above) gave the welcome address at the middle school Science Bowl and drew team names for the round robin portion of the tournament.

"What you are doing here today is so critically important," he said. "Not only for your own academic development, but also to prepare yourself for the future economy of the United States — the knowledge economy."

The Dougherty Valley High School and Hopkins Junior High School teams each will receive an all-expenses-paid trip to Washington, D.C., to compete against top teams from across the nation at the DOE National Science Bowl in late April. While this is the Dougherty Valley's first trip to the DOE National Science Bowl, several team members already have experience on the national stage. Chemparathy, Krishnan, and Prembabu were part of the Gale Ranch Middle School team that won the DOE National Science Bowl for Middle School Students in 2011. Hopkins has won the DOE National Science Bowl two times — in 2009 and 2012. In 2013, the school finished in third place.

Sandia/California began coordinating the Regional High School Science Bowl in 1992 and the Regional Middle School Science Bowl in 2004. Sandia/California's regional Science Bowls are organized and administered by the Science Bowl committee of Martha Campiotti (8310), Stephan King-Monroe (8237), Mark Musculus (8362), Ray Ng (retired Sandian), Danielle Oteri (8223), Patti Koning (8521), and Tim Shepodd (8220).

Sandia California News



Protecting PII

(Continued from page 1)

employees. More than two years ago, the Labs created the position of chief privacy officer, assigning the role to attorney Rusty Elliott. In the following interview, Rusty brings us up to date on some of the issues he is dealing with and how the Labs is ensuring that employees' personally identifiable information is handled appropriately and protected from misuse.

Lab News: So, "privacy" was named the Word of the Year for 2013?

Rusty Elliott: Yes! Dictionary.com designated the word "Privacy" for 2013 based on a number of high-profile privacy-related events that occurred in 2013. Those included revelations about the federal government's collection and use of telephone-related data, new types of wearable technology capable of taking photographs and video surreptitiously, and numerous media reports about large numbers of individuals affected by data leaks involving financial data and other personal information.

LN: Have Sandians been affected by any of this?

RE: Yes, unfortunately. We know that certain Sandia employees and contractor personnel were among those affected by a cyber incident that took place last summer where the Department of Energy was a target. Impacted individuals were notified after the event took place. Sandia, although not directly a target of the incident, assisted DOE with notifications.

LN: How can people protect themselves?

RE: Well, following a PII data breach, it makes sense for affected individuals to closely monitor their credit card statements or other financial activity for a period of time. Often, the targeted institution will offer to pay for credit monitoring. If not, it may make sense for a person to look into buying their own credit monitoring

service after a breach and release of their information. Before a breach occurs, it is wise for individuals to become familiar with the privacy policies of companies with whom they choose to do business.

LN: You mentioned "PII" — what does that stand for?

RE: Personally identifiable information. Although the term is often used generically for information of a personal nature, at Sandia we have a specific corporate definition of PII that is set forth in Corporate Procedure IM100.2.6: Control Personally Identifiable information. You can see the procedure at <http://tiny.sandia.gov/vjkiu> on Sandia's internal website.

The Sandia definition and procedure are designed to enable Sandia members of the workforce to recognize and properly protect sensitive personal information they may encounter in the course of conducting Sandia business.

The Sandia corporate procedure also explains PII-related requirements applicable not only to individuals, but to IT providers and business process owners, as well. I also ought to note that Sandia's PII requirements apply to information collected and used for official Sandia business. The requirements do not apply, for example, to personal information about yourself that you may choose to have on hand for your own personal convenience.

Personal convenience

LN: What do you mean by "personal convenience."

RE: An example would be where a Sandia member of the workforce, while complying with Sandia's policy on incidental personal use of IT resources, might individually choose to have a copy of his or her resume available for reference on his or her office computer. In a case like that, Sandia hasn't collected or used the information for a Sandia business purpose, and Sandia's corporate requirements would not apply to the information kept solely for personal convenience.

Another example can involve electronic W-2 forms. Upon request and as a convenience for employees, Sandia will provide an electronic version of their W-2 form for

use in filing personal income tax returns. If an employee chose to download one of those forms as a personal convenience, no Sandia business purpose would be involved. In that instance, the action taken by an employee with respect to his or her own W-2 form would not be governed by the Sandia corporate procedure on protection of PII. The individual would bear responsibility for his or her own information.

LN: What is the most important thing people need to remember about PII at Sandia?

RE: I believe the most important thing is for our people to be aware that sensitive personal information exists at Sandia and it needs to be protected. People need to be willing to ask questions or call attention to a situation if they encounter something involving PII that just doesn't seem right.

As a guide in making these assessments, a good place to start is with the four principles stated at the top of IM 100.2.6. Those principles are:

- **Principle 1:** Know what PII is being held on Sandia's Information Technology Resources and where it is located.
- **Principle 2:** Limit the collection, use, and retention of PII to the minimum necessary to conduct official Sandia business.
- **Principle 3:** Protect PII through appropriate security safeguards against risks such as loss, unauthorized access or use, destruction, modification, or unintended or inappropriate disclosure.
- **Principle 4:** Report any unintended or inappropriate disclosure, misuse, or failure to protect PII immediately.

