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SANDIA TECHNOLOGY

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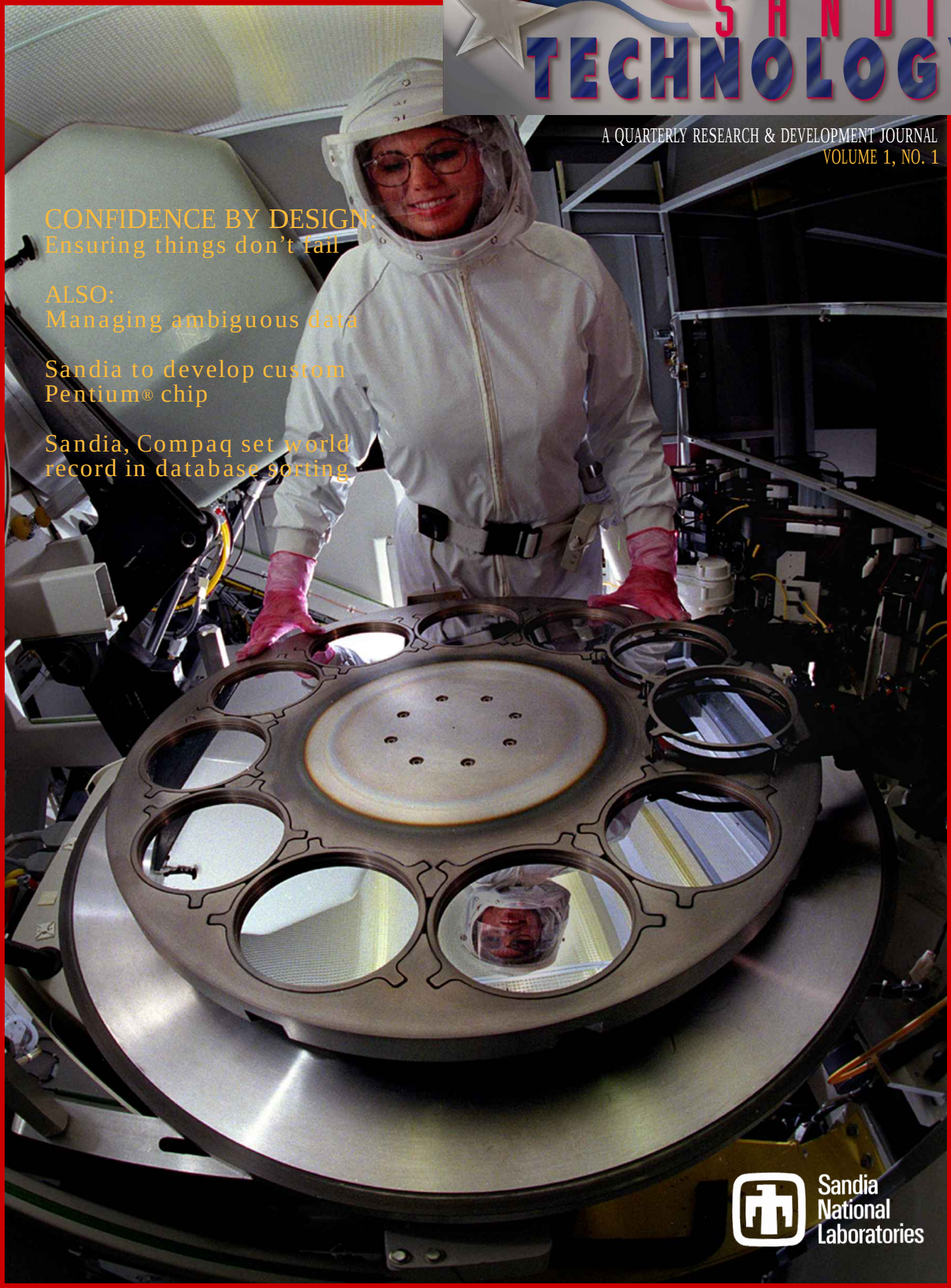


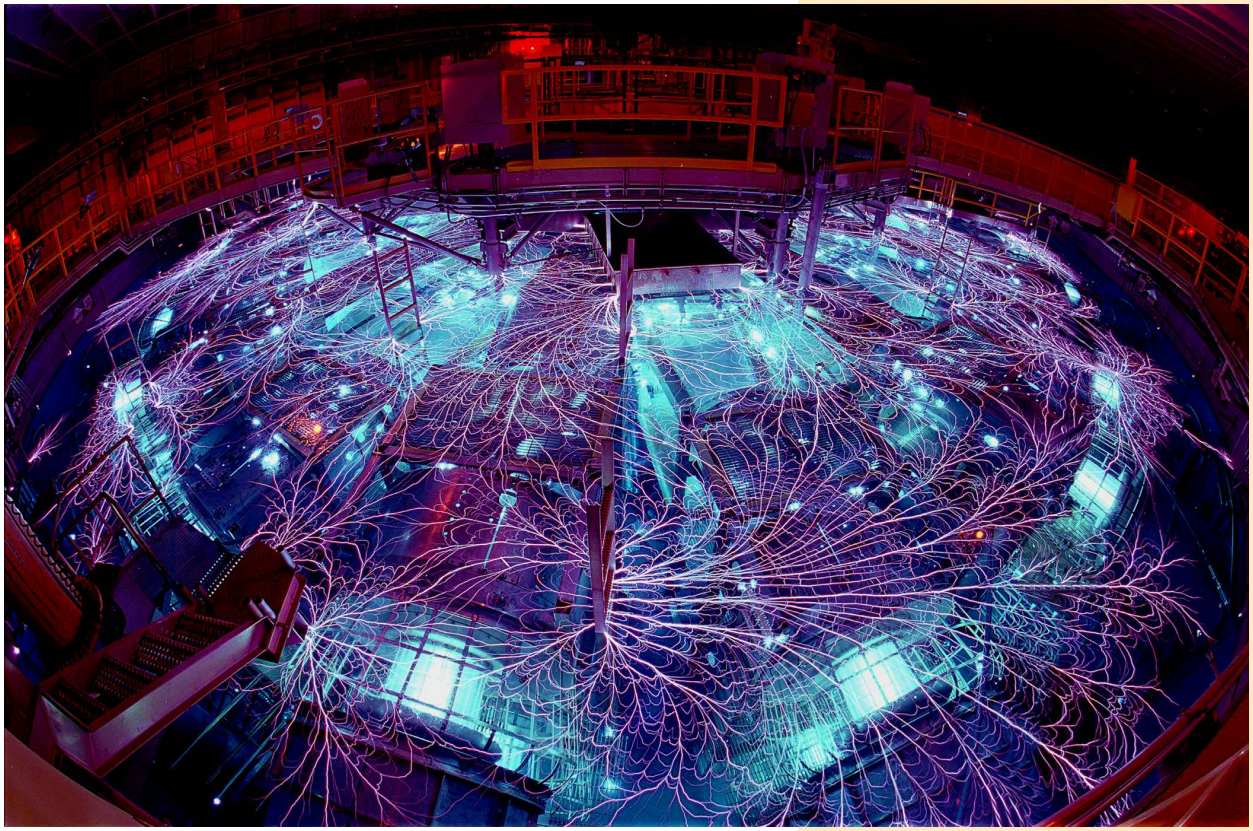
CONFIDENCE BY DESIGN:
Ensuring things don't fail

