Intelligent Machines Are Getting Smarter

Sandia Robots May Help in Environmental Cleanup, Handle Dangerous Tasks, Make Manufacturing Less Costly

"Dependable workers, but not too bright." That could describe some types of industrial "workers" today — not human workers, but industrial robots used on automotive assembly lines and in other mass-production situations. A new generation of "smart" robots is being developed, however, and Sandia has become a leader.

"This new generation of robots will have tremendous potential," says Pat Eicker, manager of Computer Sciences Dept. 1410. "These machines will have the 'ability' to program themselves to do different tasks, react autonomously to unexpected conditions, and eliminate the need to risk human lives in dangerous environments."

Smart robots could be extremely useful at many DOE facilities, according to Ed Barsis, Director of Computer Sciences and Mathematics 1400: "Among other tasks, they could handle life-threatening hazardous wastes, do certain types of environmental cleanup, and reduce manufacturing costs at weapon-production facilities."

Sandia began research into development of robotic systems to handle radioactive waste several years ago when DOE's Office of Civilian Radioactive Waste Management requested assistance with designing the Yucca Mountain repository, proposed for construction in Nevada after the turn of the century.

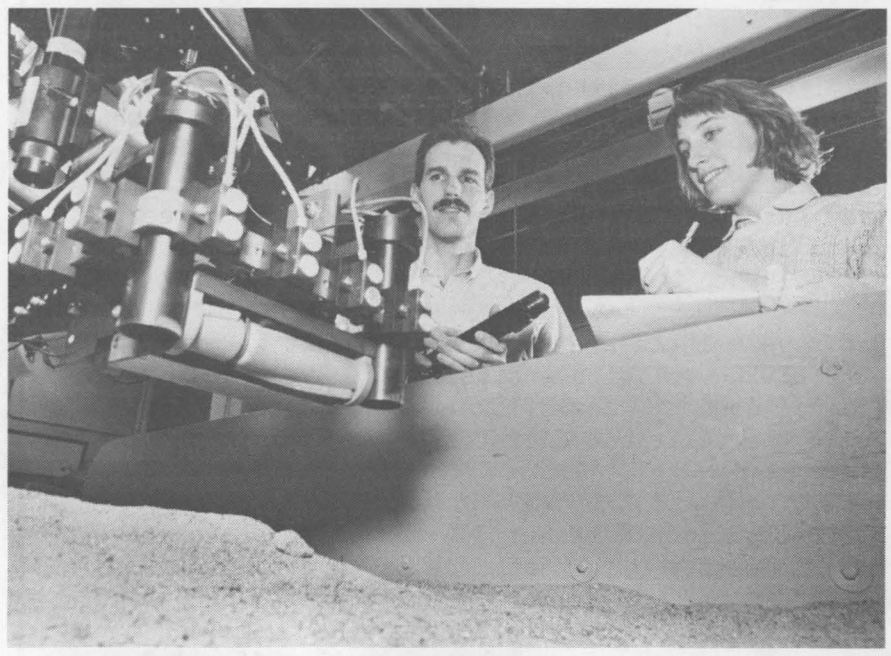
This design work is part of a larger effort in waste management run by Nuclear Waste Repository Technology Dept. 6310 and Transportation System Development Dept. 6320. Sandia now has the responsibility for planning, as well as carrying out, much of the robotic research and development for the cleanup of hazardous waste sites.

"This new generation of robots will have tremendous potential."

Sandia is collaborating with Oak Ridge National Lab, which is responsible for planning the testing and evaluation of prototype robotic site-cleanup systems.

Development of robots to help produce nuclear weapons dates back several years at Sandia. In 1985, Sandia participated in the so-called "2010 Study," a series of projections on the state of the Nuclear Weapon Production Complex 25 years in the future. Since then, Sandia has developed strong ties with the DOE plants, and is transferring technology to Savannah River, Y-12, Pantex and Rocky Flats.

(Continued on Page Four)



DANGEROUS JOB — An instrumentation package developed by Sandia enables this robot, monitored by Brian Christensen and Jill Werner (both 1414) to develop a 3D map of a simulated underground waste repository, including locations of tanks and other equipment.

'A Real Leadership Position'

"The advancements that our people have made — and continue to make — have put us in a real leadership position in developing smart-robotics technology," says Ed Barsis (1400). "And we see many potential applications in industry, as well as in the DOE complex. US manufacturers could adopt and adapt the technology to make their operations more efficient and thereby more competitive in the world market."

LAB NEWS

VOL. 42, NO. 5 SANDIA NATIONAL LABORATORIES MARCH 9, 1990

Sandians' Achievements in High-Temperature Superconductors Win Materials Sciences Award

Since their discovery in 1986, high-temperature superconductors have caused feverish activity among researchers worldwide. Waves of optimism and pessimism have alternated, reflected in article titles ranging from "New Superconductors Come Through" to "Superconductivity: Is the Party Over?" (both in *Science*, within the space of a year).

In the meantime, research into one family of high-temperature superconductors (see "Magnetic Properties Are the Key") has brought a Sandia team an award in DOE's 1989 Materials Sciences Research Competition, sponsored by the Division of Materials Sciences, in DOE's Office of Basic Energy Sciences (BES). The award-winning team consists of Dick Baughman, Dave Ginley (both 1144), Jim Kwak (1152), Bruno Morosin (1150), and Gene Venturini (1152). Their research is titled "Development of Tl–Ca–Ba–Cu–O High-Temperature Superconducting Thin Films and Demonstration of Novel High-Performance Devices."

The award, Sandia's fourteenth during the nine years of the competition, is in the solid-state physics category designated "Significant Implications for DOE-Related Technologies." (This year, two awards were made in that category — the other went to Argonne National Lab.)

Although many important uses of the new superconductor materials and device prototypes are probably still unforeseen, they appear to offer improved performance in applications such as high-speed communication systems and sensitive magnetic-field detectors.

Thallium Superconductors

"The award is for our work on the thallium [Tl] system of superconductors, our understanding of what's going on in them, the initial demonstration that they could be used in prototype electronic

(Continued on Page Eight)

Sandia Continues Its Lead

Since the first Materials Science Research Competition in 1981, Sandia has won at least one award every year except 1982. The Sandia total now stands at 14 — including 10 in the five competitions since 1985. Two other DOE labs have each won seven awards since 1985, the second-highest total for that period.

WEARING LAB ATTIRE over his team T-shirt, Ron Hellmer (1144) puts a sample into a furnace, as Ted Castillo (1152) and Mary-Anne Mitchell (1144) observe.

This & That

Just Because I'm a Nice Guy – I'm not going to reveal the name of the Sandian who recently sent a business letter to the New Mexico Network of Women in Science and Engineering and used the *sometimes* safe generic greeting "Gentlemen:"

* * *

Focus on "Sandia West" – Sandia, Livermore – particularly the Combustion Research Facility – has worked closely with industry for about 15 years to speed the commercialization of Labs technology. New tech-transfer tools – laws and Sandia policy – "are especially valuable in giving Sandia a way to join our country's effort to revitalize its industrial strength and competitiveness," says Peter Mattern, Director of Combustion and Applied Research 8300. We feature Livermore's work with industry in this issue (see middle section). LAB NEWS writer Charles Shirley wrote the copy and coordinated the project, with help from lots of Livermore folks.

* * *

Retiree Seniority Record-Holder Dies – William P. "Bill" Thomas of Albuquerque died Feb. 14. When he retired in 1988, Bill had accumulated 43.3 years of Sandia service, counting several early years at LANL where he hired on as a 17-year-old technician. When he retired, the 43+ years was a Sandia record; it remains so for retirees, although several still-active Sandians have now surpassed it. Bill spent most of his career in manufacturing development and quality assurance. He was supervisor of Quality Assurance Div. 7251 when he retired.

* * *

Bad Times for Bad Boys – There are two subjects that we avoid "religiously" in the LAB NEWS – religion and politics. But world events prompt one little political comment. Seems like the world is getting mighty tough for those in the political dictator business. Ain't it just wonderful!

* * *

Spelling Breach – Phrase from a recent job announcement in the Sandia *Weekly Bulletin*: "A measure of performance in this position is the lack of security breeches and violations. . . ." Several Sandians brought that one to my attention. I think there's another name for those types of breeches – used in medieval times – but this is a "family" newspaper, and I don't want to be "chastised" for being crude.

* * *

Mascots/Nicknames – Unless I hear about any real zingers, we'll wrap up the unusual school mascots/nicknames with this list: Paul Klarer (5267) and Jackie Hines (9334) both sent notes mentioning the Hutto (Tex.) Hippos; Paul didn't say if he's a "Hippograd," but Jackie started grade school in Hutto. Herb Pitts' (3100) high school days were spent as a Chickasha (Okla.) Fighting Chick. Don Charlesworth (8531) was a Westminster Martlet (small European swallow) in Simsbury, Conn. Barry Schrader (8522) is an alumnus of the Genoa (Ill.) COGS (for Community of Genoa Schools). Retiree Wright Van Deusen's daughter graduated from Pomona (Calif.) College – the Sage Hens. R.C. Harris (husband of Sandia retiree Dollie Harris) was a Ralls (Tex.) Jackrabbit, along with retiree Brooks Lee King. Susan Kato (2826) is a graduate of Phillips University (Okla.) – the Haymakers. Susan says the *unoffical* school mascot was a skunk because "if a skunk went to college, they'd call it PU!" Whew, that stinks, Susan.

•LP

Earnings Factors December 1989

Savings Plan for Salaried Employees (SPSE)	Earnings Factors
AT&T Shares	1.0456
Government Obligations	1.0035
Equity Portfolio	1.0251
Guaranteed Interest Fund	1.0072
South Africa Restricted Fund	1.0042
Diversified Telephone Portfolio	
Unrealized Appreciation	1.1111
Realized Appreciation	.0069*
Savings and Security Plan — Non-Salaried Employees (SSP)	
AT&T Shares	1.0455
Guaranteed Interest Fund	1.0072
South Africa Restricted Fund	1.0068
Diversified Telephone Portfolio	
Unrealized Appreciation	1.1042
Realized Appreciation	.0065*

* The 1 has been removed from the earnings factor. Current month's DTP earnings may be calculated directly: Earnings Factor x DTP Current Worth = Current Month's Earnings.

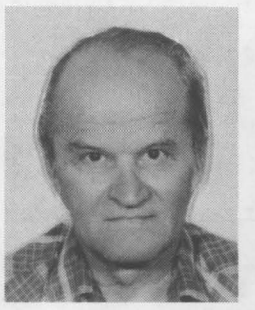
EMPLOYEE DEATHS

Irene Aiuto, shop clerk in Metal Forming and Preparation Sec. 7482-4, died Feb. 7.

She was 63 years old.

Irene had been at the Labs since June 1976.

She is survived by two sons and two daughters.



Ralph Schellenbaum, senior member of technical staff in Systems Engineering Div. 5248, died Feb. 9 after a long illness.

He was 62 years old.

Ralph had been at Sandia since September 1953.

He is survived by his wife, daughter, and two sons.

LAB NEWS

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CAMERA CREW shooting footage for a "Nova" program on high-tech devices in the electronic battlefield visited the Labs' Robotics Range last month. Here, they're lining up some shots of a prototype Teleoperated Mobile Security Station (TMSS) developed and built at Sandia by Advanced Technology Div. 5267. The TMSS, an unmanned, mobile sensor platform that could be used for reconnaissance as well as security protection, transmits video, acoustic, infrared, and radar information to a remote monitoring station. Bryan Pletta (5267) is TMSS project engineer. The public-television program's feature on electronic battlefield applications will air next fall. Public Information Div. 3161 folks hosted the Nova crew.

DOCUMENT CUSTODIANS whose work resulted in a perfect score during the recent DOE audit of more than 1700 documents pose on the Computer Center patio at Sandia, Livermore.

One of the Best Among DOE Facilities

Document Accountability System Gets Perfect Score

A recent audit by DOE's San Francisco Operations Office Safeguards and Security Division gave Sandia Livermore's document accountability system a perfect score.

DOE Security Survey Team Leader Don Thompson made extremely positive comments at the closeout meeting after the two-week site security survey was completed. He complimented Sandia's document custodians on their work in the classified document control areas, saying, "They know what to do and how to do it, and we could find no discrepancies in all the stations we surveyed."

Using a random survey technique, more than 1700 documents were physically inventoried at 43 accountability stations throughout the laboratories, and 100 percent were located.

". . .we could find no discrepancies in all the stations we surveyed."

Sharron Norris, supervisor of Mail Distribution and Document Control Sec. 8524-1, says, "This shows that our earlier LDAS (Livermore Document Accountability System) training paid off handsomely. We designed and instituted a computerized document control program beginning in February 1988 that proved to be one of the best among DOE facilities. That fact is evident when we get audit results like these."

Marlin Pound, manager of Administrative Services Dept. 8530, also has high praise for the people who operate the 87 document accountability stations: "The success of the survey can be directly attributed to the conscientious efforts and dedication of the people who perform this important custodial function. It's a team effort within the organizations, but it is the document custodians who really bring it together and have made it the program it is."

Don Charlesworth, supervisor of Physical Security Div. 8531, adds, "Our document accountability system has also been enhanced by an internal audit and evaluation program that was implemented in June 1987 by Division 8531. Through this program, our document auditor, Marge Mederios (8531), has worked closely with the document custodians to effectively prepare for outside audits." •

Happy Holidays

Spare a thought for those unfortunate office workers who never go on holiday because they fear the pile of post and problems that will surely await them on their return. Author Denys Parsons thought about this when he was press officer for the British Library.

Parsons found it always took one week to get things straight after one week's holiday. So why not, he suggested, let everyone work only every other week? That way, everyone would get just as much work done, but have 26 weeks holiday a year. History does not record the library's official reaction.

New Scientist

The Book as Fetus

In *Sociobiology and Behaviour,* David Barash thanks someone — presumably an obstetrician — for assisting "in various aspects of labor and delivery" of his literary offspring. Readers of *The Molecular Biology of the Cell,* by Bruce Alberts [et al.] must wrestle with the information that the book "has been a long time in gestation — three times longer than an elephant, five times longer than a whale." (The answer to this reproductive riddle is 5.5 years.)

Stephen Young, *New Scientist*

SANDIA LIVERMORE NEWS

Tiger Team Visits This Month

A DOE Tiger Team will visit Sandia, Livermore, for a pre-assessment briefing on March 27-28. At this time they will meet with management and Environment, Safety, and Health Dept. 8540 people to discuss the scope of the planned site survey.

The full ES&H site assessment will be conducted by DOE from April 30 through May 18. The visit is part of a nationwide effort initiated by DOE Secretary James Watkins to inspect all DOE facilities to evaluate ES&H and waste management compliance with all state and federal agency requirements.

Representatives from state and federal regulatory agencies have been invited to observe the Tiger Team's site assessment. The team is composed of three elements — environmental, management, and safety. At the conclusion of the full team's visit, a draft report will be issued on Sandia's compliance.

Fun & Games

Clarence Rogers (8513) shot his first hole-in-one while golfing at the Springtown Golf Course on Feb. 25. Clarence, who shoots in the high 80s, says he used a 9-iron to make the 100-yard-shot over the water on Hole No. 6. He was in a foursome, but was not involved in tournament play at the time. His name will be listed with the National Golf Association, and he will get a wall plaque in which to place the ball. Clarence is active in the Sandia Employees Golf Club and has been a golfer for 15 years.

Take Note

Martha Campiotti (8270) participated in a marathon aerobic dancing event for charity recently and raised $432 for the American Heart Association.

Martha was among 11 dancers at the Tracy Recreation Center on Feb. 24 who danced for a full 2 hours to fulfill the pledges she had collected from Sandians in several departments, totaling 50 people. She received an exercise mat, sport bag, and sweat shirt for her fund-raising efforts.

(Continued from Page One)

Smart Robots

Because of the similarity of some of the nuclear weapon production processes to those of manufacturing in general, such as the machining of metals or the assembly of parts, private industry is becoming interested in Sandia's robotic R&D. "Sandia is eager to transfer appropriate technologies to American business," says Ed, "and we've already begun doing that."

GM Expresses Interest

For example, a General Motors executive who recently visited the Labs expressed interest in the Archimedes computer program that enables a commercially available robot to program itself to assemble machine parts without human intervention (LAB NEWS, Jan. 12, 1990). Developed by David Strip (1412), the program directs the robot to use computer vision to locate and assemble flat cogs and pins in the proper order to produce a strong-link weapon component. The same principle can be applied to the assembly of shock absorbers and alternators, for example.

In another case, Pratt & Whitney is receiving help from Sandia roboticists in the precision grinding of edges on jet-engine turbine wheels.

Like Archimedes, the edge-finishing — or deburring — robot system, developed by Cliff Loucks and Colin Selleck (both 1411), augments a commercial robot with computer models and instrumentation to provide flexibility for the batch production that's typical of DOE manufacturing.

Using a Computer-Aided-Design (CAD) program, based on the model from which the part was originally machined, the robot computer automatically generates a motion plan and the instructions for approaching the part and finishing the edges. It automatically grinds all edges that need to be finished, relying on computer vision and force control to precisely position the cutting tool on the part.

"Sandia is eager to transfer appropriate [robotics] technologies to American business."

The force sensor also compensates for tool wear and changes in the robot's position by responding to the amount of resistance on the tool rather than relying on the precise position of the tool.

"Automatic planning and programming, along with sensors that eliminate precise fixturing and jigging, make the manufacture of small batches of products much more cost-effective," Ed explains. "Otherwise, the expense of retooling and reprogramming a robot every time a manufacturer wants to produce a new item makes robots too costly to use."