LN: When you say "ask questions or call attention to a situation" whom should people contact?

RE: Anyone who discovers theft, diversion, unauthorized disclosure, or potential loss of PII, whether actually confirmed or just suspected, should call Sandia's Security Incident Management Program (SIMP) at 505-283-SIMP. A regularly updated webpage about SIMP is found on Sandia's internal website at <http://tiny.sandia.gov/bg4jv>.

LN: Apart from loss of PII, are there any other considerations people should be aware of?

RE: I strongly encourage our colleagues at Sandia to incorporate a PII perspective into the work they perform here. This means using and maintaining critical thinking about PII and privacy considerations as projects are designed at Sandia, processes are developed, and activities are carried out. It means thinking about privacy early and where possible using our engineering and business savvy to build in PII protections from the start.

I am available and very happy to assist in those design deliberations so that we can do our best to control PII impacts both for individuals and for the Laboratories.

LN: Is there any place else people can obtain information about PII (for example, for personnel who may not have convenient access to a computer)?

RE: Yes. Sandia has included a PII training module in COM100, which is required annual training for all Sandia members of the workforce. And I always welcome calls to me (505-844-5626) if people have questions or concerns about protection of personal information. Another excellent resource is Eric Thulin, Sandia's Information Management & Cyber Security policy lead, at 505-845-9374.

How does Sandia define PII?

As spelled out in Sandia's Corporate Procedure: IM100.2.6 Control Personally Identifiable Information, PII is defined as:

Any of the information listed below that can be used to distinguish or trace an individual's identity, is collected and maintained for the purpose of conducting official Sandia business, and is not solely comprised of information that is available to the general public:

- Social Security number
- Driver's license number
- Passport number
- Other federal- or state-issued identification card number
- Bank account number (with or without routing number, access code, or Personal Identification Number [PIN])
- Financial or benefit account number in combination with any required code permitting access
- Background information or verification reports or credit report, including consumer reports

- Medical or health information, including biometric, biomonitoring, or genetic information
- Employment history, including ratings, salary, wage, deduction information, and disciplinary actions
- Security clearance history or related information
- Criminal history
- Date of birth or age
- Place of birth
- Mother's maiden name
- Race or ethnicity

Notes:

1. One means of distinguishing or tracing an individual's identity is to include the first name or the first initial and last name of an individual in combination with any information listed above.
2. PII does not include information that is on Sandia computing resources as a result of incidental personal use of computing and information resources or other assets.

Sandia soars beyond \$6 million level in ECP campaign

(Continued from page 1)

Sandia's employees in Livermore, Calif., added \$189,154, making the total employee/retiree giving between both sites \$6,239,580. The retiree share was \$809,128.

Of the total giving, \$1,575,949 was designated to the Community Fund, up \$66,347 from the previous year. The fund supports a range of nonprofit agencies and programs that help people in Bernalillo, Sandoval, Torrance, and Valencia counties.

Total Labs participation was 75 percent, up 1.4 percent from the previous year, and 75 percent of divisions increased participation. New employee participation rose 4.6 to 63.2 percent, and 121 organizations reached 100 percent participation.

And in a major milestone, Division 5000 became the first to pledge more than \$1 million. "In central New Mexico, only the University of New Mexico/UNM Hospitals, Presbyterian Healthcare Services, and Intel give more than \$1 million. At Sandia, one division gave that much," says Pam Catanach (3652), the Community Involvement specialist who coordinates ECP activities.

Deputy Laboratories Director and Executive VP for Mission Support Kim Sawyer, chair-elect of the UWCNM board of directors and a past campaign chairwoman, says the response from Sandia staff and retirees this year demonstrated the strong culture of giving at the Labs. "Sandia has a rich history of supporting those who are most vulnerable," she says. "Every year we strive to

do more to help the community."

Ed Rivera, UWCNM's president and CEO, says Sandia's generosity is an inspiration. Since the ECP was launched in 1957, Sandia has been the single largest supporter of the organization's annual campaign, contributing more than \$82 million. "Sandia National Labs is an exemplary partner in the work of the United Way of Central New Mexico," he says. "In addition to raising millions each year in their Employee Caring Program, many Sandians are engaged as volunteers throughout central New Mexico and in so many areas of United Way's work. This includes services in key leadership roles on our board of directors and in vital volunteer council work that guides our programmatic endeavors to benefit the community."

Randy Woodcock, UWCNM vice president and chief strategic officer, has provided staff support to the Sandia ECP since 1996. "In the 18 years that I have supported the campaign, I am in awe how Sandia employees and retirees continue to surpass their aggressive goals each year," he says. "Last year we celebrated Sandia breaking the \$5 million mark, and now to raise \$6.05 million in a single campaign, especially in such a challenging economic climate, speaks volumes to how much Sandians care about helping their neighbors."

Pam summed up the campaign by saying giving is truly part of the Sandia culture, from new hires to retirees. "Sandians are amazingly generous and recognize the community needs," she says.

"They just want to help."



Sandia Fellow Ed Cole



Finding invisible defects in integrated circuits

Ed Cole demonstrates in one person the two sides of Sandia: open scientific research and “closed” research on pressing national security challenges. His pioneering work and leadership in applying failure analysis techniques to the most challenging national security problems has led to novel methods for finding hidden defects.