ALSO:
Managing ambiguous data

Sandia to develop custom Pentium® chip

Sandia, Compaq set world record in database sorting

Sandia National Laboratories



Sandia's Z accelerator, the most powerful producer of X-rays in the world

Surety science and engineering began 50 years ago in the defense sector and grew from the need to know if nuclear materials were used only as intended, were safe in abnormal environments, and secure in malevolent circumstances.

ON THE COVER: Technician Stephanie Reel with plenum of one of several metal deposition systems in the Microelectronics Development Laboratory at Sandia National Laboratories. Metal deposition systems are used for radiation-hardened microelectronics processing. (See NewsNotes, page 6.)

Sandia Technology is a quarterly journal published by Sandia National Laboratories. Sandia is a multiprogram engineering and science laboratory operated by Sandia Corporation, a Lockheed Martin company, for the Department of Energy. With main facilities in Albuquerque, New Mexico, and Livermore, California, Sandia has broad-based research and development responsibilities for nuclear weapons, arms control, energy, the environment, economic competitiveness, and other areas of importance to the needs of the nation. The Laboratories' principal mission is to support national defense policies, by ensuring that the nuclear weapon stockpile meets the highest standards of safety, reliability, security, use control, and military performance. For more information on Sandia, see our Web site at *http://www.sandia.gov.*

To request additional copies or to subscribe, contact:
Chris Miller, Editor
Marketing Communications Dept.
MS 0129
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0129
Voice: (505) 844-5550
Fax: (505) 844-1392
e-mail: cmiller@sandia.gov

Sandia Technology Staff:
Laboratory Directed Research & Development Program Manager: Chuck Meyers, Sandia National Laboratories
Editor: Chris Miller, Sandia National Laboratories
Researchers: Joy Bemesderfer & Donna Drayer, Technically Write
Writer: Katharine Beebe, Technically Write
Designer: Douglas Prout, Technically Write
Photographer: Randy Montoya, Sandia National Laboratories

FROM THE *Editor*

Dear Readers:

This is the first issue of a new publication produced by Sandia National Laboratories called *Sandia Technology*, a quarterly research and development journal. We created *Sandia Technology* by merging two previous publications – *Inside Sandia* and *Emergent*. We hope you agree with us that combining the two parts does equal a better whole. *Sandia Technology* incorporates *Inside Sandia's* focus on Sandia technologies that have made it out of the laboratory and are or soon will be benefiting Americans, as well as *Emergent's* focus on innovative technological concepts now under development in the laboratory.

This issue focuses on surety science and engineering, an evolving discipline whose origins date to the development of nuclear weapons. This new era of high-consequence management has required new approaches to ensure we don't experience the unthinkable – an accidental nuclear detonation. Surety science and engineering principles have kept our nuclear stockpile safe, secure, and reliable. Many technological advances have come directly from our weapons surety program, and we believe that sharing surety practices, technologies, and strategies will benefit the nation in many other areas.

We hope you enjoy this debut issue of *Sandia Technology*. Please let us know what you think.

Sincerely,

Chris Miller
Editor

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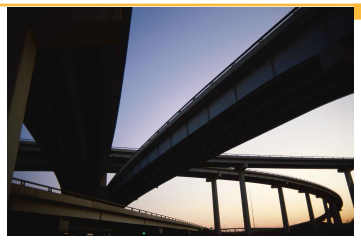
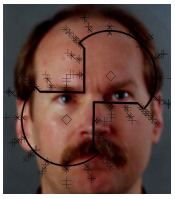
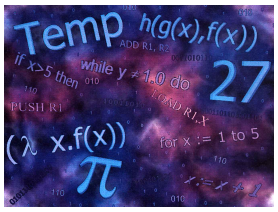






INSIGHTS

Comments by
Dr. William Wulf, President
National Academy of Engineering

What if the machine misfires?
What do we do if America seizes up?

Confidence by DESIGN

"The more important something is when it works,the more it can hurt you when it fails."

Ted Dellin, Sandia National Laboratories

The airplane your children board. Your last flu shot. The cyberspace network you trade stocks on. Whatever it is, it's safe if it cannot harm you, reliable if it doesn't fail, and secure if it's yours and functions for no one else. In other words, it's a sure thing.

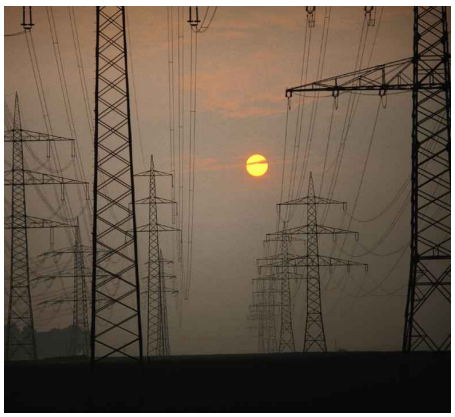
Safe, reliable, secure – sounds simple until you consider the tangle of systems that typify modern life. In a systems context, safety, reliability, and security are the challenge. Every day, people depend more heavily on technological systems. Those systems interact to serve users better. Unfortunately, as technologies evolve, so does the potential for failure – and catastrophe.

Systems are complex. Complexity spawns breakdowns. And breakdowns invite disaster.

Witness these examples:

August 1996: Power cables in the Northwest sag into tree limbs and plunge power-grid users throughout the western United States into darkness. When power is restored, some telecommunications systems are just two hours from exhausting reserves and shutting down services.

January 1998: An ice storm cripples New England and southern Quebec, leaving businesses and residents without power for as long as three weeks. Canada alone suffers losses of $1.6 billion.