Robotics: A Good Fit With the Tech Base and Corporate Culture

"A few years ago, it was obvious that site cleanup would be a big deal for the DOE, long before there was the official program that exists today," says Pat Eicker (1410). It was just as obvious that advanced robotic technologies would be required.

"We did some strategic planning and saw that Sandia's technology base could be applied to these problems. We were well positioned when the Office of ER&WM was formed last year.

"Similarly, this work, in addition to Sandia's manufacturing R&D, will open up new vistas to the Labs. There is talk of a national manufacturing initiative, and we'll be well situated for leadership in that effort. Real manufacturing flexibility is a goal of many industrial competitiveness proposals, and the use of robots for the cost-effective manufacture of small batches of products is one of the primary targets of our research.

"Mining robots, construction robots, and health service robots are other areas that could be important to the country. Interestingly, robotic planetary exploration has similarities to some of the work we are involved in for environmental restoration.

"Robotics fits well with Sandia's corporate culture because it's a systems science and we think of ourselves as a systems engineering place. If you ask Sandians what the Labs are good at, many will say the integration of science and engineering into useful systems."

It is these aspects of Sandia's research that will be at the heart of the new generation of robots, he adds.

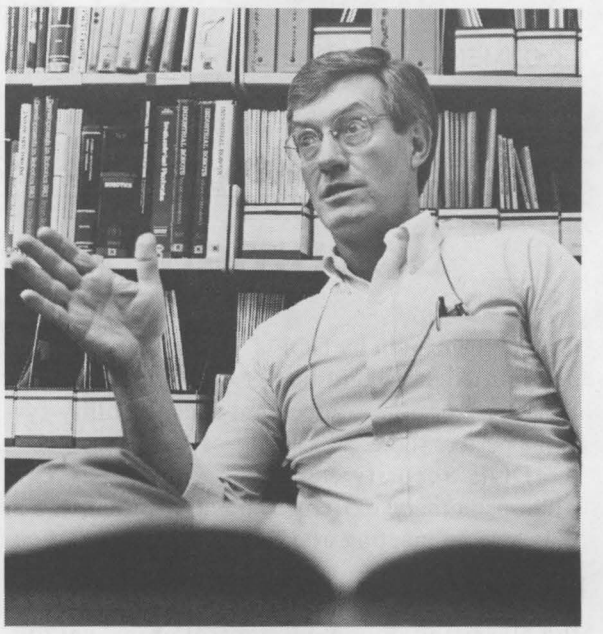
Without the capabilities of the Sandia robot, every object in the manufacturing process, including the robot itself, the deburring tool, and the parts to be chamfered (beveled), would have to be precisely positioned, or the robot's computer program would have to be changed, according to Jamie Wiczer, supervisor of Intelligent Machine Principles Div. 1411.

The work with Pratt and Whitney is part of a Technology Maturation Project sponsored by Technology Transfer Dept. 410. Pat Eicker says other industrial collaborations are in the works, including ones with the National Center for Manufacturing Sciences and with a leading American manufacturer of products completely unrelated to Sandia's traditional responsibilities. These collaborations are in agreement with the results of a study chaired by Paul Erickson, Supervisor of Software Techniques Div. 1412. That study identified ways in which the DOE weapon complex is a microcosm of US industry.

Robots That Do Environmental Cleanup

Recent public concern about underground leakage from hazardous waste deposits around the country is leading to the development of robots at Sandia that will be used by DOE in the removal and transport of radioactive materials.

The goal of the recently established DOE Office of Environmental Restoration and Waste Management (ER&WM) is to clean up radioactive and chemical wastes from disposal sites that have existed since DOE first began building nuclear weapons in the 1940s, says Pat, who led a technical team that reported to DOE on the role of robotics in the cleanup effort.



TEAM LEADER — Pat Eicker, manager of Computer Sciences Dept. 1410, headed a group of experts that reported to DOE last summer on the use of robots in environmental restoration.

"What we're doing in the area of environmental restoration is using robots where it's hazardous for people to go," he notes.

One of the cleanup projects under way at Sandia involves the development of robotic technology for mapping and removing waste from leaking underground storage tanks. Several DOE sites have these tanks. The tanks at Hanford, Wash., where chemical and radioactive waste from plutonium production have been stored, are of particular concern.

In addition to chemical wastes, these tanks contain contaminated internal structures such as pipes and other kinds of solid waste.

The use of computer models and sensors will allow the waste to be removed more quickly and safely than if a standard remote manipulator were used. In this case, however, no CAD model of the tank and its waste is available to guide the robot.

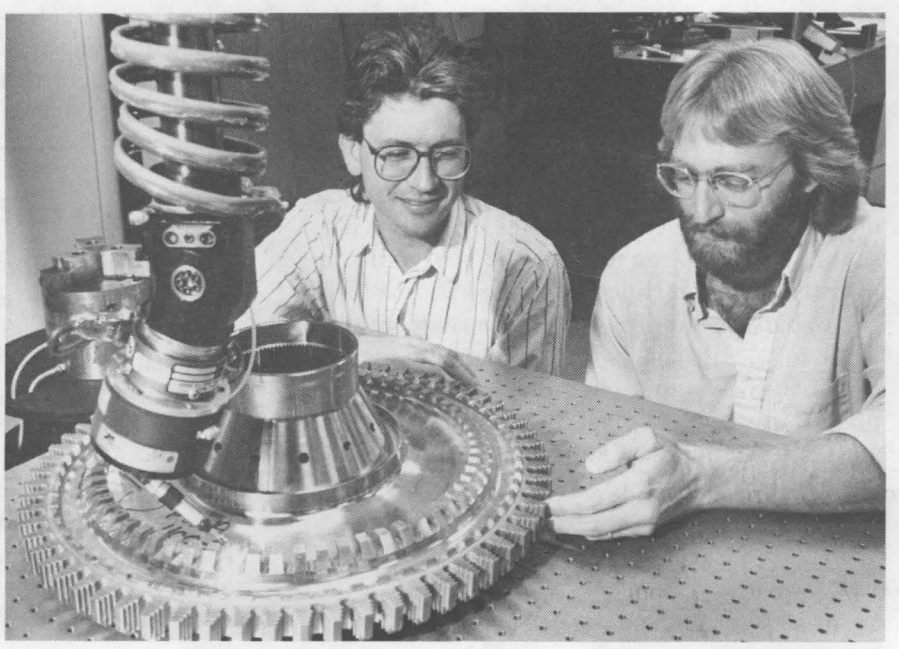
DOE Demonstration Scheduled

Instead, the robot — using a variety of sensors — must develop a map that it will use later to automatically develop programs to remove the waste. In a prototype system being developed for demonstration to DOE officials in early April, a combination of ultrasonic sensing, computer vision, metal detectors, and ground-penetrating radar will be used to make surface and subsurface maps of a simulated underground storage tank.

The system, being developed in Divisions 1414 and 7552, uses a high-performance graphics workstation as the user interface.

In the April demonstration, the workstation

(Continued on Next Page)



CUTTING EDGE — Colin Selleck (left) and Cliff Loucks (both 1411) show how the deburring robot, unassisted by humans, grinds edges to precise manufacturers' specifications.

RIPE for Robots

Language Simplifies Robotic Programming, Improves Software Reliability

Computer programmers doing robotic programming have typically had to learn a new computer language for each new type of robot that is manufactured, but no longer. Sandia computer scientists have designed a new software system that eliminates this need and provides a convenient environment for programming. Called RIPE, for Robot Independent Programming Environment, the software is object-oriented and a model for the way a programmer visualizes the system.

"You're defining the objects independent of any particular application of them," says Dave Miller, who co-developed RIPE with Charleene Lennox. Both are computer scientists in Intelligent Machine Systems Div. 1414, one of three divisions in the Computer Sciences Department that collaborate in an extensive robotics research program.

Incorporating Generic Aspects

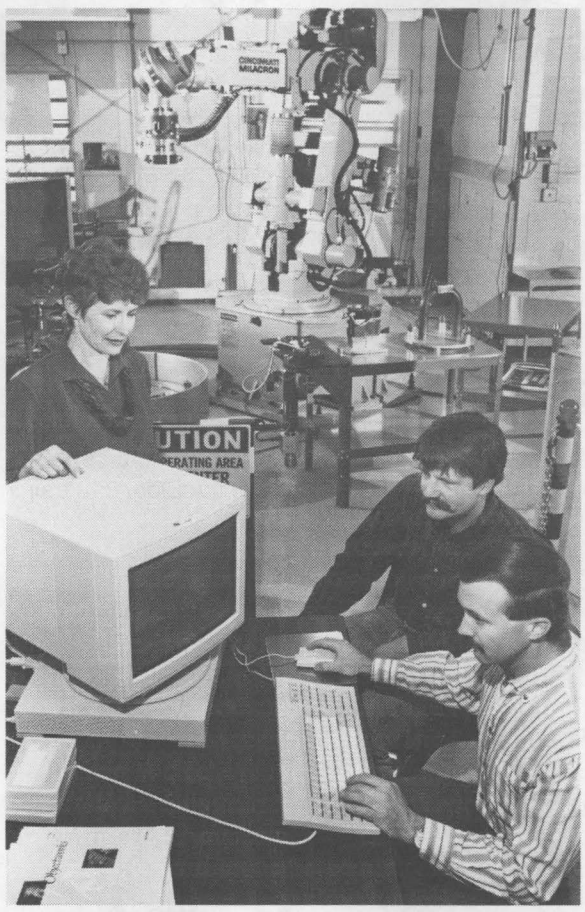
"All robots perform the same basic functions, and so the idea was to find the generic aspects of all these projects and incorporate them into the software environment," Dave adds.

In addition, similar to the way a foreign language must be translated to be understandable, the software system includes a master computer language called RIPL, for Robot Independent Programming Language, that gives generic commands, such as "move," "pick up," or "send message," that all robot systems must execute.

Because it eliminates the need to rewrite instructions in different languages, the software improves the productivity of computer programmers and speeds the process of bringing new robot systems into use.

The same software can be used again and again because it utilizes objects that are typically handled by robotic systems, such as grabbers, sensors, tools, the robot itself, and work pieces, along with their attributes and functions, all of which are defined in the data base.

Dave explains: "RIPL is a programming language like any other programming language, such as FORTRAN, LISP, or COBOL. It's the physical means by which a programmer makes the robot do what the programmer wants. RIPE is the programming model. It's the way the programmer thinks about the system. Once you define this programming model and the way you're going to think about the parts in the system, then the programming language sort of automatically falls out."



TESTING — Computer scientists Charleene Lennox, Bill Davidson, and Dave Miller (from left, all 1414), developers of the RIPE software, give computer instructions to a waste-handling robot (in background) that can open a cask of nuclear waste and check its radioactivity levels.

Charleene adds, "I think about RIPE as a way of conceiving systems, how things fit together. RIPL is how you actually do the programming."

Sandia's commitment to developing advanced robotic systems for DOE necessitates the use of different kinds of robots for different operations, such as working in hazardous environments or assembling weapon parts. As Pat Eicker, manager of Computer Sciences Dept. 1410 points out, every commercial robot has its own programming language and interfaces with other equipment and sensors.

But with RIPE and RIPL, language is no longer a hindrance because the computer codes are written in the same language — irrespective of the specific robots, sensors, or equipment employed by the system.

Bottom Line: Increased Productivity

Typically, only a small amount of computer code can be reused in a new robot system. Programmers generally spend a lot of time rewriting and debugging existing codes to extend them to new tasks or robotic devices. "But with RIPE and RIPL, the same code can be reused, thereby increasing productivity," adds Ed Barsis, Director of Computer Sciences and Mathematics 1400.

RIPE has already been successfully tested on a large pedestal robot that can remove the lid from a shipping cask like those that may eventually be used to transport nuclear waste, and on a gantry robot that performs a radiation contamination survey on such a cask. Both robots are equipped with force sensors that enable them to manipulate tools and determine their position. Even though the two systems involve different robots, different sensors, and different objects, the programmer deals only with generic objects and the generic commands, like "robot," "sensor," "move," and "grab."

"The concept can be applied to other applications as well, such as the command and control of weapon systems, and applications are being developed for robotic vehicles," says Pat. •

(Continued from Preceding Page)

Smart Robots

will permit the operator to graphically preview the robot motion and know what to expect as the robot autonomously executes a particular function. In addition, the software automatically prevents the robot from colliding with other objects in the work space. This software is key to the safe operation of robots in unstructured environments and is an outgrowth of Sandia's research.

Follow-on research will develop the technology by which the robot can generate the plan to clean up syrupy deposits typically found at the bottom of underground storage tanks and solid crystalline materials at the top of the tank.

In related work, Sandia robotics groups have developed several waste handling systems in support of DOE's Office of Civilian Radioactive Waste Management (OCRWM). These include robotic systems for monitoring radiation levels of transport casks and for burying the waste casks. All of these systems employ computer models that automatically generate robot programs and sensors that eliminate uncertainties in position.

Swing-Free May Save Big Bucks

The so-called "swing-free" technology is a particularly interesting spin-off from the work that Sandia has done for OCRWM, says Ray Harrigan, supervisor of Intelligent Machine Systems Div. 1414. A demonstration of the technology in Sandia's robotics labs shows that a heavy object, supported by a wire rope, can be moved rapidly from one point to another with no resultant oscillation.

This could be particularly useful in the design of the Yucca Mountain repository because the ability to quickly move shipping casks and fuel assemblies decreases the number of handling facilities required. "As a result," says Ed, "millions of dollars may be saved by using the swing-free technology at the repository."

Developed by Ben Petterson (1414) and James Jones (2543), the swing-free technology employs computer models and sensors to shape the acceleration profile of the robot so that it has no residual oscillation.

"The first time people see it, they say there must be a magnet in the floor," says Ed.

Sandia is transferring the technology to Oak Ridge for use in moving half-ton containers around a handling area. Discussions are also under way to apply the technology to multi-ton cranes at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, N.M., and at Hanford.

Pat believes the future is bright for the Labs' robotics R&D program (see "Robotics: A Good Fit"). "Robotics is right at the forefront of computer science and engineering, so this work is giving Sandia a chance to work on some of the really important future stuff in computing. But it involves a lot of capabilities besides computer science, and people from all around the Labs will be a part of what we do," he concludes. •LD

feedback

Q. Does Sandia have a formal method of soliciting suggestions and evaluating them? The only two I am aware of are (1) Feedback, which is primarily designed to provide information; and (2) line organizations, which can filter out suggestions before they reach the people who could implement them.

A. Feedback's original intent was to answer employee questions, but the use has broadened over time. Now, suggestions and recommendations are an important part of the program. If you have a suggestion you'd like to make, I suggest you address a Feedback to the person you think would be the decision-maker, and include your name so that you can be contacted for more information if it's needed. Because of Sandia's informal nature, a memo stating your idea and sent directly to the line manager may also be an appropriate course of action.

Herb Pitts — 3100

Welcome

Albuquerque — Robert Huelskamp (9010), Cheryl Lucas (3211), Beth McClanahan (154).

Elsewhere: *Iowa* — Carol Gotway (7223); *Texas* — William Ford (2336).

Upstairs, Downstairs

Remodeled Weapon Training Center "Open for Business"

When you say "upstairs, downstairs" to Don Bickelman, supervisor of Weapon Training and Evaluation Div. 7213, he doesn't think of a public-television program. Rather, he's reminded of the remodeled area in Bldg. 892 that his group uses for weapon-training sessions.

The 5000-sq.-ft., two-story space occupies the former high-bay area — previously used for weapon training — at the northeast corner of the 40-year-old building. The new facility is a vault; access is available only by obtaining a special clearance and then punching in an electronic code outside the door.

"The people in Facilities [7800] did a first-class job of designing a practical, yet much more functional, work space for us," says Don, who reports the facility officially opened for training sessions Feb. 1. "Instead of just one training area, we now have five separate ones," notes Don. "And they're appropriately isolated so that we can use them simultaneously for different groups — at different classification levels, if needed."

AIR FORCE TRAINEES receive briefing on the B61 weapon system from Don Benoist (7213). The setting: a 40-seat lecture hall that's part of the Bldg. 892 training center.

Lecture Hall, Display Area

The facility's lower level includes a lecture hall with seating for 40 people, a weapon display room (special clearance required), and a reception/break area.

A conference room and two training classrooms are on the upper floor. One of the classrooms is used for command-and-control training; the other, for nuclear-safety training.

The renovated training center makes possible another benefit for trainees (mostly from the military services): videotapes of training sessions for their use afterward, or for use in the field by others. Audio-visual coverage of training sessions is transmitted to the video control center, a part of the Training Aids Laboratory (TAL) — also in Bldg. 892 — where the edited tapes are produced. The TAL is operated by Judith Mead's Weapon Procedures and Logistic Support Div. 7212.

Though other space at Sandia is also used for weapon training activities, the remodeled facility in Bldg. 892 represents about a fourth of the space available for that purpose. Div. 7213 trains some 2000 people a year — a majority from the military services, with responsibilities for weapon maintenance or explosive ordnance disposal. Don's division also conducts a three-day refresher course on weapons — a briefing on the status of the stockpile — twice a year for people from the DOE nuclear weapon complex (50 people each session). "Given the number of people we train each year, the 892 facility will see daily use," notes Don.

The new facility also will be used for in-house training of Sandians involved in weapon-program work and for management briefings.