Ed’s 12 patents have been cited in more than 500 other patents, resulting in more than 60 licenses and generating approximately \$1.6 million in royalties. Despite security limitations, he is the author of 25-plus journal articles and conference presentations and has won two R&D100 awards. He joined Sandia in 1987, where he has improved and devised new nondestructive techniques to detect and locate nanometer-sized circuit failures.

“Finding defects in integrated circuits can be extremely challenging but critical,” he told the audience, “because integrated circuits are in almost all our systems.” Finding defects is necessary because operators need to know that devices work as expected with tens of millions of transistors and hundreds of millions of interconnections. “Just the way devices are designed and packaged make them incredibly difficult to analyze.”

Imagine, he said, trying to find a defect hidden under seven layers of metal. “You can’t probe through the metal, you can’t ‘see’ through the backside because silicon is opaque to visible light, and if you take it apart, you may lose the defect. We have to find suspect sites by devising methods around the obstacles. We need to identify the root cause and mitigate it somehow, particularly for the high-reliability, low-volume production we have. Performing a field return of a spacecraft on its way to Jupiter just isn’t going to happen.”

Major defects he studies include local silicon malformations, open and shorted interconnections, and marginal, intermittent failures. His methods take advantage of the physical/electrical characteristics of a given defect and how it interacts with various local stimuli. Coupled with novel, high-sensitivity signal improvement discoveries, his failure analysis techniques make defects “stand out from the crowd,” he said.

His methods are applicable not only to Sandia but a wide range of industries and “have allowed analysis times to go from months to minutes.”

He’s dealt with stress extrusion, a host of particulates, and problems arising from multiple design or process limitations. His work has helped determine reliability risks for components that haven’t failed yet, and found “soft” defects of components that limit device performance under normal conditions and determine where manufacturers can push through performance barriers. Among his tools are electron and laser beam probes, the latter for charge generation and heating purposes. He showed techniques that use a physical understanding of the target and its performance to determine failure location. In the course of his discussion, he mentioned warmly numerous colleagues whom he worked with or led. — *Neal Singer*

In a Q&A session following the Fellows talks, Ed suggested some of the most interesting science comes from an experiment that doesn’t work or works in an unexpected way. “It works the way it works — figure out why.”

Sandia Fellow John Rowe



Persistent sensing to understand what's going on

John Rowe, a recognized expert in ground- and space-based sensing, spoke on “Persistent Sensing,” the ability to deploy sensors for monitoring around the clock. The broader definition covers optical sensors, radar, and other sensing techniques, as well as sensors deployed on demand, such as those on UAVs for battlefield monitoring, he told the audience.

But John’s interest is “in how we can deploy sensors more globally, 24/7, covering the entire surface of the Earth, so that we can understand what’s going on” in matters relevant to the national interest. Deploying persistent sensors in space, which allows “unfettered access to areas of interest,” is important for treaty monitoring, he said.

But it raises significant technical challenges. Solving those demands multidisciplinary, science-based engineering involving hundreds of people across nearly every division at Sandia working on one of the Labs’ longest-standing non-weapon programs, John said.

Sandia’s heritage in persistent sensing began 50 years ago with the national security challenge of its time, the space-based Vela system developed by Sandia and Los Alamos national laboratories — collaborating with industry and government — to verify nuclear test ban moratoriums and finally the Limited Test Ban Treaty, John said. Ultimately, 12 Vela satellites were launched in pairs from 1963 to 1970 and they sent telemetry back until 1984.

Vela became one of the first globally deployed persistent systems, its optical sensors

In offering advice to early career researchers John said that along with curiosity, you must bring passion. “If you can focus on things that you really have a passion for, you will find it much easier to persevere in the presence of all the challenges.”

watching for a nuclear detonation’s brief signal from very high orbit. Data from Vela “may not have been glitzy, but it was critical,” he said.

Vela presented huge technical challenges for Sandia: how to develop a hands-off sensor system for space, miniaturize rooms full of equipment to a few hundred pounds, and have it all survive harsh environments, John said.

John transferred to the space sensing center four years after joining Sandia in 1978. He never worked on Vela, but worked with a team including some of its original scientists and engineers in developing nuclear detonation sensors on the Global Positioning System (GPS) constellation of satellites, still a key part of the US Nuclear Detonation Detection System (USNDS).

Sensor performance scales with proximity, so moving to GPS in medium earth orbit improved capabilities but presented new challenges — larger number of sensors/satellites, greater apparent motion of the earth below, more complex communications, and multi-sensor processing.

Subsequently, John led a team that explored the benefits and challenges of using staring focal plane array sensors. The work led to a large work for others (WFO) effort as well as improved USNDS sensors — the current generation employs thousands of detectors, plus digital electronics, packaged into a sensor array the size of your hand.

Sandia continues working to improve sensors. Researchers are developing focal plane arrays with higher densities, lower noise, and spectral diversity, including development of new materials. While focal plane arrays are a huge enabler for persistent sensing, they’re not enough, he said. They require appropriate optics and stable structures, accurate pointing and stabilization, high-bandwidth processing electronics, and advanced algorithms, all of which must be understood and integrated together at a systems level.