May 1998: A single failed communications satellite disables 90 percent of the pagers across the United States, along with ATMs, credit-card systems, and TV and radio networks worldwide. Physicians, law enforcement officials, and others who rely on instant communication are compromised.

December 1998: Human error shuts San Francisco down. When a construction crew overlooks a buried powerline, their work causes a switchboard blowout. The blowout shuts two generators down. Across 49-square miles, elevators stop with people inside. Trolleys, trains, electric buses quit. Traffic lights fail. Airplanes land elsewhere.

"The more important something is when it works, the more it can hurt you when it fails," said Sandian Ted Dellin, who is researching electronics reliability.

When applied to technology, surety is the methodology by which a system, any system, can be designed to operate exactly as planned every time in every circumstance. When applied to management, surety acts as a philosophy by which fail-safe decisions are made.

At Last, a Sure Thing

Enter surety science and engineering. It is an evolving discipline designed to integrate safety, reliability, and security into technologies across the spectrum, from space exploration to infrastructures. When applied to technology, surety is the methodology by which a system, any system, can be designed to operate exactly as planned every time in every circumstance. When applied to management, surety acts as a philosophy by which fail-safe decisions are made. In essence, surety is a way of approaching just about any systems-problem, an approach that considers why and how a system fails, then anticipates and prevents such failures. Fifty years of defense research at Sandia National Laboratories has done the ground work. Now Sandia is working more closely with industry, universities, and much of government to give surety a more widespread application.

Eric Bloch, a member of the Sandia President's Advisory Council (Bloch works on the Council on Competitiveness in Washington, D.C.) has endorsed surety science and engineering as "a roadmap for thinking about high-level problems."

"We believe this is a much more powerful tool than what's generally in use today," said Pace VanDevender. As Sandia's chief information officer, VanDevender sets corporate processes and requirements and ensures the Labs' information system is protected.

Consequence Determines Surety

Since the 1940s, Sandia has conducted pioneering studies in safety, reliability, and security.

Sandia's explosives-detection portal

"In the 40s we had nuclear weapons," said Jim Rice, Sandia director of Information Systems Engineering and of lab-wide surety research. "And then nuclear energy in the 70s. Recently we tried to look at it all as a discipline – all three components (safety, reliability, and security) optimized together. It's a philosophy applied to systems-engineering problems."

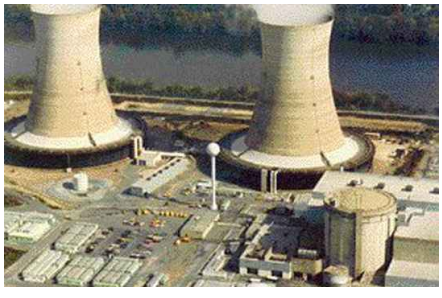
Surety science and engineering may be applied at four levels, depending on the consequences of a system failure. The greater the consequences, the higher the surety level.

Level I surety is primarily *reactive*. Standard engineering is applied, and designs are tested to ensure reliability. Used for many manufactured goods, level I is adequate when failure won't create catastrophic consequences. Typical level I surety measures include reliability insurance, warranties, and parts replacement.

Level II is *proactive*, a step up from reactive. Lives may be at risk, so people intervene before a problem occurs. For example, airports install metal detectors to prevent highjackings. Public schools do likewise to reduce gang activity. Other examples of level II surety measures include training and certification for pilots.

Level III surety is *preventative*. Science and engineering attempt to predict and reduce the potential for a system to fail by redesigning the system. Because auto accidents kill, manufacturers incorporate seatbelts and airbags – not as an add-on anymore, but – as an integral part of total vehicle design. Other level III examples include automatic cooling systems in nuclear reactors and other systems built into aging nuclear weapons.

Level IV surety, applied when failure is unthinkable, is *fundamental*. A system works in perfect harmony with, not circumventing, the laws of nature. Absolute surety is the rule here. Modern nuclear weapons, for example, are designed to function in accord with natural law.



At every level the bottom line is understanding how things fail.

Initially, developing surety as a broad discipline requires research in the hard sciences (physics, chemistry, and biology), as well as in mathematics, engineering, and the social sciences. Research investments are expected to yield returns many times over in lives saved and reduced design, production, and maintenance costs for both defense and commercial technologies.

Surety Nuts and Bolts

Sandia has been a leader in developing the following key tools that enable engineers to understand how things fail:

Modeling and simulation use the world's fastest computers to recreate a given system, then simulate its exposure to catastrophic conditions. Example: A plane crash involving a nuclear weapon.

Risk-and-reliability management began at Sandia as safety studies of nuclear weapons and reactors. Risk is calculated through studies of component- and system-reliability combined with studies on human reliability.

Architectural Surety: Earthquakes Don't Kill People – Buildings Do

Sandia's Architectural Surety program strives to enhance public safety, ensure reliable structures, and increase public awareness of the benefits associated with the new design or retrofits of public, commercial, and private facilities. The Labs have conducted surety research because threats to structures, from terrorism and natural disasters to aging materials, are making Americans nervous. Two examples:

- Whether unleashed by a hurricane or a terrorist's bomb, flying glass converts an elegant building into a killing field. Surety research is studying fracture configurations to develop glass that breaks into slow-moving, sandlike granules which are less harmful than slivers and shards of conventional glazings.
- Through modeling and simulation, engineers can understand how fire might behave based on floor plan and materials, how best to evacuate a building, and how to implement security measures against bombings, such as those of the World Trade Center in New York and the Alfred P. Murrah Federal Building in Oklahoma City.

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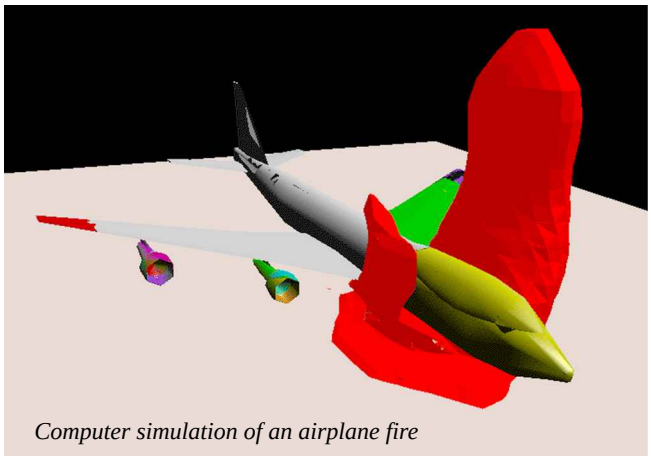


Computer simulation of an airplane fire

Applications – and More Applications

Though still a young field, surety science and engineering is likely to support applications and studies as varied as physics and finance, as different as the spread of fire and disease. Surety may be philosophical in principle, but its many applications are grounded in practicality. Here is a sampling of areas where, collaborating with government, academia, and industry, Sandia has forged advances.