"The remodeling project is one phase in an ongoing effort to renovate our weapon training center by adding modernized tools and facilities to enhance our training abilities," says Bob Sonnenberg (7210). "The goal is to modernize all of our labs and classrooms with audio-visual equipment and to provide a videotape-production capability for off-site training of the military when that is more cost-effective."

The renovation included some asbestos removal and other safety and health enhancements.

Paul Schlavin (7843) headed the design team for the remodeled training center, which was funded by DOE/AL. Other members of the team include Marty Nee (7843) and Jeff Danneels (now 7844). Paul McDonald of Dale Crawford & Associates was project architect. •PW

AL HACHIGIAN (DMTS, 7213, center) demonstrates a command-control device to Air Force trainees in one of the second-floor classrooms.

Sandia Keeps Clean-Air-Campaign Crown

Sandia bikers, bus riders, walkers, and carpoolers clinched the clean-air-challenge championship Feb. 12-16, when employees were asked to refrain from driving to work one day out of five. The annual challenge from KAFB and DOE was part of Albuquerque's Better Air Campaign. Sandia had 20 percent participation; DOE placed second with 17 percent.

What a difference a year makes! Coming from last place among internal vice-presidencies last year, Org. 7000 is at the top this year, with 41 percent of its employees taking part. "We had excellent communication among secretaries and assistants who made sure employees turned in their cards," says Shanna Cernosek, Org. 7000's campaign coordinator. "It's a long walk from the parking lots to their offices for most Org. 7000 employees," she says. "They have to plan the most convenient way to get to the office; not just at clean-air-campaign time, but every day."

Vice-presidency statistics: 1000 — 19 percent; 2000 — 13; 3000 — 9; 4000 (composed of 4000, 400, 200, 100, 30, 20, & 1) — 20; 5000 — 12; 6000 — 26; 7000 — 41; 9000 — 17.

Individual drawing winners include Felix Almaraz (153), Maricela Sandoval (1554), Ted Bryant (6217), Paul Nigrey (7472), and J. R. Turner (9231).

Linda Stefoin, Sandia's Commuter Assistance Coordinator, thanks everyone who participated, publicized, and helped in this year's challenge.

Fun & Games

Golf — Sandia Women's Golf Association is swinging into spring with its annual membership party Wednesday, March 14, at the Coronado Club, Zia Rm. from 4:45 to 6:45 p.m. SWGA has programs for every skill level — from beginner golf lessons to intermediates to 18-hole tournament play — and is open to Sandia and DOE employees, retirees, spouses, and dependents. Associate members of SERP are also eligible. For information and an application form, contact Teri Carpenter (3712) on 256-0614.

* * *

Volleyball — Sandia Volleyball Association's 1990 Spring League season is April 1 through June 16. All matches will be played at the Kirtland-West gym. Team fees, liability release forms, team rosters, and SERP non-Sandian forms should be turned in to the SERP office by Friday, March 16. For information, call Edwina Kiro (3510) on 266-7605.

Technology Transfer at Sandia, Livermore

Future Will Build on Tradition of Relationships With Industry

When the subject is technology transfer at Livermore, the future is being built on the foundation of the past. So says Mike Dyer, Technology Transfer Liaison 8302, adding, "We have a 15-year tradition of technical assistance to US industry. That gives us a solid, positive base from which to launch into better and more-effective tech transfer."

Beginning now and continuing into the future, says Mike, Livermore's tech-transfer efforts, like those throughout Sandia, will take advantage of recent developments in US law and Sandia policy.

MIKE DYER (8302)

One of those developments is a provision in the Defense Authorization Bill passed last November that allows DOE labs to negotiate cooperative research and development agreements — CRADAs — directly with industry and universities. The bill also allows the parties to a CRADA to delay publishing commercially valuable information for up to five years. Assurance that competitors won't immediately have access to the information should encourage private companies to invest the resources necessary to bring national-lab-developed technologies to market.

At Sandia, a new Technology Maturation Program (TMP) provides a way for selected Sandia technologies to be developed to the point of commercial interest (LAB NEWS, Dec. 8, 1989).

Same Goals, Better Tools

"The goal of vehicles such as CRADAs and Sandia's TMP," says Mike, "is the same goal that we've always had for technology transfer: working cooperatively with industry to speed the commercialization of Labs technology. But now we have much stronger tools available. Now that we have the option of teaming exclusively with one industry partner, when that's the best way to get technology into the marketplace, we can protect our capabilities more effectively. Changes like that will let us do a better job of technology transfer."

"We'll be able to select the most effective way to transfer our technology for commercialization."

"These tech-transfer tools are especially valuable in giving Sandia a way to join our country's effort to revitalize its industrial strength and competitiveness," says Peter Mattern, Director of Combustion and Applied Research 8300. "We'll be able to select the most effective way to transfer our technology for commercialization — with benefit both to Sandia and the country."

"Technology-transfer activities are evolving rapidly," says Dan Arvizu, Manager of Technology Transfer and Industrial Relations Dept. 410. "We're using all appropriate resources to advance our program.

"To launch our new initiatives, we're actively seeking to capitalize on the foundation of industry contacts laid down in the past," Dan continues. "Mike Dyer is working closely with us to coordinate and integrate the Livermore and Albuquerque activities into a consolidated Sandia effort."

> The stories in this section report on some of Sandia, Livermore's, work with industry over the past few years. Most of the projects and interactions described — though not all of them — are based in the Combustion Research Facility. Possible applications range from coal-fired power generation to home heating to medical uses of lasers. Although what is included is necessarily selected from among all the stories that could be told, the selection represents what has happened to date and foreshadows what may lie in the future as all Sandians turn their attention toward strengthening the technical and economic competitiveness of the US.

Must Know Market

"One new challenge for Sandia researchers," says Mike, "is to recognize whether an emerging technology has commercial value. To do that, we need to involve industry in the whole continuum of research. A researcher isolated in his or her lab can't always assess commercial value. We have to establish a dialogue with industry, so we can distinguish between what's merely 'interesting' technology and what's commercially valuable."

As an instance of what industry can tell Sandia, Bill McLean, manager of Combustion Technology Dept. 8360, mentions pulse combustion (see "Research in Pulse Combustion," page seven). "Although we had learned a lot about what controls the processes in pulse combustors," says Bill, "we didn't realize that we needed to ask the specific question a manufacturer posed to us: how to make a pulse combustor operate at a higher pulse frequency. That does not have anything to do with making the combustion itself better in some way. But it has everything to do with marketing, installation, and reliability — things that are obviously important in using the technology commercially."

BILL McLEAN (8360)

"Formal techniques will evolve. What *won't* change is our continuing spirit and tradition of interaction with industry."

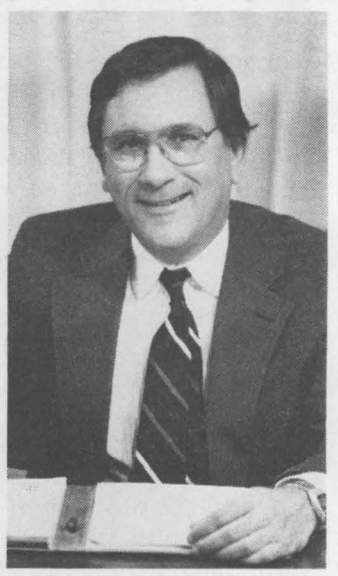
"Having a dialogue with industry doesn't mean we're going to reveal the specifics of everything we're working on," Mike points out. "It's more a matter of knowing about the needs of the market. A researcher who understands industry's perception of those needs can go into the lab and work in response to them. If the result is a commercially valuable technology, then it's our responsibility to protect it."

STEVE BINKLEY (8350)

Steve Binkley, manager of Combustion Sciences Dept. 8350, says, "In past interactions with industry, we've generally seen that companies seek exclusivity. Most of them — though certainly there have been exceptions — need assurance that the technology won't be immediately available to others. They often can't justify taking the risk of developing a product for market if they don't have exclusive rights at least for a while."

The issue of protecting technology involves changes that may be especially evident at the Combustion Research Facility (CRF). The CRF grew out of a sudden, shocking recognition of a real-world need, when the oil crisis of 1973 showed that the US must apply more research to the efficient use of energy. That origin influenced the combustion program's approach to research and to industrial collaboration, making it the major focus of tech transfer at Livermore.

Dan Hartley, now Vice-President for Energy Programs 6000, had to address many of these same issues 15 years ago, when the CRF proposal was being formulated and presented in Washington. "We had proposed essentially to do good basic research in combustion, but Jim Kane [then head of DOE's Office of Basic Energy Sciences, now liaison between the University of California and the DOE labs administered by UC] advised us to plan for a facility that would be half devoted to applications. Of course, that required 'selling' the CRF to the applied program offices in Washington, as well. Because the CRF adopted the mix Jim proposed, the basic science done at the CRF has fed into the technology, and the technology into industry."



PETER MATTERN (8300)

"From the start," says Peter Mattern, "we've viewed strong interactions with industry and the applied-research sector as part of the combustion research program's mission. Our experience has been that for an interaction to be effective, there has to be commitment on both sides. The relationship becomes a win-win one — both partners learn something."

Strong interactions will still be the norm, but the new possibilities of exclusive partnership through CRADAs, along with protecting valuable technology by withholding publication, could raise the question of fairness. One of the policies of Sandia's tech-transfer program is that there must be fairness of opportunity to industry, so that one

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Tech-Transfer Future

company is not unfairly favored over another.

"In the old mode of technical assistance," says Mike, "opportunities were fair by definition, because essentially everything we did was in the public domain. All the people who came to the CRF and worked closely with the staff had to agree that the results would be openly published.

"A shortcoming of that mode of operation," Mike continues, " is the danger that technologies described in publications may be put to advantageous use by US companies' foreign competitors. Technologies developed with federal funds have sometimes found wider use in Europe or Japan than in this country."

How is it possible to have both fairness and protection? Mike gives some examples from the TMP projects under way at Livermore.

"Though we haven't yet established any CRADAs, we expect to do so at some point for each of the TMP projects," Mike says. "One of those projects is Don Hardesty's [8361] work in steel-processing techniques. This may involve a closer interaction between Sandia and the American Iron and Steel Institute, which is the single US consortium for the steel industry. Establishing a CRADA with the consortium would enable us to protect valuable information from use by foreign competitors as well as provide fairness of opportunity to US steel companies.

"We've viewed strong interactions with industry and the applied-research sector as part of the combustion research program's mission."

"Or if there's just one US company dealing in a particular technology," Mike continues, "then we can interact with it to strengthen it in comparison to foreign competitors. An example here is Randy Schmitt's [8354] TMP project in injection-seeding lasers used in x-ray lithography for the manufacture of semiconductors [see "Injection Seeder and Faraday Isolator," page nine].

"If there are multiple companies who might apply a technology, however, it's a different matter. A case in point here is lock-and-tumbler [LAT] pattern recognition for medical applications. So far, George Schils and Philip Kegelmeyer [both 8435] are still exploring possible applications by talking with people in the medical field, people who might eventually use a device that could look at images from x rays or other diagnostic tests.

"If the LAT algorithm is to be incorporated into a commercial unit, however, manufacturers will have to be involved at some point," continues Mike. "Then, fairness will be an issue, because there are many possible companies to commercialize the unit. Our approach would probably be to advertise the availability of the technology, much as we advertise for proposals from contractors. We would give all interested US companies an opportunity and we would, through some equitable set of criteria, choose the best partner for transferring the technology."

"The formal techniques of technology transfer will evolve through the coming months and years," says Peter. "What *won't* change is our continuing spirit and tradition of interaction with industry." More than anything else, that spirit and tradition is what the stories in this section attest to. •CS

Restoring US Competitiveness

'Motivation and Knowledge Will Be the Key'

Last December, Gerry Yonas, Director of Laboratory Development 400, accompanied New Mexico Senator Jeff Bingaman on a fact-finding trip to Japan. What Gerry learned has direct implications for technology transfer in this country. Following are some of his observations.

"I have been to Japan many times in the past, but I have always had a narrow focus, primarily related to either fusion research or, most recently, the Strategic Defense Initiative. We were interested [this time] in understanding their technology management and investment approaches, their business philosophy, and to define general approaches to competition, cooperation, or both.

"I came away with a profound realization that the Japanese work hard, invest their money, cooperate with each other, and have a vision of the future that is based on their own accomplishment and competition. As long as they engage in this approach to global competitiveness and we pursue an opposite approach, namely, business dominated by litigation and antagonistic relationships between our companies and the government; as long as we have a low savings rate and high interest rates; and as long as we have inadequate emphasis on excellence in our educational system, the Japanese will continue to advance relative to us.

"We have to learn to form cooperative alliances and partnerships to lower the risk of investments and share the benefits. We have to do a much better job of collecting and distributing high technology information, and we must create a new culture of shared interests and understanding of management of business and technology. We must lower the barriers to the flow of knowledge and encourage people to learn about entirely new fields and apply their knowledge to solutions of real problems. In the final analysis, the solution is the same as the problem — people. Motivation and knowledge will be the key to our future."

Addressing Real-World Problems

Making Coal a Better Fuel Through Experiment and Modeling

Larry Baxter (8361) has as a major research theme the non-combustible mineral components of coal — typically about 15 percent of the coal's weight. When Larry came to Sandia in 1987, he was already acquainted with some people and companies in the coal business. Because of the Combustion Research Facility's emphasis on interaction with industry, he has come to know more.

In a recent study, Larry collaborated with Consolidation Coal Co. "That's a large coal-mining corporation with an aggressive research program," says Larry. "Their facilities range from lab-bench scale to pilot-plant scale." Like everybody else who produces or uses coal, Consolidation faces the problem of what happens to the mineral part that forms fly-ash and deposits within the boiler.

"Commercial-scale boilers may use 200 to 400 tons of coal per hour," says Larry. "A sizable amount of inorganic matter in the coal deposits on the heat transfer surfaces before reaching the gas clean-up systems — maybe 7 to 15 tons per hour."

Boiler-Busting Deposits

Boiler operators — at, for instance, an electricity-generating utility — spend time and money removing this material from the interior surfaces of a boiler that can be 15 to 20 stories high and several tens of feet across. If too much collects, deposits the size of a bus can fall, often knocking a hole in the bottom and bringing the boiler off-line for repairs, at a cost of about a million dollars a day.

But a more subtle problem actually costs industry more each year, says Larry: deposits on the boiler walls decrease heat transfer, thus reducing the efficiency of making steam to drive turbines and generate power. The total annual cost to industry is estimated at $500 million.

The coal used in such boilers is pulverized, making it slightly coarser than face powder. To study the movement of noncombustible particles that can deposit on the walls, Larry and colleagues used a recently completed Multifuel Combustor at the CRF. "When we got the Multifuel Combustor up and running," says Larry, "Consolidation was eager to do some of these types of studies. From our standpoint, their expertise and experience in the coal community could help us focus on real problems, practical problems."

Deposits on boiler walls can cost industry $500 million a year.

So over the course of a few weeks, two high-speed video cameras (one of which was provided by Consolidation) took pictures of how particles interacted with a simulated boiler tube. Larry points out that much of the experimental setup, especially of optics, was done by Ken Hencken (8362) and the primary operator of the Multifuel Combustor, Ephraim Arquitola (8361).

The experiments included four kinds of coal, plus one coal blend; each of the five different fuels was tested under conditions representing three different locations within an actual boiler. "The bottom line," says Larry, "is that capture efficiency — the fraction of particles that stick to the surface — is not a constant, as often thought, but a complex function of time. Furthermore, the industry uses fouling and slagging indices to try to predict how much mineral matter will deposit, but we confirmed in the lab — as many commercial-scale utility operators have found — that the indices are accurate only about half the time. That's not good enough.

"What I hope, through further study, is to be able to understand the deposition process well enough to predict more reliably the behavior of a given coal in a given commercial-scale boiler. That will help operators minimize deposition and, eventually, help designers develop new boilers." The research is continuing as a Sandia project, and another collaborative investigation is planned.

Coal in the Computer

Larry also works on computer modeling of coal-burning systems. "People are trying to develop novel ways of using coal," he says. "That

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sometimes involves slurries. A couple of the possibilities are gas turbines or coal-burning diesel engines."

A coal slurry is usually about 50 percent coal by weight. Most of the rest is water, but one percent or so consists of additives for various purposes. The slurry resembles black latex paint but is much thicker.

"In this modeling work, we're collaborating with companies trying to build gas turbines, in particular the combustor sections of the turbine," says Larry. "I work on comprehensive computer codes that describe the reacting-flow dynamics and the particle mechanics of a multidimensional coal-fired combustor. Those computer codes can help predict the characteristics and local properties of coal combustors under different operating conditions."

The two companies most closely involved at present are Solar Turbines, Inc., of San Diego, and Allison Gas Turbines (a research branch of General Motors) in Indianapolis. Recently Larry had a visitor from Solar Turbines, who with Larry reviewed the latest modeling of Solar's sub-scale combustor, ensured that the input conditions were realistic, and took the results back to his company. There, the modeling results are contributing to the design of the full-scale combustor and to analysis of the data from the sub-scale combustor. At Sandia, Larry is continuing to model the full-scale combustor.

De-Clumping a Slurry

As an example of how experiment and modeling can interact, Larry points to the problem of coal-slurry particles forming clumps larger than the individual coal particles. "The coal-slurry particles are ground even more finely than the pulverized coal particles typically used in coal-fired power plants," he says, "and if you've paid to grind them to a small size, you'd like to be able to burn them at that size. They don't burn as efficiently when they're clumped.