“Bright young faces are beginning to work in these areas, embracing the challenges that await,” said John, who is known for mentoring. “I appreciate the opportunity to work with them, and hopefully they will relish that and build upon what we have done previously, as I had the opportunity to build upon the work of my predecessors.”

— Sue Major Holmes

Sandia Fellow Jerry Simmons



Groundbreaking science = long-term commitment

Jerry Simmons came to Sandia in 1990 to research quantum electronic devices and terahertz detectors. He eventually moved into management, where he worked on solid-state lighting through an LDRD grand challenge aimed at developing light-emitting diodes (LEDs) bright enough and with a color range useful for general lighting.

Jerry, an internationally recognized research scientist, addressed wide bandgap (WBG) power electronics in his talk, “Novel Semiconductor Materials and Devices.”

Sandia’s LED work continues to this day, said Jerry, who stressed the importance of long-term research and recognized numerous researchers with whom he collaborated throughout his career.

“If you want to do ground-breaking scientific investigations, you have to commit to it for a long time,” he said. Thus Sandia’s work on wide bandgap power electronics, aimed at reducing energy consumption, builds on its solid-state lighting expertise.

Jerry noted that electricity accounts for 40 percent of today’s energy use and that will increase as more transportation becomes electric.

Electricity requires conversion — first to high voltage for transmission, then

to lower voltage for homes and businesses. That’s where power electronics comes in. Currently, power electronics make up 30 percent of conversion, but that’s expected to rise to 80 percent by 2030 because it’s more efficient, and smarter, than conventional technology, Jerry said.

WBG materials are attractive because they can handle higher temperatures and voltages. WBG power electronics raise the possibility of less complex and less costly power conversion through smaller size, higher reliability, and lower system costs compared to today’s familiar transformers, Jerry said. Power electronics the size of a 100-pound briefcase potentially could replace an 8,000-pound transformer surrounded by barbed wire and warning signs in a neighborhood, he said.

And if size, weight, and power advantages are important for civilian use, imagine what they could do for military ships or aircraft, Jerry said.

Much of Sandia’s WBG research focuses on two common materials, silicon carbide (SiC) and gallium nitride (GaN). SiC has the potential to outperform silicon, now widely used in semiconductor technology, by 100 times; GaN could be 1,000 times better, while another WBG material on the horizon, aluminum nitride, might perform 10,000 times better, Jerry said.

Sandia’s WBG work led it to compete for a \$70 million WBG manufacturing initiative. The team was disappointed in January when DOE did not choose its multidisciplinary consortium proposal, but Jerry said he expects additional DOE research and development opportunities.

In the meantime, Sandia has established strong partnerships with major industries and universities that were part of the original proposal. “We are going to be persistent,” Jerry said.

— Sue Major Holmes

In a question-and-answer session following the Fellows talks Jerry advised not focusing on getting credit or recognition. “Focus on doing the right thing. Good things will come to you later. Focus on the work at hand.”

Sandia Fellow Jeff Brinker



Look to biological systems for solutions

Jeff Brinker, whose work centers on the self-assembly of functional nanostructures, joined Sandia in 1979 as a ceramic engineer but works today in biology and medicine.

Jeff praised the “tremendous people and facilities at Sandia” and the sustained funding from DOE’s Basic Energy Sciences and Sandia’s LDRD programs “that allowed me to do things I never could have done in academia: to work in fields I know nothing about.”

His book on sol-gel processing remains a worldwide resource on the processing of inorganic and hybrid nanostructured materials. (Sol-gel processing refers to the synthesis of Jello-like inorganic networks from soluble molecular precursors.) He has been awarded the DOE E.O. Lawrence Award and the Materials Research Society Medal, holds 39 patents, has won four R&D 100 awards, is a member of the National Academy of Engineering, and is also a Distinguished and Regents Professor of Chemical and Nuclear Engineering at the University of New Mexico, where he is also a member of the UNM Cancer Center.

In his talk, he said that biological systems and materials have evolved over billions of years to solve challenging engineering problems, such as energy harvesting and conversion, the creation of “hard-tough-strong materials,” and the rapid transportation of pure water, he said.

“How can we emulate this?” he thought. “Living systems are inherently fantastically complex. It’s hard to mimic how they sense, respond, self-replicate.”

In a question-and-answer session, Jeff urged researchers to remain curious, be observant, and be willing to take risks. “Go out of your comfort zone.”

Jeff began using so-called surfactant molecules encoded with simple love-hate information. “Surfactants have hydrophilic and hydrophobic parts in one molecule,” he said. Added to water they spontaneously organize (self-assemble) into periodic nanostructures.

“We are all products of self-assembly,” he said. “We know it works.”

By adding various molecular precursors to the self-assembling systems, he used solvent evaporation during spin- or dip-coating to fabricate porous silica membranes or seashell-like silica-polymer composites with nanometer-scale precision. Evaporation of aerosol droplets resulted in self-assembly of porous or composite nanoparticles. Further atomic layer deposition enabled the monolayer-by-monolayer modification of the pore size and chemistry needed, for example, to mimic natural water purification protein assemblies.