NEWS Notes

SANDIA, COMPAQ SET WORLD RECORD IN LARGE DATABASE SORTING

Just as scientists need very fast number-crunching computers to replace physical testing with computer models, business people need a corollary procedure – the capacity to sort and manipulate large amounts of data rapidly. In a major step toward that goal, Sandia has teamed with Compaq Computer Corporation, the world's highest-volume supplier of personal computers, to sort information three times faster than the previous record, at approximately two-thirds the installed cost of current techniques.

The Sandia cluster of computers has sorted a terabyte of data – the information contained in about a million unabridged dictionaries – in less than 50 minutes. The previous record, on a shared-memory supercomputer rather than a cluster of industry-standard computers, was 150 minutes. Estimates suggest that in three years, large-scale data storage (called warehousing) will increase from a 272-gigabyte average to a predicted 6.5 terabytes, and from a $15-billion to a $113-billion market by 2002, according to a marketing report from the consulting firm Palo Alto Management Group.

Contact: Carl Diegert
505-845-7193
e-mail: diegert@sandia.gov

Architectural Surety project leader Rudy Matalucci

Surety research is studying fracture configurations to develop glass that breaks into slow-moving, sandlike granules that are less harmful than slivers and shards of conventional glazings.

Engineers can use architectural surety to simulate threats, predict outcomes, and design safer buildings that behave predictably during disasters. To manage risk and improve structural design, Sandia's computer simulations and material testing address community and national concerns about our buildings. Sandia has been coordinating interactive workshops, university courses, seminars, and conferences to bring architects, engineers, and other design professionals together to work on architectural surety issues.

Transportation Surety: Ending the Fear of Flying

Every year more and more Americans travel by airplane, making the demand for user-friendly skies more extreme. To meet President Clinton's Safer Skies program goal of reducing fatal accidents fivefold in the next decade, Sandia has put surety awing.

In the fall of 1997, the Federal Aviation Administration chose Sandia and eight universities to create an Airworthiness Assurance Center for Excellence. Now in the second year of a three-year pilot program, the Center is developing improved maintenance, inspection, and repair techniques; crashworthiness initiatives; safer propulsion and fuel systems and landing gears; and improved aircraft materials. The Center combines top expertise and cutting-edge software tools to detect and correct underlying problems before they set into motion a chain of events that ends in disaster.

Sandia's role focuses on developing nondestructive inspection technologies, along with providing structural-defect samples, reliability assessments of new technologies, and technology transfer from the Center to the industrial sector.

"By targeting and preventing the leading causes of fatalities and injuries," Vice President Al Gore has said of the Safer Skies initiative, "by expanding engine inspections and by improving pilots' warning and detection systems, we will significantly reduce the number of plane crashes and save ... lives."

Some of the causes of U.S. air crashes that the Center is studying include lost control (32 percent of fatal accidents); runway incidents (12 percent); ice and snow (9 percent); and windshear, sabotage, and highjacking (each 3 percent).

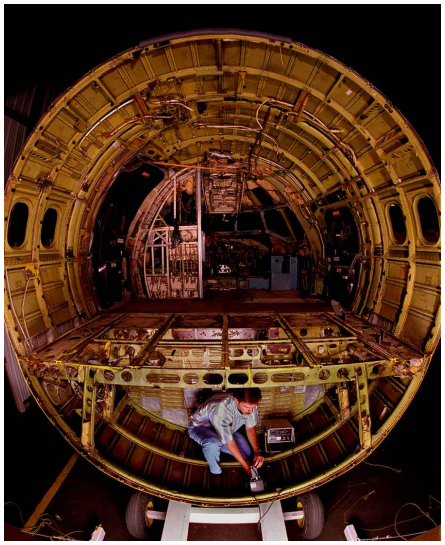
Another Sandia-FAA partnership produced a portal that checks passengers and carry-on luggage for explosives. Located inside an airport terminal, the portal emits a puff of air onto a person and baggage, and a sensor scans the air for chemicals. This device was tested recently at the Albuquerque International Airport.

Transportation-surety research is applied also to nuclear weapons and hazardous-materials transport, as well as to railroad-transportation safety.

Electronics Surety: A Key to Global Leadership

Could surety science and engineering techniques promise defense and economic superiority? Quite possibly so.

Defense superiority, Sandian Ted Dellin told a national surety workshop last fall *(see sidebar page 9)*, depends on reliable electronics. And affordable economic leadership rests on sustaining the electronics revolution, said Dellin, deputy director of reliability at Sandia and an adjunct professor at The University of New Mexico.



Defense research has led to numerous microelectronics breakthroughs, many of which have evolved into commercial technologies. Thus, many U.S. defense initiatives support economic stability.

A problem, however, occurs when microelectronics advances outpace reliability developments that support weapons and marketable products. Level III surety, Dellin said, may provide the solution whereby reliability keeps up with invention. How? By finding all sources of failure, developing models that will predict these failures, and then building reliability into the design of technologies.

Life-Cycle Engineering: Designing Affordable Products Consumers Can Rely On

The life cycle of a product might be compared to that of a living being experiencing birth, life, and death. A product is "born" when designed and manufactured. It "lives" while it functions. And it "dies" when it breaks or is replaced.

Supported by the Laboratory Directed Research and Development fund, life-cycle engineering, which serves Sandia's mission of nuclear stockpile stewardship, has laid the groundwork to manage life cycles for many products in the commercial sector as well. The key lies in predicting the effects of time and stresses on materials and systems. The result is affordable products of superior quality that perform and age predictably. In addition to nuclear weapons stewardship, life-cycle engineering has applications in medicine, computing, air and space travel, and in various other technologies where failure is not an option.

Infrastructure Surety: The Heartbeat of a Nation

Cripple infrastructure and you cripple nations. Power, water, and energy systems; public transportation systems; air-traffic control; financial services and communication all comprise infrastructure, as do fire, medical, law-enforcement, and other complex networks. Increasingly, infrastructure systems are computer operated and interconnected. The result is a fast, effective "machine" that improves quality of life for millions.