"We performed a series of experiments and found that some of the additives put into the slurry contributed significantly to the aggregation of coal particles as the slurry dried. This effect was caused particularly by the surfactant [material that reduces the viscosity of the slurry]. If you can leave out the surfactant, you nearly halve the diameter of the aggregated particles.

"I hope . . . to understand the deposition process well enough to predict . . . the behavior of a given coal in a given commercial-scale boiler."

"Then I took these experimental results and used them in the computer code to predict the effect in a commercial-scale unit. The result was improvement in nearly every aspect of performance — carbon conversion, flame stability, pollutant production, and others.

"That's about all we can do ourselves at this point," Larry concludes, "but we've been involved in some planning with Solar and a slurry manufacturer to try some larger-scale tests." It's safe to predict that once the next round of tests begins to yield results, the cycle of computer modeling and experimentation will continue — as will the cooperation of Sandia with companies whose increasing knowledge about coal can translate to better use of US energy resources. •CS

MARK ALLENDORF (left) and Larry Baxter (both 8361) are working in seemingly opposite directions: Mark to cause deposition of material (for forming composites) and Larry to prevent it (when coal burns in boilers). Both say they try to keep current on what problems are important to industry researchers.

And Improving Processes

Investigating Formation of Composites

Like his colleague Larry Baxter in Combustion Research Div. 8361 (see "Making Coal a Better Fuel"), Mark Allendorf is working with industry to investigate deposition. In Mark's case, the problem is not to prevent deposition, but to understand how it happens — in a process used by Thermoelectron Technologies Corp. to make silicon-carbide composite materials.

"Composite materials often have desirable properties," says Mark. "Silicon carbide is highly resistant to corrosion and has good heat-resistant properties. So it's desirable for things like car engines, turbine blades on combustors, aircraft parts, various chemical manufacturing processes, and things like that. The problem is how to make the process reproducible, how to get the same desirable properties every time."

What brought Sandia and Thermoelectron together, says Mark, was that managers in DOE's Energy Conversion and Utilization Technologies program were aware of common interests between Thermoelectron and the Labs. "Thermoelectron has developed a technology but doesn't understand, at a fundamental level, how it works. This is a common problem in industry — having a process, but not enough understanding of it to be able to scale it up or adapt it."

"The problem is how to make the process reproducible, how to get the same desirable properties every time."

Results of this collaboration are still in the future. A reactor that duplicates critical aspects of Thermoelectron's process is being developed and should be ready for use sometime this spring. The reactor is designed to allow extension of experiments to other materials and other processes than those Thermoelectron is interested in.

Mark's work with Thermoelectron will take advantage of some of the knowledge developed when he collaborated with AT&T/Bell Labs researchers on understanding what happened in a process that uses a flame in making optical fibers. "The Bell Labs people were visiting scientists who carried out experiments with us," says Mark. "Using laser diagnostics, we found that the configuration of the flame was important for the proper deposition of sub-micrometre silica particles.

"We have some unique tools [to] understand and optimize complex manufacturing processes."

"We also used laser spectroscopy to probe the temperature fields in the flame. From that, we learned that the flame itself is strongly affected by the materials used to form the particles. The people at Bell Labs who are computationally modeling the flame need to know that — otherwise they might use temperature measurements and other diagnostic measurements made in the flame without particles, because they're easier to obtain. But we showed that that simplification would not be valid, and we made measurements in the flame under conditions that more closely approximate the actual manufacturing process."

The benefit to Sandia — particularly to Sandia's role in the upcoming Thermoelectron study — was experience in working with high-temperature particulate-laden flows. That's just one example of the value Mark finds in the exchange of information with industry.

"We have some unique tools that can help them understand and optimize complex manufacturing processes," he says. "Every time I go to a conference, I seek out the industrial people. It's important to find out what matters to them. Even if we don't work on their process directly, at least we keep in mind what questions are of interest to them. That helps us keep our research relevant to industry's needs." •CS

Scale-Up Needed

Chemical Processing of Carbon-Carbon Composites

Although the nature of the research done in the Combustion Research Facility has resulted in its having the bulk of interactions with industry, the CRF doesn't have a monopoly. For instance, there's Computational Mechanics Div. 8245, which is collaborating in a program with United Technologies Research Center (UTRC) of East Hartford, Conn. UTRC manufactures parts from "carbon-carbon" composite structures — carbon fibers in a carbon matrix.

"It's a strong and lightweight material," says Bob Kee, 8245 supervisor, "but if you put a pure carbon-carbon part into something like an aircraft engine that's running lean — excess oxygen, which is the normal case — it's like putting a piece of coal into the engine. It'll burn up.

"The answer is to put a coating on the outside. One good oxidation barrier is silicon nitride, which can be applied to the carbon in a CVD [chemical vapor deposition] process. United Technologies has such a process, which it has been working with for almost 30 years. People there have demonstrated it quite successfully on small, benchtop-size reactors.

It was impractical simply to build a large reactor and try it out.

"Now they need to scale it up to much larger reactors," Bob continues, "but they were uncertain about exactly how some of the chemistry works, how the chemistry interacts with the fluid mechanics, and things like that."

It was impractical simply to build a large reactor and try it out. That would take more than six months and nearly a million dollars, too much of a gamble with unknown scaling factors. So UTRC inquired whether Sandia might be interested in collaborating to create computational models of the process, which could then be used for scaling the design.

"So that's where we came in," says Bob, "along with several other Sandia organizations." The others include Advanced Materials Research Div. 8342, Theoretical Chemistry Div. 8357, Surface-Processing Sciences Div. 1126, and Physical Chemistry and Mechanical Properties of Polymers Div. 1812.

"We're doing analysis, modeling, and a considerable amount of experimentation to get data for the modeling," says Bob. "One of our major tools is an enormous body of software called CHEMKIN, which we've written over the past ten years. It's used for modeling chemical kinetics in flowing systems. Sandia has distributed CHEMKIN widely — a large fraction of the people who are serious about simulating complex gas-phase kinetics use it. It's applied on a broad front of research, from aerospace to chemical processing to combustion, and many more.

"In the case of the UTRC collaboration," Bob continues, "UTRC is developing the design. What Sandia is really bringing to the collaboration is the development of a fundamental understanding of the process, which will allow us to put together an engineering-level design model. That will permit UTRC to scale up confidently from a benchtop system to a much larger one. The program is funded by the Defense Advanced Research Projects Agency." •CS

FRAN RUPLEY and Bob Kee (both 8245) discuss proposed changes to CHEMKIN, a computer code for modeling chemical kinetics. Fran has worked closely with Bob on the development of CHEMKIN.

Sandia Diagnostics, Industry Test Chamber

Teaming With Aerojet in a Rocket-Motor Program

Sometimes industry seeks out Sandia as a collaborator. A case in point is Aerojet TechSystems, a Sacramento-area Operating Unit of GenCorp Aerojet.

The company wanted to do some work in advanced small-rocket chambers for NASA — but when they laid out a proposed program, says Aerojet's Sandy Rosenberg, a necessary piece was missing. They needed a way to obtain a better understanding of the processes that limit the life of small rocket thrusters. He thought his company might find the missing piece at Livermore.

"I had some awareness of the Combustion Research Facility and the kind of skills they have," says Rosenberg.

"But besides that," he continues, "years ago — I don't remember just when — I worked on a program with Glen Otey [5160]. That was on reentry vehicle research. Aerojet and Sandia were both funded by the Air Force, and we worked together without a formal relationship. I was Aerojet's program manager, and Glen was Sandia's. It went very smoothly.

"So when I realized this time that our strategy had a hole in a certain area, I reflected on my experience with Sandia. I said to myself, 'Well, if I can get us together, there's no way we can lose.' "

Making an initial contact with Peter Mattern (8300) and then Steve Binkley (8350), Rosenberg eventually found himself working with two divisions, one (Reacting Flow Div. 8351) in the CRF and the other (now Advanced Materials Research Div. 8342) inside the Tech Area. These divisions will supply the missing pieces in Aerojet's plan by studying what happens when candidate rocket-chamber materials — refractory metals and oxides — are subjected to a simulated rocket-chamber combustion flow in a materials sample test apparatus (MSTA).

Aerojet is building the MSTA and plans to deliver it to Livermore this spring. It's a pressure vessel with a mount for a material specimen, a burner for rocket propellants, and several windows for laser diagnostics. Members of Div. 8351 will study gases near the material specimen.

"We'll be using laser diagnostics to observe the gas-phase species in the boundary layer close to the surface," says Bob Lucht, Div. 8351 supervisor. "We plan to monitor radical profiles close to the surface, so that we can tell if they are being formed or destroyed on the surface. If they're neither formed nor destroyed there, then probably they aren't attacking the surface chemically."

Div. 8342 — which was supervised by Marshall Lapp when these plans were being made, but is now supervised by Rick Stulen — will look closer to the surface. "We'll be looking either at the surfaces themselves," says Rick, "or at material that is in the gas phase but driven off the surface."

These studies should give Aerojet a much more detailed understanding of what goes on in rocket chambers to limit their lifetimes. They may also, says Sandy Rosenberg, lead Aerojet to set up its own laser diagnostics.

"Now," he says, "we start with a long, de-

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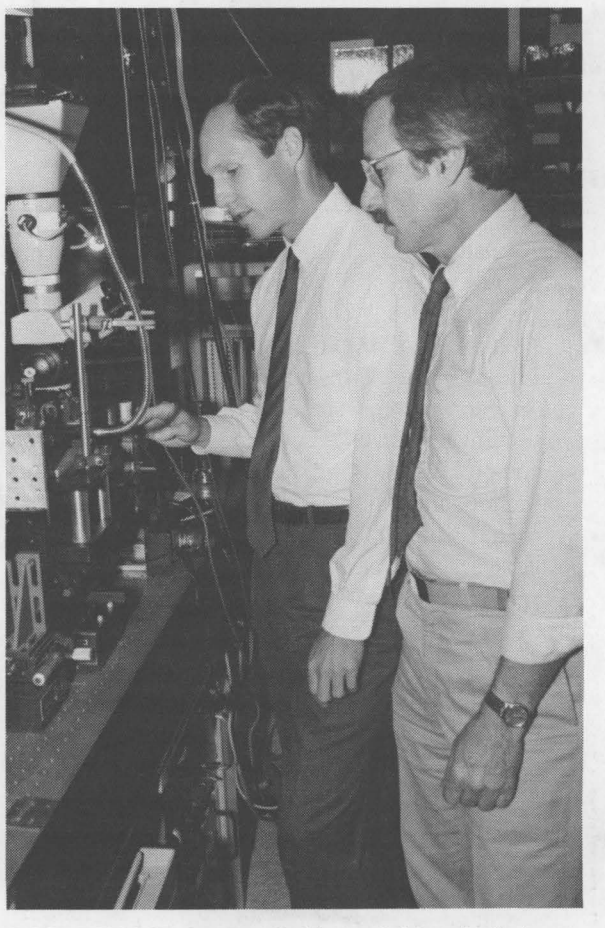


BOB LUCHT (8351, left) and Marshall Lapp (8350A) worked with Aerojet TechSystems to plan a joint project for the investigation of rocket-chamber materials.

Cummins Engine, Sandia Diagnostics

Sandia–Cummins Collaboration May Help Diesels Meet Tougher Emission Standards

Like all diesel-engine manufacturers, Indiana-based Cummins Engine Company faces a challenge: new limits being placed on emission of particulates and oxides of nitrogen (NOx) from diesel engines. The Environmental Protection Agency's new standards began taking effect in 1988. The limits will be tightened in 1991 and will become stricter still in 1994.

From January 1987 until last October, a Cummins employee, Axel zur Loye, was at the CRF as a DOE Industrial Fellow. (Under the Industrial Fellow program, administered by the DOE's Office of Energy Research, the participating industrial firm pays the fellow's salary, and DOE provides funds for other expenses of the fellow's research assignment at a DOE lab.)

Axel worked closely with Dennis Siebers, who last July became acting supervisor of Combustion Applications Div. 8362. The aim of their research was to obtain data about the formation of particulates — soot — that would help in the design of engines able to meet the 1994 standards.

"Although what counts is the soot that comes out the exhaust," says Axel, "it's formed in the cylinder. So if you want to affect soot formation through design changes, you've got to look into the cylinder."

As he continues, Axel hints at why industry researchers find CRF diagnostic equipment valuable: "It's not good enough just to look at the exhaust and say, 'Okay, I made a change here and the emissions changed.' You need to have a pretty good idea of *why* there was a change."

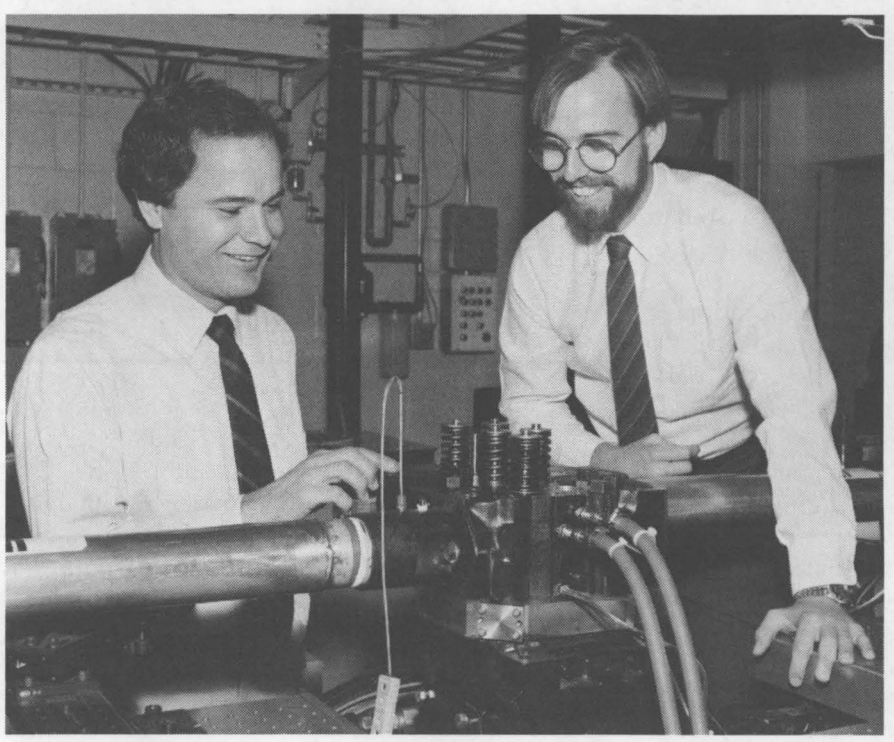
Cummins supplied an engine duplicating one cylinder of a heavy-duty truck diesel. The complete engine system included optical-access hardware and auxiliaries such as dynamometers, pumps, and heaters. During installation, Cummins sent a second engineer to Livermore — Henry Ng — who continued providing support (arranging for special parts, for instance) once he was back at Cummins.

Cummins made a considerable contribution in special parts such as new pistons or cylinder heads. "These aren't off-the-shelf parts," says Dennis. "Whenever we needed something new, Cummins had to design it and specially machine it. That's in addition to the normal spare parts they supplied."

According to Cummins' Director of Combustion Research and Thermodynamic Analysis, Roy Primus, there were two primary research objectives: "One was to get information on in-cylinder air motion for our heavy-duty diesel engines and compare that with computational fluid-mechanics work being done with the KIVA code [a computer code for simulating fluid motion in engines] at Los Alamos National Lab. The other was to find out more about what happens during combustion, especially how particulates are formed and oxidized, as well as how they move around in the cylinder."

During the first phase of the work, laser Doppler velocimetry revealed the patterns of air

(Continued on Page Six)



DENNIS SIEBERS (8362, left) and Axel zur Loye, of Cummins Engine Company, check instrumentation on the engine that Cummins supplied for research at the CRF.

(Continued from Preceding Page)

tailed analysis, then come up with a design and build a rocket engine — and sometimes find that it doesn't last for the many hours we expected, but only a few minutes, because the chamber material wasn't compatible with the propellants or their combustion products." One of Aerojet's goals is to use diagnostic chambers and, eventually, computer codes in the design of rocket engines and the choice of propellants.

And what will this work mean to Sandia, or to American industry? "For one thing," says Marshall, "what's driving this program technologically is the ability to produce a highly resistant material for a combustor liner. The same kinds of high-temperature materials could go into other applications — aerospace, or on the ground. What Sandia and Aerojet are studying could apply to any technology where you have to have a device operating in a really hostile atmosphere.

"Besides that," Marshall says, "there are some really good science experiments involved here. If we can pull off the things that will help this engineering endeavor, we'll be adding strength to our tech base." •CS

Improving Radiation Sensors

Rick Stulen (8342) has taken over part of the responsibility for the Aerojet collaboration (see "Teaming With Aerojet") from former 8342 supervisor Marshall Lapp, but he's not new to collaborations with industry. For the past two years, Rick's former division (Surface Science and Chemical Physics Div. 8343) has been the home of an effort to get around some of the difficulties encountered in manufacturing detectors of x rays and gamma rays.