Working with former Truman Fellow Bryan Kaehr, he demonstrated the replication of mammalian cells in silica and then carbon. The replica preserves and captures the features of a cell to nanometer scales. The replica can be preserved at room temperature instead of cryogenic conditions, making it easy to dissect. “This allows you to reexamine biology in a way you can never do with normal imaging techniques,” Jeff said. “You can take apart the replicated cells.”

Jeff now is working on encapsulating a chemotherapeutic drug in a nanoparticle, called a protocell, that will deliver its cargo only to a cancer cell while leaving surrounding tissue unharmed. Such delivery systems need multiple characteristics, including an artificial cell membrane that prevents the protocell’s contents from premature release.

The Defense Threat Reduction Agency is funding the protocell platform for applications in biodefense and infectious disease.

In closing, Jeff said, “As engineers, we have to think about sustainability. Nanotechnology in general is right for many of these problems.” — Neal Singer

Sandia Fellow Gordon Osbourn awarded 2014 Rank Prize for envisioning strained-layer superlattices



GORDON OSBOURN at the desk in his office at the time of his 2002 appointment as Sandia's fourth Fellow. Gordon, now retired, was the first Sandian to be designated a Fellow while still an active on-roll researcher. (Photo by Randy Montoya)

By Neal Singer

In 1982, then-Sandia researcher Gordon Osbourn published a theoretical paper that asserted the previously unthinkable: that ultra-thin layers of mismatched atomic lattices could overcome the strain of their union and successfully form a defect-free bond.

Going against the grain of the times, Gordon's calculations stimulated creation of the new field of strained-layer superlattices. Just one of the myriad results of that insight — strained-layer lasers — today dominates the entire semiconductor laser market. Approximately 1 billion are produced each year for a market valued at approximately \$5 billion.

The new insights also opened a path to the high-bandwidth optical fiber network of the Internet. High-power strained-layer lasers also are used as power

sources for optical amplifiers, an application that requires reliable operations for at least 25 years. Others in the cornucopia of products that emerged down the line include laser printers, DVDs, blu-ray players, certain solar photovoltaic devices, very efficient sensors and pollution monitors, optical mice, laser pointers, and the vertical-cavity surface-emitting lasers (VCSELs) used in commercial atomic clocks.

For that early work, Gordon, a retired Sandia Fellow, shared with three other scientists a portion of the 2014 Rank Prize, a major award in the field of optoelectronics. The awards are made every two years for achievements considered by a panel of prize committee members "to be of significant benefit to humanity."

"It's very satisfying to see just how widespread the impact of our work at Sandia has become," emails Gordon. "Most people aren't even aware of Sandia's essen-

tial role in creating so many modern technologies."

"Gordon's prediction of the existence and power of strained-layer superlattices was transformational," says acting Div. 7000 VP and Chief Technology Officer Julia Phillips. "His insight opened the eyes of scientists to the possibility of tailoring the properties of semiconductor devices in a way that had previously been viewed as impossible. It is hard to imagine life in the 21st century without the technologies that this discovery has enabled."

Following in the footsteps of Gordon's pioneering work

Semiconductor lasers are produced by the sequential deposition of nanothin layers of different materials. Their arrangement controls the optical and electrical properties of the device. Sandia, and later many other institutions, invested much effort in the study of these new structures following in the footsteps of Gordon's pioneering work.

That is because Gordon's paper and its follow-ons predicted a large and completely unexpected set of new semiconductor structures for possible use in device technology. The initial paper predicted not only that certain mismatched lattices would be stable but that they would have unique electrical and optical properties, contradicting the then-common scientific belief that each lattice layer should have the same or very similar crystal structure to ensure that the composite structure was not subjected to mechanical strain.

Even more remarkably, Gordon's follow-on calculations supported the unexpected, and initially widely disbelieved, prediction that the strain itself could be used to improve the properties of devices made from these new materials.

Ripples from those initial, much-disputed papers led researchers to fabricate structures they hadn't thought about trying, because they had been convinced the structures wouldn't work.

(Other important applications for strained-layer materials have been developed extensively outside of Sandia that do not involve lasers at all. These include strained silicon germanium layers in microprocessor chips, and high-frequency HEMT amplifiers used in cell phones and satellite television receivers.)

In Gordon's category for "pioneering work on strained-layer laser structures," each of the four scientists seminal in advocating the use of strained-layers to improve semiconductor lasers was awarded £15,000 (about \$25,000) in a ceremony that took place in London on Feb. 12. The other three honorees are Alf Adams of the University of Surrey, UK; Eoin O'Reilly of Tyndall National Institute, Cork, Ireland; and Eli Yablonovitch of the University of California.

Sandia manager honored for STEM support

By Nancy Salem

Dorothy Stermer, manager of Space Systems Engineering Dept. 5578, was one of eight women honored by the New Mexico Technology Council with 2014 Women in Technology awards.

The awards recognize women from around the state for their success in professional, business, community, education, and leadership roles in STEM (science, technology, engineering, and math). Dorothy received the award last month at the sixth annual Women in Technology event at the Albuquerque Marriott Pyramid.