But when the machine misfires, lives may be imperiled. Whether by plan or by mistake, an individual connected to the Internet could bring these interdependent systems to a catastrophic halt. Natural disasters have done so already.

Research to protect the aging nuclear stockpile and its underlying nuclear infrastructure has yielded surety science and engineering applications outside the weapons complex. Through modeling and simulation, Sandia has recreated infrastructure breakdowns and is developing a warning system to predict – plus techniques to repair and prevent – infrastructure breakdowns, break-ins, and catastrophes.

Crime may have America by the throat, but Sandia surety engineers have developed a pilot program to deter crime

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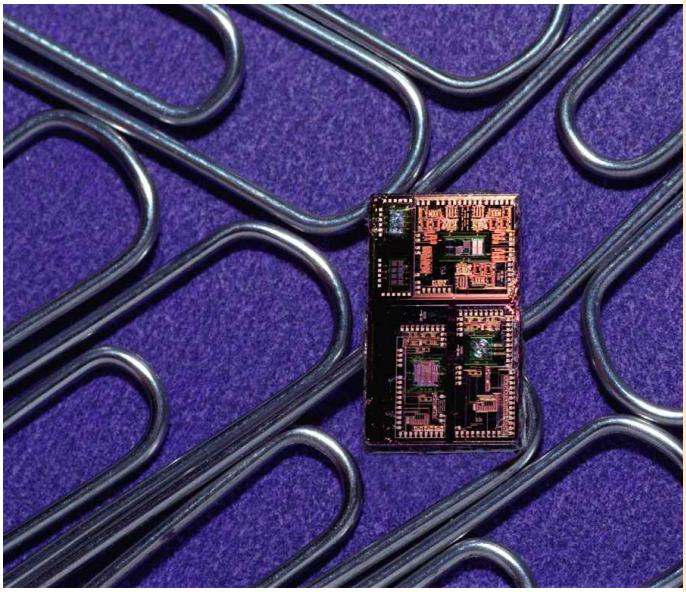


A complete inertial guidance system is smaller than a paperclip

NEWS *Notes*

SANDIA TO DEVELOP CUSTOM PENTIUM ® CHIP FOR SPACE & DEFENSE NEEDS

Intel Corp. will provide a royalty-free license for its Pentium® processor design to Sandia for the development of custom-made microprocessors for U.S. space and defense purposes. The agreement saves taxpayers hundreds of millions of dollars in microprocessor design costs and provides the federal government with a 10-fold increase in processing power over the highest-performing existing technology.

Sandia, DOE's lead lab for microelectronics research and development, will develop a custom, radiation-hardened version of the Pentium processor for use in satellites, space vehicles, and defense systems. Radiation hardening is required to "immunize" systems and applications from radiation, such as cosmic rays, which affect the reliability of conventional electronics.

Secretary of Energy Bill Richardson heralded the agreement as a model of industry and government cooperation. "We're proud to be a part of this unique opportunity to partner with Intel to significantly advance the state of the art in space and defense electronics," Richardson said during a news conference announcing the agreement.

Contact: Robert Blewer
505-844-6125
e-mail: blewerr@sandia.gov

Whether by plan or by mistake, an individual connected to the internet could bring these interdependent systems to a catastrophic halt. Natural disasters have done so already.

in schools. Tested two years ago in a New Mexico high school and using Sandia-developed technologies, the program put cameras, sensors, and metal detectors, along with a security guard, on site and gave parents kits to detect drug use.

Although the pilot program cost more than most schools can afford, it identified these surety approaches to safer schools: Greater use of inconspicuous technologies, especially those that maintain themselves; use of artificial intelligence to customize security solutions for individual schools; and improved building design.

Small wonder crime is a problem when prevention tools and methods haven't changed much since horse-and-buggy days. Meanwhile, crime has developed new faces: In addition to violent crime, we have white-collar as well as cyber crime.

In response, Sandia has developed a "smart" gun that fires only for its designated user. Gun manufacturer Colt is commercializing the technology.

Another offspring of Sandia's weapons experience, a team of experts in bomb-disablement technologies, is now available to the Federal Bureau of Investigation and the Albuquerque Police Department. President Clinton recognized two of the team members for dismantling a mail bomb found in the Unabomber's Montana cabin. The evidence the two Sandians gathered helped convict the Unabomber.

Other Sandia technologies providing surety science and engineering to the criminal-justice system include an evidence detector – a forensics tool that detects crime-scene evidence such as blood, fingerprints, and semen. The Albuquerque Police Department crime lab is collaborating on development of this technology.

The community-wide pilot reduced theft by 98 percent; vandalism and false alarms, each by 90 percent; fights by 75 percent; and truancy by 35 percent.

Another technology, a software program called VRaptor, sets up a hostage situation in virtual reality and allows law-enforcement trainees to identify and practice shooting at the criminal, not the victim, during the confusion, impaired visibility, and rapid changes of a crime that is unfolding. VRaptor research was supported by LDRD funding.

But more than focusing on individual technologies, Sandia research focuses on protecting the interdependencies of our infrastructures. These increasing interdependencies can cause an outage in one infrastructure to cascade or ripple through other infrastructures, causing failures there too. Sandia models interdependent networks, such as power, transportation, and communications infrastructures, together as one. Systems of economic infrastructure are also being studied. Through computer simulation, the goal is to predict in real time the consequences of national infrastructure failures.

Infrastructure, however, is becoming more and more global, and Sandia has launched efforts to identify infrastructure requirements around the world. These extend beyond services, to the essentials for survival: water, food, and clean air, for example. This effort

A robotic system is used to dismantle munitions

has brought Sandia surety experts together with the Environmental Protection Agency and the departments of Energy and of Defense to develop environmental surety.

Food Surety: Smart Steaks Snitch if They Thaw en Route to the Market

Ever wonder if frozen food thawed before it reached the store? That will become a concern of the past with Sandia's patented food sensor. Placed visibly on each food parcel, the inexpensive device reveals a red "flag" when the temperature of meat and other foods rises above freezing. A "smart" material tells the tale. The diameter of a thread and less than half an inch long, a thin wire curls when warmed above 32 degrees F and tears a piece of green paper to expose red paper underneath. The technology evolved from solar research at Sandia.

"When there's pressure from Washington on food processors, transporters, and displayers to protect consumers against spoiled food, we have a technology patented to do just that," said Sandian David Martinez, who co-developed the technology with Professor Mo Shahinpoor of The University of New Mexico College of Engineering.