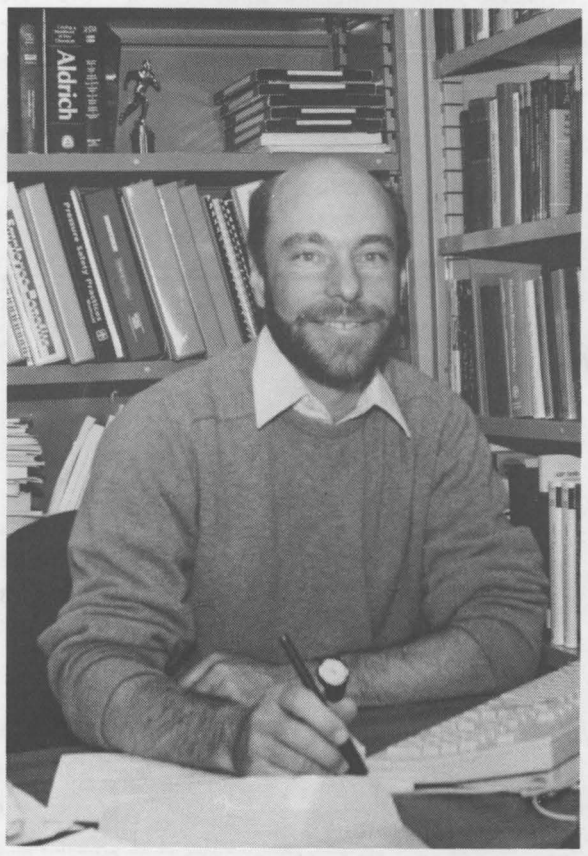
"Mercuric iodide is a crystalline material that you can turn into an efficient sensor of x rays and gamma rays," says Rick. "It can operate at room temperature. Most x-ray and gamma-ray sensors require low-temperature operation to reduce electrical noise.

"With mercuric iodide sensors, you could make a compact device, more or less pocket-size, that would be a detector of special nuclear material — but first you'd have to overcome some manufacturing problems."

About two years ago, Roger Hagengruber (9000) suggested that Div. 8343 attack one of the problems that EG&G — the only US company working on the sensors — had encountered: difficulty in making a reliable electrical contact.

"Mercuric iodide reacts chemically with almost everything," Rick explains. "If you try to deposit a copper contact on it, for example, you find out that after some time, because of a slow chemical reaction, the detector stops working.

"We got funding for two years of work from Venky Narayanamurti's [1000] Exploratory R&D program," Rick continues. "EG&G saw our progress and was enthusiastic about having us continue research on contact deposition. We came up with three materials as possible electrical contacts that we think are promising. In the next phase, with the support of DOE's Nevada Operations, EG&G will be depositing those on mercuric iodide crystals and testing how well they work."



RICK STULEN (8342) now supervises one of the divisions working with Aerojet.

(Continued from Page Five)

Sandia-Cummins Collaboration

movement within the engine's cylinder as the piston rose and fell. This research was necessary because few of the diesel engines previously studied experimentally have the same characteristics of air-fuel movement as Cummins' "quiescent" designs.

"To summarize," says Axel, "the majority of our results and the KIVA computations agreed very well. We did, however, find some discrepancies between our measurements and the model results that could be traced directly back to using a 2-D version of KIVA. That in itself was important information, because although it's nice to know that the results matched reasonably well, we also needed to know what kind of compromises are made when using the 2-D version of KIVA."

Detour

The intended second phase was to use laser light to look at a "slice" of the volume inside the cylinder and see where and when soot was forming — "the time-varying spatial distribution of soot in the cylinder, as a function of engine conditions" is how Dennis describes it.

But at this point, the close collaboration of Cummins and Sandia led the research fruitfully astray. Cummins engineers had become concerned about a new problem in some of the advanced-development engines they were working on in their efforts to reduce particulate and NOx emissions in future production engines: soot accumulation on the cylinder walls.

So instead of starting immediately to look at the distribution of soot throughout the chamber, Dennis and Axel began to see what they could learn about the mechanisms that led to soot getting onto the walls. That detour in the program paid off — not by finding a cure for the problem, or even isolating a single cause, but by narrowing the range of hypotheses that researchers in Cummins' labs needed to consider (see "Unplanned Research Paid Off").

Soot Concentrations

When they returned to the planned second phase of the program, Axel and Dennis continued to look at soot concentrations. One method was to put in a sheet of pulsed laser light and use an intensified video camera, connected to a computer, to get an image of the distribution of soot at a given instant — or during a time of 10 nanoseconds (10 billionths of a second), to be precise (see photo). Another method was to use a larger beam, not distinguishing individual particles, but measuring how the total amount of soot in the chamber varied over time.

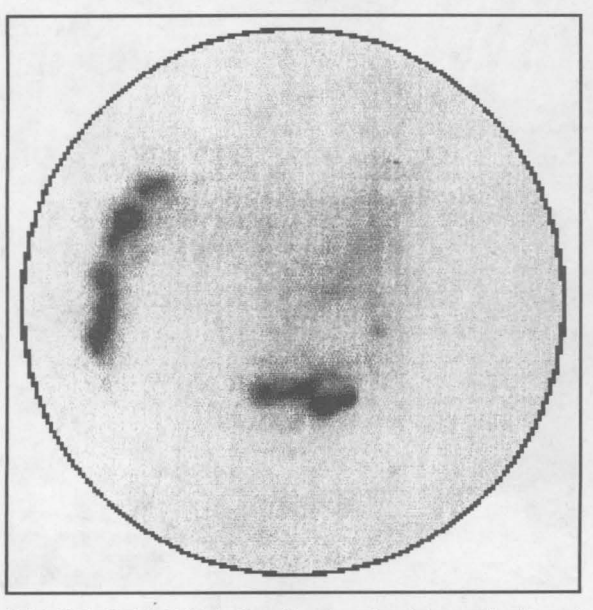


IMAGE OF SOOT distribution inside cylinder of diesel engine.

Over-the-Shoulder View

Unplanned Research Paid Off

While Cummins researcher Axel zur Loye was working at the CRF as a DOE Industrial Fellow, he and Dennis Siebers (8362) sidetracked their planned research to look at a more immediate problem.

Says Axel, "We went off on a tangent to investigate the mechanisms that led to soot collecting on the cylinder walls of some advanced-development engines that Cummins was working on. We hadn't initially set out with this as a goal, but it became obvious that we had the opportunity."

"That opportunity evolved," says Dennis, "because of close cooperation — being aware of industry's problem and seeing the chance to investigate it. I was literally looking over Axel's shoulder at some data one day, and I said, 'You know, we've heard that they have this problem with soot. This measurement may be showing us something about that. Maybe we ought to . . . '

"So we started talking with Cummins and generated a lot of interest," says Dennis.

Dennis and Axel started looking at the deposition of soot on a window in the wall. They found that the distribution of soot was uneven throughout the cylinder, and that the concentration was greatest in areas that were in the line of fuel spray coming from the fuel injectors.. They also found that most of the soot was deposited during a short period of the engine cycle: the combustion phase.

For Cummins, the real value of this information is that it narrows the field of candidates for a specific mechanism: "There were a dozen or more hypotheses," says Axel, "and everybody was convinced his or hers was right. Our conclusions were strong enough to totally rule out some of the hypotheses, allowing efforts to be directed to the ones that are much more likely to be correct."

Roy Primus, Director of Combustion Research and Thermodynamic Analysis at Cummins, was impressed both by the flexible redirection of the research plan and the relevance of the results: "The evidence that Dennis and Axel got, which wasn't anticipated on the front end of the program, has already had a real impact on some of our development work. It's ironic — something that wasn't planned has had the most immediate impact of the things we did during the joint program."

That work is over now, too, and Axel is working in Cummins' lab rather than Sandia's. Reflecting on their work together, he and Dennis agree that Cummins' real-world experience with diesel engines and Sandia's capabilities in laser diagnostics gave the project a combined strength that would have been hard to match in any single institution, industrial or governmental. Dennis says, "Given enough money and time, I suppose either side could have done the job. But it would have been terribly inefficient — it would have cost too much in both money and time."

And even if it could have happened in a single institution, something would have been missing. Axel sums up: "What was great was not just the material resources that I had available, like lasers and optics, but also the expertise of the whole CRF. It was no more than a two-minute walk to experts in many different fields. I could just knock on a door and say, 'Do you have a few minutes to talk about this?' That's invaluable. Add Cummins' awareness of real diesel-engine problems, and Cummins' years of expertise with diesel engines, and we had a fantastic combination." •CS

Dialogue of National Labs, Universities, Industry

Groups Help to Focus Research

Part of the background of technology exchange at the Combustion Research Facility (CRF) — and frequently mentioned by researchers as they discuss their work — is DOE's Energy Conversion and Utilization Technologies (ECUT) program. A significant fraction of the research done at the CRF is under ECUT's Combustion Technology Program.

The Combustion Technology Program is divided into two parts: Engine Combustion and Continuous Combustion. In both areas, national labs, industry, and university researchers have formed cooperative working groups. The industrial partners in the cooperative working groups are corporately funded, receiving no government support. Sandia is a member of all the working groups.

"The groups don't help industry partners work on their next year's design or even help them with day-to-day problems of R&D," says Mike Dyer (8302). "They focus on broad problems facing industry in general."

As an example of the results of this focus, people at Chrysler were familiar with Pete Witze's (DMTS, 8362) work — and thus raised the question that occasioned Pete's spark-plug probe ("Barrack Witze Probe," page eight) — because Chrysler and Sandia are both members of the Dilute Homogeneous-Charge Group. Also in that group are Ford Motor Company, MIT, Penn State, UC Berkeley, and a few others.

Each group meets twice a year to share current research results. This interaction helps researchers identify key issues and make results available for industrial use.

Other groups in Engine Combustion, and the industrial partners, are Direct-Injection Stratified Charge (General Motors), Knock (Unocal, General Motors), and Diesel (Cummins, Navistar, Exxon).

Continuous Combustion includes a Pulse Combustion Group that has as industry partners two of the companies that Sandia's pulse-combustion resarchers have been working with — Lennox Industries and Forbes Energy Engineering — as well as the Gas Research Institute and university researchers. The other Continuous Combustion group, Spray Combustion, does not yet include an industry partner.

All these groups give participants something that researchers value: a place to discuss ideas with colleagues while the ideas are still in a preliminary state. "One reason the groups have been successful," says Mike, "is that they're not an open public forum. There's opportunity for sharing ideas while you're still developing them, even for making mistakes, without having your technical reputation at stake every time you make a presentation. It's okay to have some wild ideas."

Significant Progress Since '83 Start

Research in Pulse Combustion Helps Increase Understanding of a Long-Mysterious Technology

The Combustion Research Facility's work in pulse combustion started as a *quid pro quo*: The Japanese firm of Toshiba wanted to send someone to the CRF to learn about laser diagnostics and offered, as an exchange, to bring Toshiba's pulse-combustor water-heater technology and to let a Sandia researcher work for several months at Toshiba. (The exchanges began in 1983 and ended in early 1988.)

Pulse combustors are generally more efficient than conventional combustors and produce smaller amounts of nitrogen oxides. They operate in a series of short burns, rather than continuously as conventional furnaces or gas-burning water heaters do.

The trouble with developing them is that the details of how they work have long been mysterious. Engineers have — literally — cut and tried, cutting metal and building trial models to see how well a new design works.

But the research of Jay Keller, Taz Bramlette (both 8364), and Pam Barr (8362), partly in a series of industrial collaborations with Lennox Industries of Carrollton, Tex., and Forbes Energy Engineering of Springfield, Mass., has made significant progress in understanding the operation of pulse combustors. The outcome may be to replace the trial-and-error approach with methods based on fundamental understanding.

Pulse combustors are generally more efficient than conventional combustors and produce smaller amounts of nitrogen oxides.

Toshiba Exchange Gave Confidence

"When we started the program with Toshiba in 1983," says Jay, "our goal was to develop a design methodology based on having a fundamental understanding of the processes that occur in a pulse combustor. Before that, it was almost an art form to design them.

"After the interaction with Toshiba gave us some confidence in our modeling capability, we visited Lennox and discussed working with their people. They had been working in collaboration with the Gas Research Institute and the American Gas Association to develop a first-generation domestic space heater for the US market. Some Lennox people then came to a workshop we were holding, and out of that evolved a design study."

Lennox had a specific objective: to build a system that operated at a higher pulse frequency than the first-generation furnace. The company wanted to do this partly because pulse combustors are noisy — they depend on effects that are essentially acoustic — and high frequencies are easier to muffle than low frequencies.

Two Lennox engineers spent two weeks at the CRF in October 1986, working with Pam's computer model to predict the operation of many design variations.

Taz describes the next stage: "They went back to Lennox, selected three designs, and built prototype systems. They evaluated those with the instrumentation they had available. Then they brought one of those three systems here, and we instrumented it for further study. We worked with them for six months on that. What we used were not advanced diagnostics by CRF standards, but they were things that industry researchers just don't have."

Lennox's Hal Rhea, Vice-President for Research and Development, says these interactions with Sandia have helped his designers direct their efforts: "This collaboration helped us zero in on the areas that we needed to address in our new-generation product, rather than using a lot of trial and error."

But Lennox wasn't the only beneficiary, Jay points out: "We took the knowledge we got by making measurements in the Lennox combustor and put it into the model. Our ability to 'educate' the computer and have it reproduce what we see in the lab is a good indication of how well we understand the process going on in a pulse combustor. Any industry interaction that lets us add knowledge to the model is valuable to us."

"Any industry interaction that lets us add knowledge to the model is valuable to us."

Model Predicted Duds

As Pam continues to work on the model, it becomes more and more useful as a design tool. Says Taz, "For one thing, Pam's model correctly reproduces experimental trends when volumes are changed. But it's maybe even more important that, when we were working with the Lennox device, the model correctly predicted the operating limits. As we changed the geometries, there were cases where the model predicted that the combustor wouldn't run — and for those geometries, Jay found in the lab that it either in fact wouldn't run or would only run roughly."

It might appear that it's time to offer the computer model to industry for use in the design process. But that's not really so, agree Pam, Jay, and Taz. Despite the progress in understanding pulse combustion, the model is still a research tool, not an off-the-shelf software package.

"Using this kind of computer program successfully," says Taz, "depends on its being part of a continuing interaction between practicing industry engineers and the researchers that developed the program. Without that personal experience and awareness of the boundaries of the program, it's possible to get odd results and not understand why."

So the modeling work continues, partly with data from Forbes Energy Engineering Company. Funded largely by the Gas Research Institute, Forbes designs engineering models for industry to use (perhaps with modifications) and introduce to the market. For several years, Forbes has been supplying test data for Pam to use in extending the model.

'Unpleasantly Costly Items'

Forbes' president, Peter Kardos, emphasizes the importance of continuing to develop a fundamental understanding of pulse combustors: "It's not enough to just know that it works — you can't scale the thing if you don't have any key. We have to build test models in actual size, large combustors of maybe a hundred million BTUs. And we can't make them out of balsa wood or papier-mâché — we have to use stainless steel and other unpleasantly costly items."

At the moment, however, there are what Kardos calls "some different opinions" about what actually happens in large pulse combustors. Describing her work in modeling multi-tailpipe combustors of the sort that Forbes is designing, Pam says, "We've been puzzled by the results they got in their tests."

"It's not enough to just know that it works — you can't scale the thing if you don't have any key."

Such differences, however, only emphasize the need for continuing cooperation between the Sandians working in pulse combustion and their industry counterparts. Forbes is interested in continuing the cooperation, says Peter Kardos. So is Lennox, whose Hal Rhea says, "So far, I believe we've only scratched the surface." •CS

PAM BARR (8362, at computer keyboard) has been developing and refining a pulse-combustion model for several years. She, Jay Keller (left in background) and Taz Bramlette (both 8364) have collaborated with several industry engineers in understanding and improving pulse combustion.

Fiber-Optic Spark Plug

'Barrack Witze Probe' Sprints to Commercialization

When it comes to rapid commercialization of tech-transfer products, Pete Witze's (DMTS, 8362) spark-plug probe for seeing the inside of automobile engines just might hold the record. Whether or not that's so, two years from an "aha!" by a researcher to a product announcement by a company is indeed quick.

The speedy transition from concept to marketplace came about for a combination of reasons, including the motivation for the basic idea, Pete's approach to turning the idea into a research instrument, and how the instrument meshed with a manufacturer's product line.

"I said something like, 'You know, you really don't need the gas velocity. You just need to know if the flame kernel moves, and in what direction.' "

It all started when a group of Chrysler engineers wanted to talk with Sandians who were in Detroit for a Society of Automotive Engineers (SAE) conference in February 1987. "We've had a long history of technical interchange with Chrysler under the DOE/ECUT [Energy Conservation and Utilization Technologies] Engine Combustion Program," says Pete (see "Groups Help to Focus Research," page six). This time, the subject turned out to be the problem that all automobile manufacturers have had, in recent years, with rough idling in some of their cars. Chrysler researchers' tests, and those of consultants, had ruled out some possible causes for one particular model. Now they needed help in confirming what they believed to be the source of the problem.

"What they hypothesized," says Pete, "was that as soon as the spark plug fired, the small flame kernel was moving away from the center of the cylinder's diameter. Then, somewhere near the cylinder wall, the burn would get started. The effect would be the same as the spark plug being off-center. Instead of pressure in the cylinder coming up to a peak at the proper time, the burn would take longer, the pressure would rise slower, and the engine would idle roughly."

On-the-Spot Idea

"To check out this hypothesis," Pete continues, "they wanted me to look at spark gaps with a laser Doppler technique to see whether I could measure the gas velocity in the gap — and find out whether the direction and speed of the gas movement correlated with whether the pressure rose fast or slow."

The Chrysler people were showing the Sandians various cylinder heads and talking about where windows might be put into the heads for laser access, when a different approach occurred to Pete.

"As I recall," he says, "I said something like, 'You know, you really don't need the gas velocity. You just need to know if the flame kernel moves, and in what direction. A ring of detectors could let us see if the flame goes off-center. Maybe we could put optical fibers into a spark plug.'