The council says the award is designed to create role models in STEM-related fields and inspire young women to pursue careers in technology. Women are considered critical to growing the STEM workforce so the US can remain competitive in the global economy.

"It's important to inspire young women because there really aren't enough role models in STEM," Dorothy says. "As more women get involved, there will be more role models. Young girls will see their moms, aunts, or cousins in STEM."

Dorothy, who grew up in Silver City, N.M., was inspired by her parents and high school teachers, who encouraged her interest in math, chemistry, and leadership. "It was a very supportive environment for technical and leadership growth at a young age," she says.

Dorothy has long been an advocate for women at work and in the community. As one of a handful of female graduates in the University of New Mexico's chemical engineering program, she says educational opportunities are important for women pursuing STEM careers. And she says women should support each other's success. In 1996, Dorothy co-founded the Sandia Women's Inreach Network focused on developing skills and leadership. It worked in tandem with the



DOROTHY STERMER

"Why exclude half the population, or anyone, from exploring professional career options?"

— Dorothy Stermer, Women in Technology award winner

Women's Program Committee, which recruited women to Sandia. The programs continue today as the Sandia Women's Action Network.

In her 23 years at the Labs, Dorothy has been recognized for contributions to a variety of fields. She is manager of Space Systems Engineering, a department that supports DS&A's Space Mission Program addressing a wide range of complex national security issues in space. She formerly was manager of the Management Assurance Department, responsible for program cyber and network security, network system administration, and information management and technical operations. Prior to her work in DS&A, she was program manager for Lockheed Martin/Sandia Strategic Technical Partnerships and led teams in environmental restoration and pollution prevention.

Dorothy gives back to the community in her free time. She has taken on leadership roles for nonprofits that help promote local culture, education, and the economy. She says her volunteer work for the United Way, where she evaluated funding applications and mentored young women, has been particularly rewarding.

"It's important to encourage women to consider STEM to see if they can be passionate about it, to show them why it is important and exciting and can complement other aspects of their life," Dorothy says. "Why exclude half the population, or anyone, from exploring professional career options?"

She says she shares the Women in Technology award with many at Sandia. "There are countless gifted women who give their technical and leadership talents," she says. "This award is for all of us for our diverse contributions to our national security missions."

Engineering challenges of landing a one-ton robot on Mars

Symposium featuring JPL Director Charles Elachi helps Sandia mark National Engineers Week

By Stephanie Hobby • Photos by Randy Montoya



JPL DIRECTOR Charles Elachi makes a point during his National Engineers Week/National Security Speakers Series talk at Steve Schiff Auditorium.

Charles Elachi, director of NASA's Jet Propulsion Laboratory, spoke at Sandia as part of the National Security Speakers Series and to help kick off Sandia's celebration of National Engineer's Week. The Steve Schiff Auditorium was full as Elachi talked about some of the engineering challenges surrounding the Mars Science Laboratory mission, which safely landed the one-ton, car-size *Curiosity* rover to the Martian surface on Sunday, Aug. 5, 2012. Elachi also discussed other current and future missions of JPL.

He started the presentation with a video highlighting the formidable challenges of putting the largest and most sophisticated rover on the surface of Mars and the subsequent "seven minutes of terror." The phrase refers to the entry, descent, and landing of the mission. It takes 14 minutes for a signal from the spacecraft to reach Earth, and seven for the rover to enter, descend, and land on the surface. By the time mission control first gets word that the vehicle has hit the top of the atmosphere, the vehicle has been alive or dead on the surface for at least seven minutes. This was all taking place as 50 million people around the US watched the event unfold on television, the Internet, at museums, and on the Times Square video screen.

The challenges were colossal. Elachi said the team had to overcome the 100 million mile distance, ensure accuracy in hitting the landing spot, which he said was comparable to hitting a golf ball in Los Angeles

and making a hole in one in Scotland while the cup is moving, and dissipate energy of the spacecraft going 13,000 mph and slowing it to zero in seven minutes. The entry, descent, and landing sequences were all computer-controlled, and if any one thing didn't go exactly as planned, Elachi said, the mission would have been over.

Sandia had role in mission

Fortunately, the entire sequence went off without a hitch, and the engineers and researchers who had worked for so many years to make this happen burst into applause as the first signal came back to Earth that the rover was ready to get to work. Sandia researchers were a part of that effort. *Curiosity* is powered by a multi-mission radioisotope thermoelectric generator, or MMRTG, and in 2006, DOE tasked Sandia with the tremendous responsibility of conducting the safety analysis report. For five years, a team of Sandians, led by Ron Lipinski (6223), analyzed millions of combinations of potential scenarios to ensure the risks to people, animals, and the environment were minimal as the Atlas V launched in November 2011.

This year, on Wednesday, Feb. 12, *Curiosity* celebrated having driven 5 kilometers since landing in

August, and the team at JPL ran a 5K to mark the occasion.

Immediately after the talk, Labs Director Paul Himmert and Sandia VPs Bruce Walker and Steve Rottler joined Elachi on the stage for a panel discussion about past and future engineering challenges. When asked what one piece of advice they had to offer engineers beginning their careers, the group was encouraging. "Make sure you stay curious in your life. Don't let that ever fade away, and don't be afraid of failure. If you really are pushing the limits on what you are doing, I can guarantee you that you are going to do good and the obligation to avoid doing harm. And Bruce reminded them to enjoy the journey. "A lot of times we get engrossed in hard work and the challenge of the moment, but enjoy the journey and note the contributions you are making and have a passion for what you do."