This UNM-Sandia collaboration has produced eight patents.

Nuclear Stewardship: Always a Priority

Surety science and engineering began 50 years ago in the defense sector and grew from the need to know if nuclear weapons and materials were used only as intended, were safe in abnormal environments, and secure in malevolent circumstances. Surety remains a keystone of nuclear stockpile and energy stewardship. Storing, moving, and processing plutonium and enriched uranium, for instance, present a global challenge, particularly when emerging nuclear powers may be politically and economically unstable.

However, as a partner with the Department of Energy, the Nuclear Regulatory Commission, and other national laboratories, Sandia has refined a systems approach to nuclear safety that can benefit the broad expanse of modern life outside the defense sector. This approach has roots in understanding how accidents – all kinds of accidents – occur. In modeling and simulation capabilities, materials testing, and risk-management studies, Sandia has the tools and experience to recreate, in the safe and virtual world of computers, events such as accidents involving nuclear weapons. The Labs then can study the causes and consequences, and ultimately, design a world with greater safety, reliability, security – and *confidence* – built in.

NEWS Notes

RESEARCH FOCUSED ON ECONOMICAL, LONGER-LASTING LITHIUM ION BATTERIES

Efforts by a team of Sandians to improve the lithium ion battery may mean that one day soon people will be driving affordable electric cars and operating their CD players and cellular phones on smaller, longer-lasting batteries.

The research combines a new mixture of metals to create the cathode portion of the lithium ion battery – a high-tech, environmentally friendly electrical-energy-storage device.

"We've tried various combinations of lithium (a light-weight metal) with manganese, cobalt, nickel, chromium, and aluminum and are making some breakthroughs," says Sandia inorganic chemist Tim Boyle.

If the right combination of materials can be found, lithium ion rechargeable batteries may become economical enough and have a long enough run time to be practical to power electric cars or replace existing traditional lead-acid batteries. Lithium ion batteries are commonly found in laptop computers and camcorders. Their use, however, is limited to small electronic devices because of their cost and safety concerns.

Contact: Tim Boyle
505-272-7625
e-mail: tjboyle@sandia.gov

SURETY INSTITUTE: An Enduring Forum

An American Institute for Surety Science and Engineering is slated to provide a clearinghouse for surety information. It will link researchers from government, academia, and industry with one another as well as with data and cutting-edge tools. The Institute will drive surety science and engineering as a discipline applied to problems affecting mainstream life and American infrastructures. As applicable, the Institute will house databases, web sites, and a library, and will offer awards for breakthroughs. It will also support university courses, technology transfer, and research-and-development partnerships. Technological and theoretical advances will be applied to solve real-world problems, ranging from economic to environmental issues and much in between.

For more information, contact Ted Dellin (505) 844-2044; email: dellinta@sandia.gov. Or Ray Bair (505) 296-3505; email: bair@compuserve.com. Or visit the Institute Web site at www.isse.org.

Neutron tube bake station

SURETY METHODOLOGY WORTH DEVELOPING?

National Workshop Votes Yes

What united these challenges was the need to predict and prevent accidents and the crippling consequences that system failures cause.

Representatives from industry, academia, and government convened last fall in Washington, D.C., to consider a new discipline at the first-ever Surety Science and Engineering Workshop. Orchestrated by Sandia National Laboratories and co-sponsored by the U.S. Department of Energy, National Academy of Engineering, and National Academy of Sciences, the workshop explored the methodology of surety science and engineering and its potential uses to address some of the nation's most pressing problems.

What united these challenges was the need to predict and prevent accidents and the crippling consequences that system failures cause. Many Sandia researchers believe a new discipline, called surety science and engineering, has evolved from their work to protect the nation's nuclear stockpile. They further believe the discipline can be applied to many national and global problems, such as protecting our nation's critical infrastructures, making our air transportation system safer, improving the reliability of electronics, and even fighting crime (see cover story).

More than 100 experts from government, industry, and academia brainstormed on how surety science and engineering principles can be applied to national problems and whether it can be considered a new discipline. Helping to lead the discussion was William Wulf, president of the National Academy of Engineering (see Insights, inside back cover); Vic Reis, DOE assistant secretary for Defense Programs; and Pace VanDevender, Sandia's chief information officer. At the end of the workshop, most attendees felt surety science and engineering has great potential, although they determined much work remains to be done.

AMERICAN INSTITUTE FOR SURETY SCIENCE AND ENGINEERING

"The workshop gave us a strong vote that surety science and engineering does have broad applicability beyond its original roots in nuclear weapons," said Joan Woodard, workshop chairperson and Sandia vice president of Energy, Information, and Infrastructure Technology Division.

Navigating Computational WRONG TURNS

Sandian Stephen Bespalko is developing a technology to manage ambiguous data. He calls this advance mission surety for large-scale, real-time information systems. Bespalko's concept allows researchers to backtrack and recover when designing algorithms that must process data containing errors.

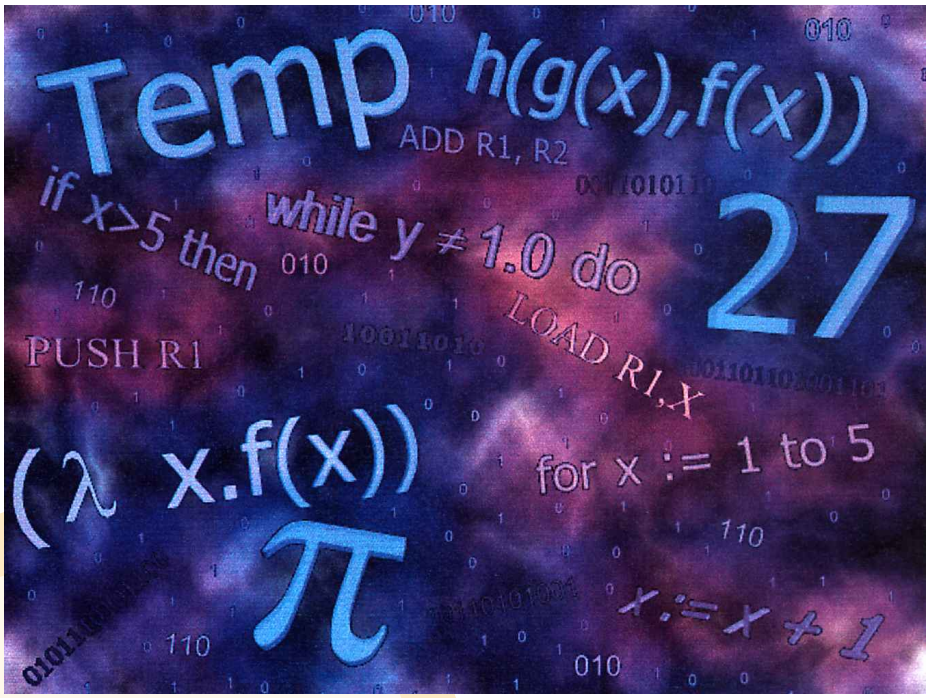
"Military and defense applications must deal with ambiguous information and/or data with errors," said Bespalko. He is creating a technology that determines if decisions based on incomplete or inconsistent data or data with errors are still correct as new information is received.