"So," Pete continues, "the idea actually came about there on the spot, at Chrysler."

When Pete got back to the Combustion Research Facility (CRF), he started to see if a spark-plug probe could be made. The first question was what a spark plug really looked like on the inside — so Jim Boehmke (8154) cut one in half lengthwise. There appeared to be space to drill holes and thread optical fibers through, so the next step was to make up a drawing and send it out for a machine shop to drill eight long, narrow holes.

"The plug came back beautifully done," says Pete. "It's a tricky job, and since then, we've had more plugs butchered than not, but we got off to a great start with that first one."

During late spring and summer of 1987, Pete worked with Matt Hall, a postdoctoral fellow supported by the Gas Research Institute, at turning spark plugs into probes. "When this started," he says, "I had no expertise in optical fibers, so there was a lot of learning to do. We spun our wheels in more ways than you can imagine, trying a bunch of elaborate ideas that didn't work. But by the fall, we finally had a design we were ready to put into the research engine in my lab."

"From day one . . . I was thinking about how it could be used in a typical auto manufacturer's lab."

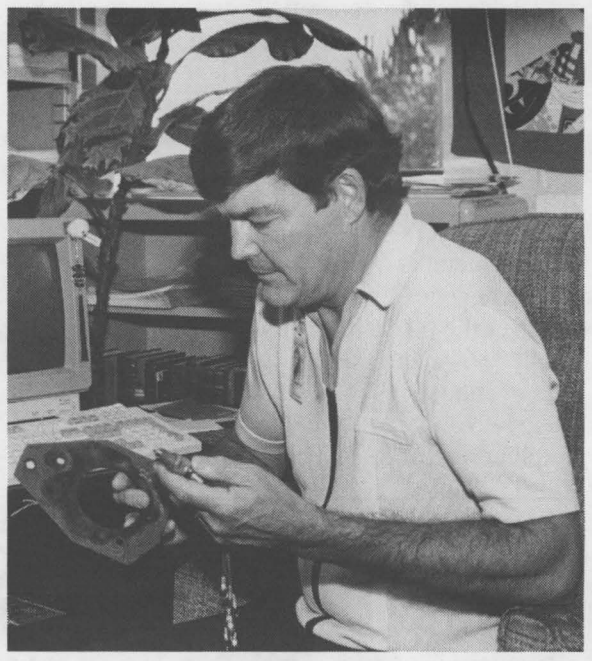
Making It Usable

Through the rest of that year, the fiber-equipped plug underwent evaluation in the lab. A signal processor was also in the works — each optical fiber would transmit a pulse of light when the flame front reached it, but something had to be done to turn light pulses into usable data.

UNDER THE HOOD for one of the first tests of the spark-plug probe: Eldon Porter (8362), who built the prototype signal processor, and Pete Witze (DMTS, 8362).

Pete was also talking with engineers of the US auto companies, and other engine researchers, to let them know what he was working on and how much progress he had made. He set out from the beginning to develop the plug into an easily usable system.

"From day one," he recalls, "when I decided to build one of these and lend it to Chrysler to try, I was thinking about how it could be used in a typical auto manufacturer's lab. I realized that I couldn't spend six months integrating the plug into a huge data acquisition system that has been built up on a test stand over the past 20 years. It had to be a stand-alone system. So the way we designed and built it, the plug connects to a signal processor that Eldon Porter (8362) made, and the signal processor connects to a special board that goes into a PC [personal computer].



PETE WITZE (DMTS, 8362) holds his original lab-model spark-plug probe and a prototype for a gasket that incorporates ionization probes.

"I'm convinced," Pete continues, "that if we as a national lab want to show industry we've got a new instrument that can help them, we've got to take it to the point where they can get some results quickly. Then their research people can show their management that it's worthwhile. Later on, when they have management's confidence, they can get more elaborate and integrate it with other systems."

Drive-In Test

By the spring of 1988, the system was ready for a real engine. "We borrowed a car from the motor pool," says Pete. "We drove it to the back of the lab, took out a spark plug, put in the fiber-optic spark plug, and put a timing 'doughnut' on the plug wire to tell us when the plug fired. It took about five minutes, and we were running."

In late summer, Pete and his management were ready to go public through a news release — which was timed to coincide roughly with the publication of an SAE technical paper. Before that, only researchers in the US auto companies, plus a few others, had heard about the plug.

The news release stimulated interest. "We were inundated with all sorts of inquiries," says Pete. "They kept us busy."

Best-Laid Plans Get Better

Because it was clear that researchers would be wanting systems, and because the CRF expected to have two of them, plans were made to assemble enough documentation that a Bay-area fabrication shop could build Sandia's second system. After that, presumably, the shop would be able to build identical systems for others.

As it turned out, however, Barrack Laborato-

(Continued on Next Page)

Saved a Year of Development

Injection Seeder and Faraday Isolator Helped Solidify Two Young Companies

Over the past half-dozen years, the efforts of Diagnostics Research Div. 8354 in developing laser diagnostics for combustion research have led to products that aided the start-up of two companies. Now the technology is to be transferred to a third company, where it may assist the manufacture of semiconductors.

The first development was the injection seeding of lasers, needed to produce pulses of light that are not only high in power, but also high in spectral purity — that is, light at only one optical frequency. A commercial seeder, to which Sandia's technology contributed substantially, became what the president of five-year-old Lightwave Electronics Corporation (a Mountain View, Calif., firm) calls a "cornerstone" of the company.

Larry Rahn (DMTS) and Randy Schmitt (both 8354) developed the injection seeder for Nd:YAG lasers (in which neodymium ions are embedded in an yttrium-aluminum-garnet crystal host). In simplified description, the system uses a small diode laser to pump a monolithic Nd:YAG laser — which is also small, only a few millimetres in length and diameter, and from which it's relatively easy to obtain light of a single frequency. The output of the miniature Nd:YAG laser is then introduced into a larger, Q-switched Nd:YAG laser.

The term "injection seeding" refers to the fact that the light from the miniature Nd:YAG laser is amplified by the large laser to produce a much more powerful pulse that's still spectrally pure — "sort of like planting a small seed of corn and having a lot of corn grow from it," says Larry.

"Diode-pumping a YAG laser wasn't really new," Larry continues, "and small monolithic lasers weren't new, and injection seeding wasn't new, but putting it all together and developing a locking circuit that worked — that was new. I first had a complicated system involving an argon laser and a dye laser, as well as YAG lasers. Randy and I built the diode-pumped injection seeder, which replaced the argon and dye lasers with a simple little diode."

Injection seeding can produce pulses of laser light that are not only high in power, but also in spectral purity.

New Product for a New Company

Injection seeding became an interest of Lightwave Electronics in February 1985, just a month after the company was formed. "We were aware of the general idea of injection seeding," says Lightwave's president, Bob Mortensen. "Several of us knew about the injection-seeding work of Bob Byer, a professor at Stanford. It was a little later that we heard about Larry's work — I already knew him, from interactions at the company where I worked previously. When I learned that he was using laser diodes to pump the Nd:YAG crystals, I arranged an appointment to go see what he was doing."

With two or three people working full-time, it took Lightwave two years to turn the injection-seeding concept — which had been described in publications — into a commercial product. Bob Mortensen says, "The engineering details were all our own. Of the 'soft' input — potential problem areas, concepts, how things work, and so on — maybe one-third came from Sandia. But I would say that interacting with Sandia saved us about a year of development time."

Lightwave now employs more than 40 people and has annual sales of more than four million dollars. Injection seeders — sold mostly to laser manufacturers who offer them as options on their products — account for more than a million dollars annually.

"I'm hoping to buy one myself," says Larry. "I've still got the first diode-pumped injection seeder running in my lab. It's been there for three or four years."

Randy Schmitt praises the simplicity of the

(Continued on Page Ten)

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ries of Marlborough, Mass., approached Sandia first. "I had been out to Sandia to visit Mike Dyer, and had toured Pete's lab," says Steve Plee, Barrack's Vice-President and General Manager.

"I've known both Mike and Pete since I worked in research at General Motors," he continues. "I had also heard about the plug through a mutual friend — Jay Martin, at the University of Wisconsin — who did his PhD thesis research at Sandia.

"So I knew about it informally, and then when Pete published the SAE paper, we started talking about transferring the technology. It really fit into our plans nicely, because we were developing our own optical sensor that Pete's would complement." Barrack's announcement that it would offer the probe came in February 1989, just two years after Pete thought of putting optical fibers into a spark plug.

Barrack has made several improvements in what it markets as the Barrack Witze Probe™, most notably adding sapphire windows in the plug to make optical fibers last longer (by isolating them from combustion gases), and narrowing the view angle for each fiber to increase the precision of measurements.

A standard spark-plug probe is sold for $1200 (custom plugs can also be made), a detector/amplifier for the probe is $14,000, and a computer board with software costs $5000. Barrack also offers complete research packages for single- and four-cylinder engines. "In all of these components," says Plee, "we started with what Pete did. We modified and enhanced it for commercialization.

"We've had a good reaction from the market," he continues. "So far we have about five systems out. We've sold them to research labs, automotive companies, and oil companies."

Specialized, but Handy

Pete points out that neither his lab version of the probe nor Barrack's commercial version is an all-around research tool — a point that Plee agrees with, noting, "It's for people who want to concentrate on the early flame development." But, in addition to its value in that area of research, it's attractive because of its ease of use.

"You don't have to modify an engine," says Pete. "You don't even have to have the engine on a test stand. That's a major reason people have liked it."

"You don't have to modify an engine. You don't even have to have the engine on a test stand."

Pete is now working on a first cousin to the spark-plug probe — a set of ionization probes in a gasket. "Replacing the head-gasket isn't as quick as replacing a spark plug," he says, "but in the auto industry's labs, it can be done easily. If you put ionization probes — which are really just wires — around the edge of the gasket at the cylinder bore, they'll tell you when the flame reaches the cylinder wall. That gives you a very-late-time instrument to add information to the spark-plug probe's very-early-time information. And neither one of them requires putting any extra holes in the engine."

After whatever further work he does on the ionization probe, Pete expects to return to laser diagnostics, from which the Chrysler inquiry diverted him for a couple of years. "I haven't had any other ideas along the line of these probes," he says. "So I'll be back to shining laser beams through windows to get my data. I really think, though, that we're going to see commercial versions of both of these instruments in industrial labs." •CS

First Interaction With Automakers

Variable-Displacement Engine: An Early Effort in Tech Transfer

A laboratory-model variable-displacement engine developed by Sandia in the 1970s might be viewed as an early instance of technology transfer that didn't quite come off — or as a glimpse of the Combustion Research Facility's later successful interactions with industry.

From about 1974 to 1978, Harvey Pouliot (ret.) and others at Livermore were working on an unusual engine design. Instead of the throttle opening in the carburetor being changed to increase or decrease power (as in a conventional engine), the length of the piston stroke could be changed while the engine was running. The design was first computer-modeled, and then an engine was built and lab-tested.

"It performed about as predicted," recalls Harvey. "Fuel consumption at idle was about one-fifth that of a conventional engine of comparable power. It was about half on the Federal Urban Driving Cycle [a simulation of city driving], and a little more than three-quarters on the highway cycle."

Information on the engine was made available to US auto companies. "They sent representatives to Livermore to observe," says Harvey. "They asked for specific tests to be run, though none of them pursued a design like this, as far as I know.

"This was probably the first time Sandia worked closely with the auto manufacturers, " Harvey continues. "Even though it didn't lead to a product on the market, I would call it the first effort in the engine field between industry and Sandia."

(Continued from Page Nine)

Injection Seeding

commercial version. "Lightwave made it into a reliable turnkey system — you just switch it on and it works. Ours is reliable, too, but it takes a Sandian to tweak it."

Randy mentions an additional reason to be pleased that injection seeding went commercial: "So many people are interested in injection seeding that it could be a full-time job telling them how to build a system. Now we can just tell them to buy one."

The first lab-version injection seeder involved contributions of a number of people, points out Rich Palmer, supervisor of Diagnostics Research Div 8354: "The initial work in injection seeding included Bob Byer and his student at the time, Tom Kane," says Rich. "They contributed to the development of monolithic neodymium-YAG lasers."

"We collaborated actively with them," Rich continues, "but our needs for spectroscopy at the Combustion Research Facility led us to go a step further by building an injection-seeding system that we could couple with large commercial lasers. Del Owyoung [now 1160] and Peter Esherick [1164] collaborated with us on several aspects of injection-seeding technology, including gain-switching of the monolithic laser to achieve high power for the seed laser."

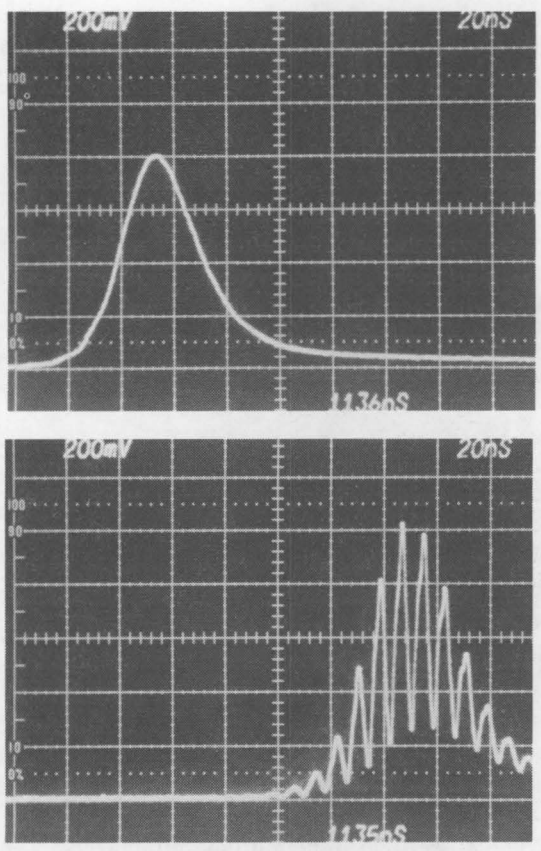
RANDY SCHMITT (left) and Larry Rahn (DMTS; both 8354) developed laser technology that could prove important in the manufacture of semiconductors.

Optical Diode Needed

One requirement for a successful injection seeder is a way to keep the large Q-switched laser's light from coming back into the seeder and either damaging it or upsetting its operation. That requirement is fulfilled by a one-way device called a Faraday isolator.

In a Faraday isolator, a magnetic field rotates the polarization angle of light as it passes through; polarizing filters in the isolator let the light through in one direction but prevent it from passing through in the other direction. The device is sometimes described as an "optical diode," analogous to an electrical diode that lets current pass in only one direction.

"We found we had to have really good isolation of the seeder from the big YAG laser," says Larry. "That's what led us to work on permanent-magnet Faraday isolators."



WITH AND WITHOUT injection seeding: smooth curve (top) is oscilloscope trace of oscillator output of injection-seeded Nd:YAG laser. Bottom is same laser without injection seeding.

"Isolators are useful in other parts of laser systems," adds Randy. "For instance, they can isolate laser oscillators from amplifiers. Or in a system that has several amplifiers, the amplifiers can actually couple together and start lasing prematurely on their own. Putting isolators between them prevents that."

Electromagnets Eliminated

Faraday isolators were built and used in the past, but their magnetic fields were usually produced by electromagnets. Sufficiently strong permanent magnets weren't available. The electromagnets consumed a lot of power and generated a lot of heat — enough that water was required for cooling them. All the hardware took up valuable lab space and, in general, added complications to experimenters' lives.

"Permanent-magnet Faraday isolators were made practical by recent advances in rare-earth permanent magnets," says Randy. "They can be made much stronger than ten years ago. We use samarium-cobalt magnets and neodymium-iron-boron magnets [samarium and neodymium are rare-earth elements] in our systems. I did some computer modeling — it was a simplified model, but we could use it to calculate isolator designs for particular applications."

That use of permanent magnets for a Faraday isolator opened the way for another new commercial product — one that has turned out well for another young company, Electro-Optics Technology, of Fremont, Calif.

"Our company started out with some different products in mind," says Electro-Optics' president, Dave Scerbak. "But those were moving slowly for us, and we started thinking of other things we could do. We knew there was a possible market for Faraday isolators, so we started talking to Larry Rahn about the possibility of setting up a technology-transfer program for us to work with him on designing these devices."

Says Larry, "We decided to try out a technology-transfer avenue that Sandia had at that time — technology-transfer consulting. So I worked with Electro-Optics on a consulting basis, and they came up with a successful product." (Such consulting arrangements have since been replaced by more formal arrangements, such as Cooperative Research and Development Agreements and Work For Others.)

Both Larry and Randy point out that they didn't exclude others who inquired about the new permanent-magnet Faraday isolators. "I have a long list," says Randy, "of individuals and companies that we gave information to — our design and how we did it. But Electro-Optics really picked it up and wanted to make it into a product."

That product has reached a sales volume of several hundred thousand dollars per year, says Scerbak. The sales rate has doubled in the second year, though he expects it to level off at some point. "We've had a certain amount of success in the marketplace," he says, "and we'd like to believe that we've helped out scientists who need these devices."

A formal tech-transfer effort has been helped along by a previous informal collaboration with Lawrence Livermore Lab.

Randy agrees that the commercial isolators have been a help. "When I built these things myself, I had to sit at my computer and design them — which was fun at first, but got to be repetitious. Then I had to write up a half-dozen purchase orders for the components, and coordinate these with several vendors, which could take up quite a bit of my time. It's much better to be able to write one order, then when the device comes, just bolt it down and use it."