Paul added, "Always learn, and always look to lead. Lean in to look for the challenges." He encouraged anyone who felt that Sandia didn't offer that to contact him.

Steve encouraged engineers to remember the engineering code of ethics, which is both an obligation to do good and the obligation to avoid doing harm. And Bruce reminded them to enjoy the journey. "A lot of times we get engrossed in hard work and the challenge of the moment, but enjoy the journey and note the contributions you are making and have a passion for what you do."



JPL DIRECTOR CHARLES ELACHI, left, and Sandia VPs Bruce Walker, right, and Steve Rottler (beside Bruce) are amused by a point being made by Labs Director Paul Himmert during a panel discussion following Elachi's National Security Speaker Series talk about the challenges of robotic space exploration. The talk was held in conjunction with National Engineers Week.

Nonproliferation treaty faces challenges, ambassador says

By Cathy Ann Connelly

"The NPT (Nuclear Non-Proliferation Treaty) is the most important international security arrangement we have that is protecting the world community. . . . Its loss would be catastrophic and irreparable," said Ambassador Thomas Graham Jr. in a recent Sandia presentation as part of the ongoing National Security Speaker Series (NSSS).

Titled "Nuclear Dangers: The Nuclear Non-Proliferation Treaty Under Threat," Graham's presentation highlighted his views about the NPT in limiting nuclear weapon proliferation and the current threats to the treaty's continuation and enforcement, most notably the actions of North Korea and Iran. Graham, a senior US diplomat, was involved in the negotiation of every single international arms control and non-proliferation agreement from 1970 to 1997.

The ambassador summarized the NPT as a "strategic bargain" in which 184 non-nuclear weapon states "gave up forever the right to acquire the most powerful and destructive weapon ever created in exchange for the commitment from the five states allowed to have and to keep nuclear weapons to share peaceful nuclear technology and to engage in disarmament negotiations aimed at the ultimate elimination of their nuclear stockpiles." Those five nuclear states are the United States, the United Kingdom, France, Russia, and China.

Graham also reviewed the NPT's historic context since it was opened for signature in 1968, and its permanent extension status in 1995, highlighting the role a commitment to a Comprehensive Test Ban



AMBASSADOR THOMAS GRAHAM is executive chairman of the board of Lightbridge Corp., which develops new types of nuclear power fuel. In December 2009, he was appointed to the International Advisory Board of the United Arab Emirates, helping guide that country's nuclear energy program. Graham is also chairman of the board of CanAlaska Uranium Ltd. of Vancouver, Canada, a uranium exploration company. He is internationally known as a leading authority in arms control and non-proliferation agreements designed to limit and combat the proliferation of nuclear, biological, and chemical weapons. (Photo by Lloyd Wilson)

Treaty (CTBT) played in accomplishing the extension — even though the CTBT has never been ratified by the US Senate.

Non-nuclear weapon states parties have overwhelmingly indicated that a comprehensive test ban is the most important near-term indicator of the weapons states' commitment to long-term nuclear disarmament, Graham said. He viewed this as "political balance," which he deemed as "essential to the survival of the NPT for the indefinite future."

Graham pointed out that the NPT is in crisis in part because of the essential failure of the related disarmament agenda, but also in part "because of the continuing high political value of nuclear weapons, whereby the possession of nuclear weapons is seen as the distinguishing feature — at least among prominent countries — separating first class states from other states. The NPT is threatened from many sides but primarily at this time directly by the nuclear programs in Iran and North Korea."

Graham said the nuclear programs in these two states threaten to break open the NPT regime in the Middle East and northeast Asia and thereby unleash wide-scale nuclear proliferation. He said, "There is a strong symbiotic relationship between the objectives of effectively constraining these programs of Iran and North Korea while reinforcing the NPT Basic Bargain. A strong NPT for the indefinite future, supported by the entire world community, will contain these two programs and inhibit other future threats. It will thereby hold the line so as to prevent the occurrence of a proliferation nightmare and make conceivable one day the global elimination of nuclear weapons that could significantly enhance the potential for a more peaceable world."

Willis Whitfield inducted into Inventors Hall of Fame

Legendary Sandia engineer honored posthumously for invention of laminar airflow cleanroom



TOUCHING MOMENT — Belva Whitfield, widow of Sandia legend Willis Whitfield, inventor of the laminar airflow cleanroom, gets a gentle greeting from a Sandian in a cleanroom in Sandia's MESA complex. Willis will be inducted posthumously into the National Inventors Hall of Fame in May. (Photo by Randy Montoya)

By Heather Clark

The inventor of the modern cleanroom, Willis Whitfield, will be honored posthumously by the National Inventors Hall of Fame for a technology that revolutionized manufacturing in electronics and pharmaceuticals, made hospital operating rooms safer, and advanced space exploration.