"Say, you're driving to a city and come to a fork in the road, and the roadsign is partly covered," Bespalko said. "You're at a fork where everyone always gets confused, and you take a wrong turn because you only see half the sign. You have to make a decision at the intersection, but the decision may be wrong because you don't have enough information. Then you go the wrong way until you see a sign that makes it clear you have to turn around and go back."

With Bespalko's software, the engineer can design a system that *can* go back. Recovery is built into the technology, into the problem-solving process.

"Before, systems would ignore the errors or eventually throw out the results and start over when it became clear the system had made a big mistake," Bespalko said. "And sometimes you wouldn't know till you drove to the wrong city."

Mission surety technology allows the software to detect the wrong turn as soon as possible, figure out how far back the decision-making process has to go, backtrack, then continue down the correct path.



Recovery is built into the technology, into the problem-solving process.

Benefits include greatly reducing development costs for certain information-intensive defense systems. Defense-system cost is a major concern. The U.S. Air Force has set a goal of reducing the cost of developing command-and-control systems by 90 percent. Mission surety supports that goal.

In addition to defense applications, the software has many other uses, particularly those involving spatial data. With undergraduate assistant Holly Dison from the University of New Mexico mathematics department, Bespalko is adapting his technology to make less expensive and more accurate models of roads and other large components of the nation's infrastructures.

Mission surety is attracting attention worldwide. Last fall Bespalko spoke at a software-engineering symposium in Zurich, Switzerland. He has also addressed a National Academy of Sciences meeting about transportation uses as well as speaking to other international audiences about his ideas.

Laboratory Directed Research and Development (LDRD) funding has supported Bespalko's software engineering advance. LDRD is an exploratory research fund that supports national security and enhances Sandia's technology base. The LDRD program is dedicated to early exploration and exploitation of innovative concepts that arise during laboratory work.

Walking on Eggs

during and after the Cold War

Surety science and engineering has its origin in Sandia's mission of nuclear-stockpile stewardship, which includes safeguarding nuclear technologies as well as the associated infrastructure. Indeed, all things nuclear must be safe, reliable, and secure.

Yet potentially catastrophic incidents, extending back 40 years, have demonstrated that, despite layers of well-studied precautions, accidents still happen. From the beginning, Sandia has researched and refined surety science and engineering to prevent further such incidents. The following examples demonstrate the need for surety science and engineering.

[*Indeed, all things nuclear must be safe, reliable, and secure.*]

May 1957,
South of Albuquerque, N.M.

A B-36 aircraft carrying an atomic bomb approaches Kirtland Air Force Base to land. When the plane is at an altitude of 1,700 feet, the bomb drops through and tears off the bomb-bay doors. Although the attached parachute opens, the weapon hits the ground with enough speed to set off the high-explosive charge – but not the nuclear component – destroying the bomb and leaving a crater 12 feet deep and 25 feet in diameter.

Radiological survey of the area discloses no radioactivity beyond the lip of the crater at which point the level is 0.5 milliroentgens. There are no health or safety problems. Both the weapon and capsule were on board the aircraft but the capsule was not inserted for safety reasons. A nuclear detonation was not possible.

January 1966,
Palomares, Spain

A B-52 and KC-135 collide during a routine high-altitude air-refueling operation. Both aircraft crash near Palomares, Spain. Four of the 11 crewmen survive. The B-52 carried four nuclear weapons. One is recovered on the ground, and another is recovered from the sea on April 7 after extensive search and recovery efforts. Two of the weapons' high-explosive materials explode on impact with the ground, releasing some radioactive materials. About 1,400 tons of slightly contaminated soil and vegetation are removed to the United States for storage at an approved site. Representatives of the Spanish government monitor the cleanup operation.

January 1968,
Thule, Greenland

On approach to land at Thule Air Force Base, a B-52 carrying four nuclear bombs catches on fire and crashes during an attempt to land. Six of seven crewmen eject safely. Fire destroys all four weapons. Some 237,000 cubic feet of contaminated ice, snow, and water, with crash debris, are removed to an approved storage site in the United States over the course of a four-month operation. Although an unknown amount of contamination is dispersed by the crash, environmental sampling shows normal readings in the area after the cleanup is completed. Representatives of the Danish government monitor the cleanup operation.

NEWS *Notes*

NATIONAL SCHOOL SECURITY TECHNOLOGY CENTER BASED AT SANDIA

Sen. Jeff Bingaman, D-N.M., has announced the establishment of a new national center of expertise in school security technology to be based at Sandia National Laboratories in Albuquerque. Funding to establish the School Security Technology Center is included in the FY99 spending bill as part of Department of Justice appropriations. Sandia will be invited to apply for $1.4 million.

The initiative seeks to make the nation's school grounds safer for thousands of elementary, middle, and high school students by improving security on hundreds of school campuses. Efforts to improve school security have intensified following recent shootings at campuses across the country. The Center will draw on Sandia's decades of experience designing and evaluating security systems as part of its DOE mission to protect materials vital to U.S. national security.

In the spring of 1996, Sandia security technology experts first recommended a set of measures to address a variety of problems at Belen High School in New Mexico. Since then Sandia has advised administrators at dozens of other New Mexico schools and at more than 100 schools nationwide.