YLFs for Semiconductor Manufacture

The next step in the story is the extension of injection-seeding technology to uses beyond research. With funding from Sandia's recently established Technology Maturation Program (LAB NEWS, Dec. 8, 1989), Randy is returning to injection seeding.

He's working with Hampshire Instruments, the only US company that makes x-ray lithography equipment for the semiconductor industry. Their process involves a high-power laser system to generate the x rays.

"What's different about this," Randy says, "is that we're seeding a neodymium-YLF laser — that's yttrium lithium fluoride — instead of a YAG."

That formal tech-transfer effort has been helped along by a previous informal collaboration with Lawrence Livermore Lab. "They had a laser they wanted to injection-seed, and we had the

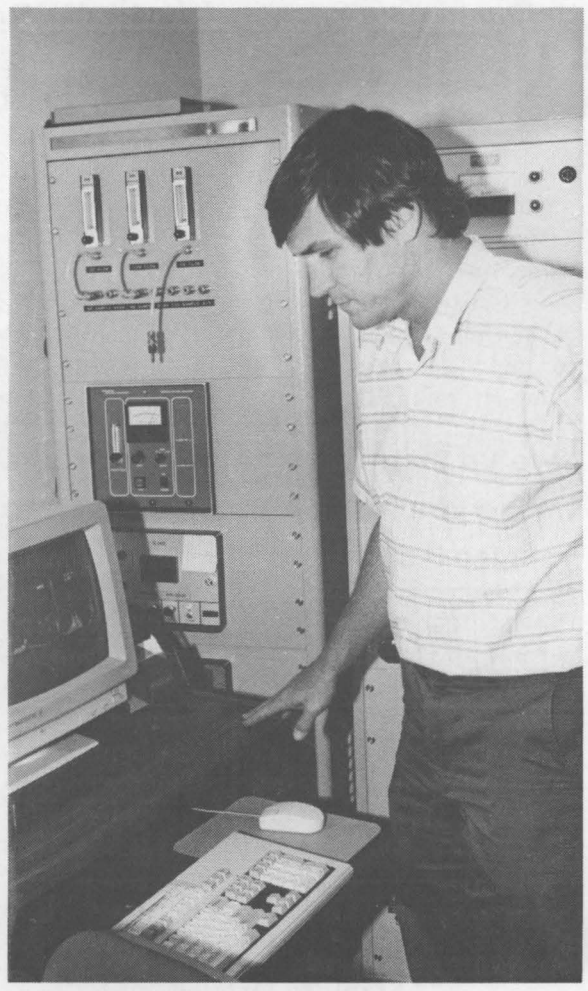
(Continued on Next Page)

Two Who Took Their Ideas Outside

The number of options for commercializing Sandia-developed technology has recently increased. Previously, there were few opportunities within Sandia to take a technology to the point of commercial attractiveness. That's one reason so many inventors in past years left Sandia and tried — successfully or unsuccessfully — to develop technologies for the commercial market. In such cases, the inventor was often granted rights to technology originating at Sandia.

Now, technologies can be developed to the point of commercial attractiveness through such avenues as the Technology Maturation Program. Such new options, along with emphasis on choosing tech-transfer methods that will both benefit Sandia and contribute to the restoration of US industry's competitiveness, mean that the inventor-entrepreneur may not be the best choice for commercializing a technology, and thus will not necessarily have first opportunity to secure the rights.

But that's now. Just a few years ago, the most attractive option for two Sandians in the CRF was to leave and found their own companies: Don Holve started Insitec in 1986, and Bob Perry began Technor, Inc., in 1987. Through a combination of sales, consulting, and R&D contracts, they have brought their companies through some of the precarious early years. As the next two stories show, these entrepreneurs are pleased with what they've accomplished so far, but both also point out that much is left to do.



BOB PERRY, former Sandian and president of Technor, Inc., demonstrates part of the data-analysis system he's using in developing applications of the RAPRENOx process.

Niches for Infant Technology

RAPRENOx Goes Commercial

Bob Perry left Sandia in May 1987, not with a product but with a process: RAPRENOx, or RAPid REduction of Nitrogen Oxides. Since then, Bob has been president of Technor, Inc., the company he formed in Livermore to market the process.

RAPRENOx removes nitrogen oxides (NOx) from combustion exhausts, which could help reduce smog and acid rain. The process uses the heat of exhaust gases to transform solid cyranic acid ($C_3N_3[OH]H_3$) into gaseous isocyanic acid (HNCO), which then reacts with NOx to produce nitrogen and other non-smog-causing gases. DOE waived its title to the process so that Bob could commercialize it.

Technor has licensed the process to Cummins Power Generation, Inc., a wholly-owned subsidiary of Cummins Power Systems. A few months ago, a Cummins engine was installed in Technor's lab for research.

Cummins Power Generation's Director of Clean Combustion, Ralph Slone, says, "Our basic objective is to develop and sell clean, benign energy. The near-term application we foresee is the continuous-duty stationary power business — mobile engines are more difficult because their operation is transient. Because of future emissions restrictions, however, RAPRENOx's potential for reducing NOx emissions from mobile engines also will be investigated." He notes that in Bob's lab, applying RAPRENOx to the stationary diesel engine has resulted in a 90-percent reduction of NOx in the exhaust.

Fighting for a Chance

Success in the lab is good news, but Bob points out that there's more than just technical feasibility to worry about: "I've had to learn a lot about the regulatory process. Once you start installing systems in different places, you have to get the process certified as best-available control technology. So besides what we did at Sandia in showing that the technical concept is feasible, we have to go through solving the toxicology problems, making sure there aren't harmful by-products, doing the reporting. It's far from trivial."

Even with many technical and regulatory problems solved or on the way to solution, Bob is conscious that it's a struggle to compete commercially: "We're still an infant technology, so we're fighting for demonstration sites, either with other people who have infant technologies, or with people who have established technologies and would

(Continued on Page Twelve)

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seeding technology," says Randy. "We collaborated on the diode-laser-pumped Nd:YLF laser. That work turns out to have great practicality for this Hampshire venture.

"So you could say that this injection-seeding technology — which Larry started working on about six years ago — is finding wider and wider application," says Randy. "It's not just for lasers used in spectroscopy, which is probably Sandia's main emphasis."

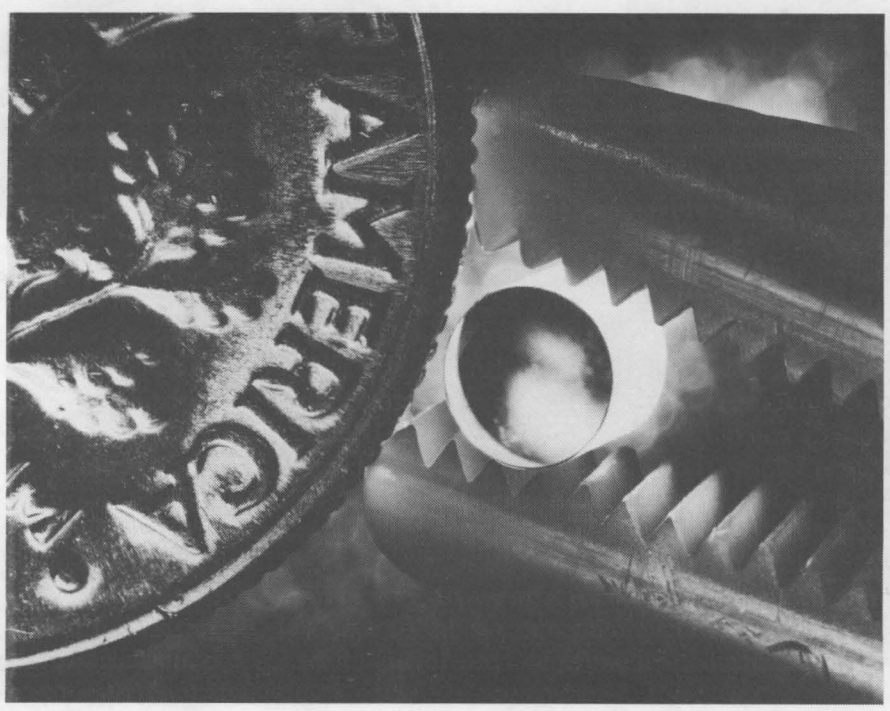
Rich Palmer agrees, and points out some other possibilities: "It's for many applications in which you need a laser with good stability. For instance, LIDAR [light detection and ranging] to look at pollutants and aerosols in the atmosphere. For that, having a smooth, well-characterized outgoing pulse makes it much easier to analyze the return signal. Or in ophthalmology — if you can stabilize your laser pulse and make it more reliable, you have greater precision and control in surgery. Even in welding, if you can avoid pulses that have big, random power spikes, you're less likely to damage something."

Thus, work that began in an effort to improve diagnostics for combustion may eventually offer benefits as localized as the human eye and as widespread as the earth's atmosphere. •CS

Public Testimonial

Electro-Optics Technology's president, Dave Scerbak, wrote a letter published in the September 1989 issue of *Laser Focus World*. It included the following paragraph:

"For the past 11 months, our company has been involved in a Technology Transfer program with Sandia National Laboratories, Livermore, Calif. The goal of this program was to transfer certain large-aperture Faraday rotator technology developed at Sandia by Dr. Larry A. Rahn [8354] and coworkers. The Sandia management was particularly helpful in lending their support to this program. This allowed our company to quickly receive essential input from Dr. Rahn on a timely basis. His input translated directly into our ability as a company to offer large-aperture Faraday isolator products. . . ."



JAWS OF FORCEPS hold miniature monolithic Nd:YAG laser next to a dime. In the Sandia-developed injection-seeding technique, a laser like this is pumped by a diode laser and, in turn, pumps a larger Nd:YAG laser. (Photo by Lynda Hadley, 8285)

In-Situ Measurements of 'Nasty Materials'

Insitec's Particle-Counter Market Is Still Emerging

Don Holve left Sandia in January 1986 to begin a business in his home — what he describes as "a classic garage operation." The company name, Insitec (now in its own quarters in San Ramon, Calif.), is intended to suggest "*in situ*," because Don markets a growing line of instruments for making *in situ* measurements of particles in combustor exhausts, liquid sprays, and similar flow streams. The instruments can measure particle sizes and velocities, and count the particles, in size ranges from 0.3 micrometre to 200 micrometres.

"We've dealt with nasty materials, things you wouldn't want to put into your lab instrument."

"All our effort is directed toward doing this on-line," says Don. "In big coal-fired power boilers, for instance, we can measure the fly-ash coming out. We've dealt with nasty materials, things you wouldn't want to put into your lab instrument, or things that change before you can get them into a conventional laboratory."

Stanford Origins

Don came to Sandia in 1980 with the basic idea for a particle counter already in mind. It was, he says, "a software concept, a mathematical deconvolution method" that he developed at Stanford in 1978. Stanford examined the possibility of a patent, but algorithms were not patentable at that time.

Don developed prototype hardware at Sandia, extending the measurement range down to sub-micrometre. His prototype instruments found use in research measurements on pulverized coal and slurry combustion. "I thought when I came to Sandia that I knew how to build a prototype, but it was very difficult," says Don. "And the prototype was only partly successful — I could get it to run, but nobody else could."

The first instrument was best suited for R&D-size applications, Don says: "It would handle process streams up to about a metre in diameter. You could put windows in a duct, put this thing up to the windows, and make the measurement."

Bigger and More Specialized

After Don left Sandia to commercialize the prototype, some of his initial work was done under DOE sponsorship: "Along with some other contracts, I had one with DOE's Small Business Innovative Research [SBIR] program to build a new, larger version of the particle counter."

Under the SBIR contract, Don developed an instrument capable of making measurements in places like big power plants — inside ducts perhaps 40 feet across. "It's basically the same instrument," he says, "but it's in a water-cooled probe that you can insert into a large system. You have to do that because it's not feasible to put a transmitter — that is, a laser — on one side of a 40-foot duct full of hot gas and get a measurement on the other side."

Don has also had contracts for other, more specialized particle counters. For the National Science Foundation, he developed a version that can be used under high-speed conditions, to measure the particles in explosions or rocket exhausts. For the Environmental Protection Agency, he is developing a low-cost instrument that measures the total volume of material and the average size, but does not give a detailed size distribution.

Until last year, Insitec depended heavily on R&D contracts. They brought in about 40 percent of the company's revenue — mostly through the SBIR program. For 1989, however, Don attributes only 15 to 20 percent of Insitec's income — about $1 million to $1.1 million for 1989 — to that kind of source. The remaining 80-85 percent was from instrument sales and lease/consulting (where Insitec sends someone with an instrument to take measurements).

Insitec's revenue has approximately doubled each year, and the company now employs ten people. But it hasn't been easy to make progress like that, says Don. "An idea is one thing, but it's been more than ten years since I had the idea. The hardest part has been to take it from that stage, go to proof of concept, and then — hardest of all — make a usable instrument out of it. And, of course, do the marketing and otherwise take care of business. It's been terribly time-consuming, expensive, and difficult."

Don sees plenty of opportunity for even more hard work. The market for particle counters has been emerging for the past ten years, he says, but probably won't be mature for another ten. He would also like to work toward some form of closed-loop manufacturing-control process. "That'll take time — and probably something different from our present instruments — but it's the ultimate objective." •CS

(Continued from Page Eleven)

RAPRENOx

be happy to keep us out of the picture. In a few places, we've been closed out by the competition before we had a chance to demonstrate."

One advantage of the tie with Cummins, says Bob, is that he can let that company secure some of the opportunities for demonstration sites while he spends time with the technical problems. According to Ralph Slone, a demonstration on a stationary diesel engine at a power-generation site in the Los Angeles area is going on during the first quarter of 1990.

Wood Fires

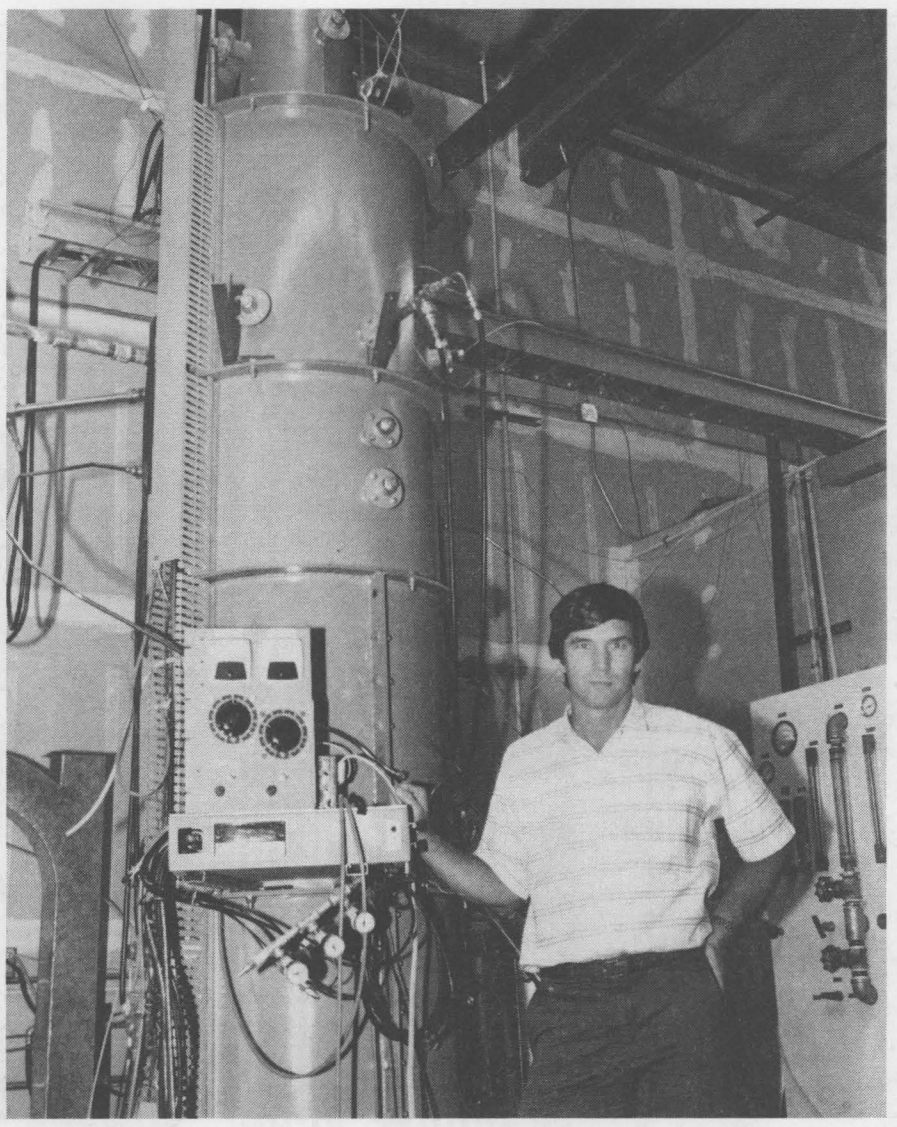
Bob isn't confining his efforts to diesels, however. "We're also working on some wood-fire demonstrations," he explains. "Recently, for example, I've been traveling to a wood-production facility in California where sawdust and wood chips are used in a 15-megawatt cogeneration system. The plant uses part of the electricity and sells the rest to Pacific Gas and Electric. There are restrictions on the carbon monoxide [CO], the particulates, and the NOx that are emitted. But in operation of the plant, there's a trade-off between CO and NOx. If RAPRENOx can help them meet their requirement on NOx, then they can burn more efficiently and lower their CO.