Willis, the son of Texas cotton farmers who became a physicist, retired from Sandia in 1984 and died Nov. 12, 2012, shortly after the laminar-flow cleanroom invention's 50th anniversary. With slight modifications, his invention is still the standard.

Whitfield is among 15 inventors being inducted this year into the Alexandria, Va.-based National Inventors Hall of Fame. His work will be honored at a Washington, D.C.,-area celebration in May.

"The technological solution that Willis Whitfield designed for the laminar airflow cleanroom is illustrative of the long tradition of innovative research at Sandia National Laboratories. Willis' invention has stood



WILLIS WHITFIELD records data in his lab notebook while working in an early version of the laminar airflow cleanroom. Willis will be inducted into the National Inventors Hall of Fame in May.

the test of time, making the modern microelectronics industry possible," says acting Div. 7000 VP and Chief Technology Officer Julia Phillips. "It's that same type of groundbreaking interdisciplinary research that advances the frontiers of science and engineering and enables our national security mission at Sandia."

A panel of experts in science, technology, engineering, and patents selected the potential inductees. The National Inventors Hall of Fame "requires candidates to hold a United States patent that has contributed significantly to the nation's welfare and the advancement of science and useful arts."

Past inductees include Apple co-founders Steve Jobs and Steve Wozniak, Beulah Louise Henry, inventor of the ice cream freezer, and cotton gin inventor Eli Whitney.

'Mr. Clean' modest, but would appreciate Hall of Fame honor

When Willis announced the invention in 1962, researchers and industrialists didn't believe it, but within a few short years, \$50 billion worth of laminar-flow cleanrooms were built worldwide and Whitfield had been dubbed "Mr. Clean" by *TIME Magazine*.

Belva Whitfield says her late husband was always modest about his invention, and the accolades he received didn't change the unassuming scientist.

"This honor means a great deal to me," Belva says. "I have always been so proud of Willis and his accomplishments. It is hard to say how proud I am because I don't think words are enough to express my feelings."

Belva says Willis would have underlying feelings of great appreciation to be in the Inventors Hall of Fame, though outwardly he would remain modest. "He would certainly be honored that he was in the company of Eli Whitney, Henry Ford, Samuel Morse, Wilbur and Orville Wright, and so many more," she says.

Willis' likeness can be seen in a bronze statue that graces an entrance to Sandia's Microsystems & Engineering Science Applications (MESA) complex, where cleanrooms and clean benches based on Sandia's invention are used to manufacture precision mechanical assemblies in microsystems for national security needs.

MESA also is home to Willis' original lab note-

books containing diagrams of his invention and his notes as his research unfolded.

Willis began creating the laminar-flow cleanroom to improve the reliability of miniature mechanical components for Sandia parts. But the invention enabled the growth of the semiconductor industry, which in turn made modern electronics, computers, and information technologies possible. Cleanrooms also contributed to breakthroughs in biotechnology, nanotechnology, health sciences, and healthcare.

History of Sandia invention

In 1959, nuclear weapon components — mainly mechanical switching parts — were becoming smaller and microscopic dust particles were preventing Sandia from achieving the quality needed, Labs historian Rebecca Ullrich says. The practice at the time was to tightly seal cleanrooms, wear protective clothing, and vacuum often, but still contaminants entered the room and particles interfered with the precise work.

Willis' solution was to constantly flush out or "sweep" a room with highly filtered air. In an initial model, he designed a workbench along one wall. Clean air entered the room from a bank of filters that were 99.97 percent efficient in removing particles larger than 0.3 microns. For example, cigarette smoke blown in one side comes out the other as clean air.

The air was circulated in the room at a rate of 4,000 cubic feet or about 10 changes of air per minute. The resulting linear speed of the air was slightly more than 1 mph, which is about the same as that felt walking through a still room.

In a later modification, the air was passed down over the work area instead of across, letting gravity help carry troublesome particles into the floor, which was covered with grating. Filters underneath cleaned the air and it was circulated back around to re-enter the room.

Disbelief, then wonder as invention was announced

When the first cleanroom was tested instruments that counted the dust particles registered zero, causing Willis and others to assume they were broken, Willis said in 1993.

The laminar-flow cleanroom created a work environment that was more than 1,000 times cleaner than the cleanrooms in use at the time. According to tests at the time, the laminar-flow cleanroom's work area contained an average of 750 dust particles one-third of a micron in size or larger per cubic foot of air. (A micron is equal to 40-millionths of an inch.) That's compared to average dust counts of more than 1 million particles per cubic foot of air in one of the best conventional cleanrooms in use at the time.

RCA and General Motors Co. were early adopters of the cleanroom, and the predecessor to Lovelace Medical Center in Albuquerque was the first hospital to use laminar-flow cleanrooms in its operating rooms to prevent infections, Rebecca says. Eventually, Willis worked with NASA to provide techniques to sterilize spacecraft and planetary quarantines during missions to the moon and Mars.



A TIME FOR REMEMBERING — Belva Whitfield, wife of Willis Whitfield, and son Jim, pause for a moment's reflection in front of the bronze statue of Willis that stands at the entrance to Sandia's MESA complex, where cleanrooms and clean benches based on his invention are used to manufacture precision mechanical assemblies in microsystems for national security needs. (Photo by Randy Montoya)