Contact:
Mary Wilson Green
505-844-7746
e-mail: mgreen@sandia.gov

COMPUTER PROGRAM 'SEES' BEYOND 3-D TO BETTER CLASSIFY DATA

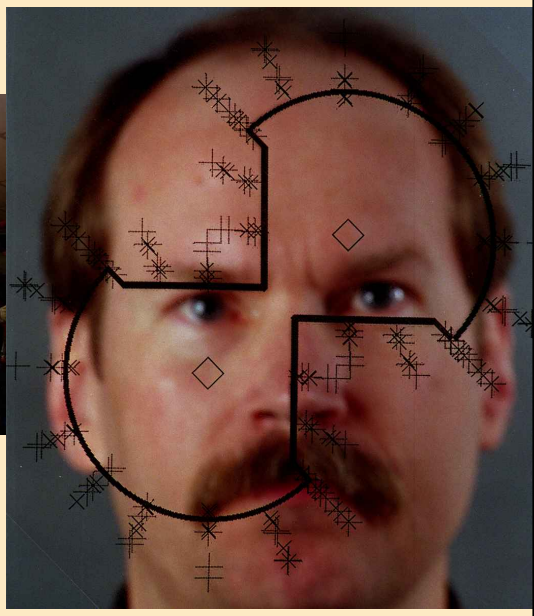
A sophisticated new data classification scheme is being incorporated into the design of Sandia National Laboratories' hand-held "lab-on-a-chip" chemical sensor system.

The classification method – based on human perception rather than mathematical equations – is so simple that it can be hard to grasp for those who expect complexity.

It is based on the human ability to visually group real-world objects seen near each other, says the technique's principal developer, Gordon Osbourn. "In the area of visual perception, no computer has ever matched a biological system – for example, a dog's or a two-year-old's," says the Sandia physicist.

Osbourn says the program is based on people's tendency to group objects within the confines of a dumbbell. The subconscious mind sizes the dumbbell so that each bell centers on a point. If no other point intrudes in the space, one considers the two points a group, he says.

But while biological visual systems are limited to analyzing two-dimensional plots or 3-D patterns, Osbourn's system offers the opportunity to "see" in many "dimensions," in effect cross-analyzing patterns among many data sets. The same empirical judgments made by human eyes are made by a computer program to judge closeness among the points of many groups of data. The relations between data may be too complex for a human to see, but the same empirical process used in human decision-making is followed in the computer program.



Gordon Osbourn

"In the area of visual perception, no computer has ever matched a biological system."

Because the technique is based on observation of how people empirically group objects they see, it is called VERI, for Visual-Empirical Region of Influence. A patent is expected to be issued this year.

Contact: Gordon Osbourn
505-844-8850
e-mail: gcosbou@sandia.gov

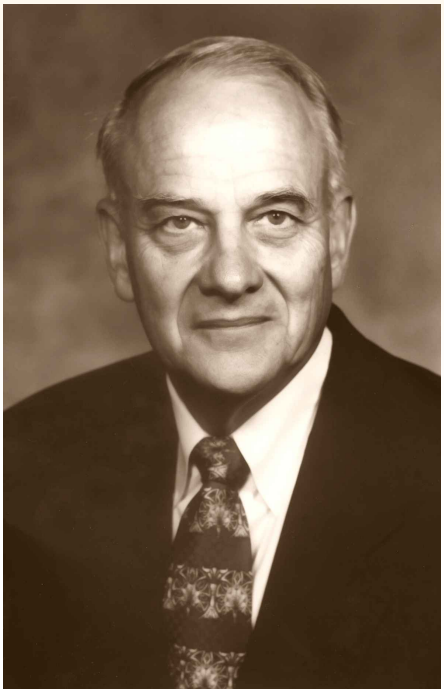
INSIGHTS

by Dr. William Wulf, President, National Academy of Engineering

The power grid fails on theWest Coast, the 911 number is jammed in Atlanta, and a bank is having something else happen in Chicago. Are we under attack?

**The world that we're about to enter is one that's very different from the world that we prepared for during the Cold War.* Then we knew who all the players were and what the rules were. Today, the dramatic reduction in the cost of a cyber attack, the proliferation of weapons of mass destruction, and the blurring distinction between states and terrorist groups make it extremely difficult to know with certainty either the rules or the players.

Indeed we may not even know we're under attack. The power grid fails on the West Coast, the 911 number is jammed in Atlanta, and a bank is having something else happen in Chicago. Are we under attack? There probably isn't a single individual who knows that those things are going on, much less has any way of determining whether they are a single concerted attack.



Dr. William Wulf, President, National Academy of Engineering

The most challenging of the problems in this new world arise because they are not "just technical issues." They are mixtures of technical issues with people issues, with social issues, and with policy issues. Whether the subject is global economic interdependencies, the cost and priority of fixing aging infrastructures, or chemical or biological threats – they all have technical, social, and policy components.

Furthermore, all this is happening in a context in which technology is changing extremely rapidly. Indeed it is the speed with which the technology is changing (and our dependence on it correspondingly increases) that lends great urgency to addressing these challenges. The cost of an attack in cyber space is falling dramatically, while the consequences are rising just as rapidly. The longer we delay in addressing the problem, the worse it gets.

Our national leaders are beginning to grope with these issues, but they are both very complicated and very different from those of the past. We don't have the legal or conceptual structure to deal with some of them. For example, in this new world there is, and must be, a blurring between law enforcement and national security – yet current law strictly divides what our military can do from what our law enforcement agencies can do. As another example, we have profound issues of how to manage these new threats without destroying the openness in our society or violating the privacy of our citizens – that is one of the fundamental disputes in the debate over national cryptographic policy, for example.

The Academies (National Academy of Sciences, National Academy of Engineering) provide independent balance and authoritative advice to the federal government. These are almost always on policy-related issues with a strong technical component. For example, Presidential Directives 62 and 63 were written in response to the report of the President's Commission on Critical Infrastructure Protection. The directives call for the Academies to convene a roundtable on the subject.

"Roundtable" is a term of art in the Academy context. It's a standing committee that includes industry, university, *and* government people. Normally we exclude government people from situations where we would be giving advice, since we don't want the government giving advice to itself and putting the imprimatur of the Academy on that advice in the process – so roundtables don't provide advice to the government. However, they *do* provide a forum in which the issues can be discussed, in which various perspectives can be brought into play and where we can decide whether we need to spin out a study on a specific issue.

When Pace VanDevender and Eric Bloch came to see me about this workshop on surety science and engineering, I jumped at the chance to host it here at the NAE. This is a wonderful first step in what is going to be a long journey, and it's a long journey on which we must move out smartly. The technology of attack is outpacing the technology of defense, and the technology is moving at the speed of Moore's Law (doubling every 18 months). So this is an extremely important meeting, and I'm delighted that we could co-host it.

■

**Excerpted from talk given at Surety Science and Engineering workshop.*
(see page 9)