"In this case," he continues, "it turned out that the mixing of the gases is a much harder problem than the chemistry, because of the size of the system. We've been working on how to get good mixing rapidly and inexpensively. That was a background I didn't have as a chemist, so I had to develop it and also hire some people to work on that problem."

Bob describes himself as "fairly confident" on both the diesel and the wood-fire cogeneration demonstrations. In addition, he has been working on another demonstration involving incinerators, as well as doing a so-far-limited amount of work on coal-fired systems.

Although Bob still has a visiting-scientist relationship with the CRF, he doesn't get to spend much time there. "I miss that a lot," he says, "doing the science and interacting with people at Sandia."

For now, though, the company comes first. "The longer we survive," says Bob, "the better our chances get. A company like this has to grow until it's viable — it's been hard up to now. But we're still surviving, and I'm encouraged by that." •CS



COMBUSTION EXHAUSTS are simulated in Technor's lab with this multifuel flow reactor, shown here with Bob Perry.

Medical Corner

How's Your Self-Esteem? Make It Your Number-One Mental Health Goal for the 1990s

By Arlene Price (3300)

Self-esteem refers to how you evaluate yourself and your accomplishments. Your level of self-esteem reflects the difference between your real self and your ideal self — the way you would like to be mentally, physically, emotionally, socially, and professionally. The discrepancy or similarity between your real and ideal self determines how positively you regard yourself. The more positive you feel, the better you feel and the more able you are to meet life's challenges.

How you feel about yourself is learned from infancy, through early childhood, and on into adulthood and old age. Your early years are particularly important because of relationships with the important people in your life. Those relationships affect your relationship with yourself — the thoughts, feelings, beliefs, and attitudes you have toward yourself that affect your self-confidence and self-esteem.

One explanation of how you form your attitudes toward yourself is that people you care about regard you either conditionally or unconditionally. Conditional regard means they love and accept you only if you live up to their expectations. If you're unable to meet their expectations, you may be rejected.

Unconditional regard does not depend upon your behaving the way others wish you to — no matter what you say or do, the people you care about still care about you. They will not withdraw their love even when you behave in ways they don't like.

Everyone needs self-regard, so everyone seeks the esteem of others. When you're regarded conditionally, you come to regard yourself conditionally. You may develop distorted ways of seeing yourself. As a result, you may constantly underestimate your abilities. This learned tendency to diminish yourself causes you a great deal of pain. In other words, when you have low self-esteem, you reject yourself. If you have high self-regard, you acknowledge making mistakes or having disappointments, but deep down inside you continue to like and accept yourself.

How can you can begin to develop a healthy level of self-esteem? Begin by giving yourself unconditional positive regard. Quit picking on yourself and criticizing all your imperfections. Even when you make mistakes, wish you had behaved differently, or have deep regrets, forgive yourself.

Doing this means not struggling so hard to be different from what you are. When you want to improve yourself or your situation, evaluate what you did that worked and what you did that didn't work, then figure out what you need to do to make things better, rather than endlessly blaming yourself. So the first step in increasing your self-esteem is to give yourself the same support and encouragement that you would give a friend or loved one. Give yourself unconditional, positive regard. •

Judge to Discuss Family Court Issues

COMMUNITY FOCUS

Trying to resolve divorce issues in a courtroom is like trying to extinguish a fire with gasoline, says a district court judge who will speak in the Community Focus series at noon Monday, March 12, in the Technology Transfer Center Auditorium.

Anne Kass, presiding judge in the Domestic Relations Division of the Second Judicial District, will discuss "Bernalillo County's Family Court: An Insider's View." Seating is on a first-come basis.

The adversarial system is not an effective way to resolve domestic relations disputes, Kass says. She advocates self-education for the public and conflict resolution as a curriculum subject in the public schools.

ANNE KASS

"After seven years of private practice in divorce law, I recognized that litigation was not an effective way to solve my clients' problems," she says. "It has become even more clear to me as a judge that the legal system does not effectively deal with domestic relations disputes."

Local courts are backlogged with divorce suits and related matters. The three-judge family court currently has 3682 cases pending. Those cases include divorce, annulment, legal separation, custody, and child support suits.

In her talk, she will discuss the differences between a divorce suit and a traditional lawsuit, and she will discuss the legal aspects of joint-custody agreements.

A native of South Dakota, Kass received a bachelor's degree in communications from the University of New Mexico in 1974. She received her law degree from the UNM School of Law in 1977, and was the sole local practitioner in family law from 1977 to 1984. She has been a district judge since 1985.

Take Note

The 26th Annual Symposium of the New Mexico Chapter of the American Vacuum Society is April 23-26 at the Holiday Inn Pyramid. Symposium sessions include "Surface Science," "Electronic Materials and Processing," and "Applied Surface Science." A short course program will also be held. Instructors include Sandians Warren Taylor (ret.), Leonard Beavis (7471), Diane Peebles (1834), and Alan Galuska (1823).

For information on technical content of courses, call Jay Fries (LANL) on 665-0721. For reservation information, call registrar Jerry Nelson (1823) on 4-5200.

A topical conference on Applied Surface Analysis will be held April 25 in conjunction with the symposium. For information, contact David Harradine (LANL) on 667-1176.

* * *

Daffodil Day for HomeCare and Hospice is March 16. The sixth annual city-wide flower sale will benefit Hospital HomeCare and Hospice Patient Care Fund, which provides care for indigent patients and those whose medical expenses have depleted their insurance and personal resources. To order flowers, call 842-7142.

* * *

The Rio Grande High School Class of 1970 is planning its 20-year reunion. Class members should contact Phyllis Padilla (3521) on 831-0330 for more information.

* * *

This year's Albuquerque Academy Parents' Association Gilbert and Sullivan production will be "Iolanthe," March 16-18 at the Academy's Simms Fine Arts Center; 8 p.m. Fri. and Sat., 2 p.m. Sunday. Sandians involved in the production include Allison Davis (6313), director; Dick Schwoebel (2500), Tom Lockner (DMTS, 1264), Tom Cutcheon (2560), and George Novotny (7222), chorus. Jennie Schwoebel (Dick's wife) has the role of Phyllis; Bill Burnett's (3210) wife, Joanne, is the musical director and plays the role of the Queen of the Fairies, and Pace VanDevender's (1200) wife, Nancy, has the role of Fleta. Tickets are available at the door; $4/adults, $3/students.

NATIONAL ENGINEERS WEEK (Feb. 18-24) activities, sponsored by the Albuquerque Chapter of the National Society of Professional Engineers, included a tour at Sandia by a group of selected high-school students. Here, some of the visitors learn about the Particle Beam Fusion Accelerator II from Bob Clevenger (1266, second from right).

(Continued from Page One)

Materials Science Award

devices, and the realization of the potential impact that such devices could have on DOE programs," says Dave. "This all comes from the fundamental research sponsored by BES."

Other high-temperature superconductors at present include compounds that contain yttrium or bismuth instead of thallium, along with various combinations of calcium, barium, strontium, copper, and oxygen. Two of the various forms under investigation at Sandia are $Tl_2CaBa_2Cu_2O_8$ and $Tl_2Ca_2Ba_2Cu_3O_{10}$. Thin-film materials — of thickness typically between 0.1 and 1.5 micrometres— are grown by depositing layers of each metal onto a substrate, then carefully heat-treating them. The thin films are suitable for use in microelectronics. (See "More Than Shaking and Baking" for additional detail on processing.)

"A [processing] technique may work today, fail tomorrow, and work again a week from now. That's natural at this stage . . ."

World Leader

"Sandia is a world leader in the thallium system," says Bruno Morosin. "These thallium materials are not simple. There are five or six different types of crystal structures, and the atoms in them are in layered, but complex, arrangements. We've made a lot of progress in processing the materials to create superconducting thin films. When I attend scientific meetings, I find that our materials are generally leading the field."

One characteristic of the Sandia-produced materials is their high critical current density: They can carry large electrical currents — nearly a million amps per square centimetre at the liquid-nitrogen temperature of 77 K (-196°C or -321°F).

All high-temperature superconductors are "Type II" materials. Placed in a magnetic field that's within a certain range of strength (the range varies with the material and the temperature), the superconductor is penetrated by the field. However, the field is bunched into flux lines (see figure), confined to specific regions rather than spread uniformly throughout the material.

If these flux lines are "pinned" in place, perhaps by small impurities or flaws in the structure, there's no resistance to current — the current remains lossless in the magnetic field. If the flux lines can be moved by the effects of the current and field, however, they absorb some of the energy of the current. Energy is dissipated, and the material no longer has zero resistance. Whether flux is pinned is an important consideration, because most applications for superconductors involve magnetic fields.

(A Type I superconductor either is not penetrated by a magnetic field of a certain strength, and thus remains completely superconducting, or is penetrated and ceases to be a superconductor. There's no in-between range.)

Novel Materials, Novel Devices

During the past year, researchers have disputed whether "flux flow" — energy-dissipating movement of flux lines within high-temperature superconductors — will prevent the materials' use for practical applications. But the Sandia team believes that the new materials can be exploited by a new way of thinking.

"Conventional low-temperature superconductors have a certain set of properties," explains Gene Venturini, "and devices were designed on the basis of these properties. The new materials have a new set of properties, particularly at the higher operating temperatures."

With the help of collaborators at the University of Wisconsin — professors Jim Beyer and Jim Nordman, and graduate student Jon Martens — the Sandians have demonstrated that flux flow can be used as a basic principle in new types of electronic devices. Using superconducting films produced at Sandia, the Wisconsin team made the first flux-flow transistors: devices that could improve on current technologies in areas such as high-speed, low-noise communications.

The Sandia team believes that the new materials can be exploited by a new way of thinking.

"This is one of the first active superconducting devices," says Dave Ginley. "It's so new that we're just beginning to see its potential." Sandia researchers are now working to develop techniques by which superconducting microelectronic devices like the flux-flow transistors can be produced through essentially the same processes as conventional semiconductors.

Dick Baughman emphasizes that the thallium materials are still in the research stage: "Right now it's almost an art, rather than a science. In general, we know how to make a film of fairly high quality nearly every time we try, but we haven't learned all the specifics yet. A technique may work today, fail

(Continued on Next Page)

Producing and Evaluating Superconductors

More Than Shaking and Baking

For Sandia's high-temperature superconductors, developing the materials and understanding them have gone hand in hand. One of the early steps in working with the thin films was to study their molecular structures (with techniques such as x-ray diffraction and scanning electron microscopy) and understand how different structures were related to different processing techniques.

Now, the Sandia group has a fairly routine procedure for producing the materials, but they're still gathering data as processing conditions and results vary. Regularly involved in preparation and characterization of the samples are Ted Castillo (1152), Ron Hellmer, and Mary-Anne Mitchell (both 1144).

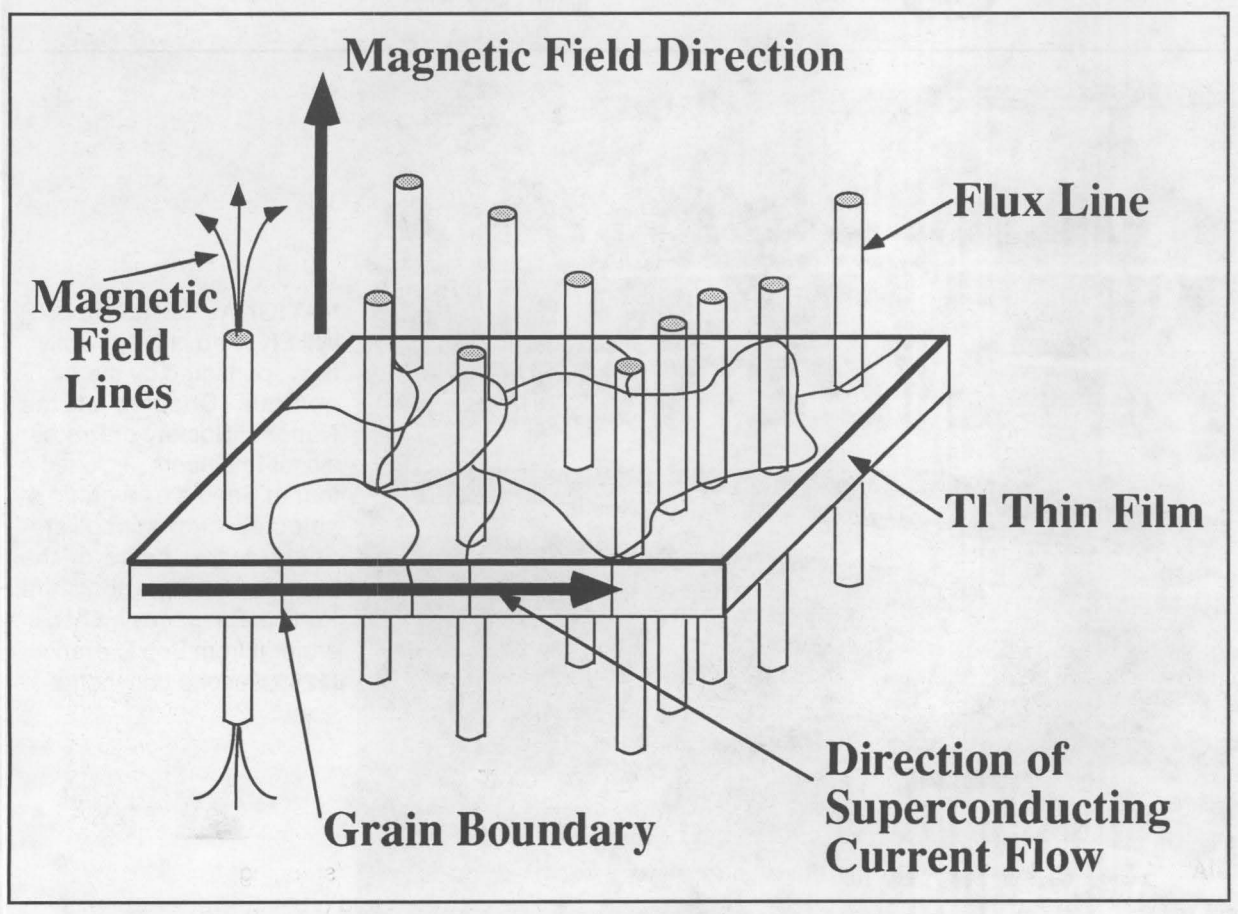
The films are produced by depositing layers of copper, barium, calcium, and thallium (in that order) onto substrates from one to five centimetres in diameter. The deposition is done by electron-beam evaporation: a high-energy beam of electrons directed at a metal source heats the metal, causing atoms to leave it and deposit on the substrate.

Once the metal layers are deposited, a crucial step is sintering — heating the film to a temperature somewhat below the melting point, under a controlled atmosphere of thallium and oxygen vapor. The films are polycrystalline — that is, each consists not of a single crystal, but of many small, crystalline grains. One effect of sintering is to fuse the grains to each other. Sintering conditions can be varied to produce films consisting of grains whose crystal structures are either randomly oriented or aligned.

The film on its substrate is cut into a number of samples. Each is measured to find out how much electrical resistance it has at normal temperatures (above the superconducting transition temperature). The normal-state resistance can indicate the quality of the sample — such as whether the current crosses grain boundaries.

For samples that have favorable normal-state resistance and become superconducting at a sufficiently high temperature (perhaps 110 K), further — and more time-consuming — measurements are made. One of them is critical current density in liquid nitrogen — the maximum current that can be carried by a given area of the material. Magnetic properties are also measured, to assess the flux pinning and the fraction of material that is superconducting.

Some samples are turned into experimental microelectronic devices, such as the flux-flow transistors mentioned in the main story. The prototype devices are made with photolithographic processing similar to that used in producing other microelectronics.



MAGNETIC FIELD is bunched into flux lines in a high-temperature superconductor.

(Continued from Preceding Page)

tomorrow, and work again a week from now. That's natural at this stage — results will gradually get more and more consistent."

"The work for which the award was given," says Dave, "was fairly early on the learning curve. We're accelerating rapidly, but we got to this point only because everyone on the team did his part. It would be misleading to try to specify who did exactly what, because everybody contributed a lot of ideas."

"We were working a lot of hours," Jim Kwak says, "but I think one thing that helped hold us together as a team was taking time for an occasional party."

"Don't forget the T-shirts!" says Bruno, who explains: "Early in the program, Dave's wife, Lucy, designed T-shirts that we had made up — blue shirts with hot-pink drawings of the crystalline structure and experimental results proving superconductivity. They are our symbol of team spirit."

More Techniques, More Prototypes

"As we see the possibilities expanding," says Bruno, "we're exploring the use of other techniques available here at Sandia, such as ion implantation. More and more people are getting involved."

Besides the flux-flow transistors, there is the possibility of developing other types of prototype devices. "One objective," says Gene, "is a SQUID — a superconducting quantum interference device. SQUIDs are sensitive magnetic-field detectors, and it would be useful to be able to operate them at liquid-nitrogen temperatures." Another important possibility is a type of infrared detector that might be used in weapon programs.

Besides finding and refining uses for the present materials, there's also the possibility of modifying the materials so that the flux doesn't flow. They would then be more suitable for conventional superconductor applications — which today include, for instance, magnetic-resonance imaging for medical diagnosis.

Gene likens the present state to the early days of work with conventional superconductors: "Those materials actually suffered from many of the same kinds of problems initially. But ways were found to get around a lot of the problems. That's pretty much where we are now." •CS

Comment From 1000 and 1100

"I am delighted that the Office of Basic Energy Sciences has recognized Sandia's work on high-critical-current thallium superconductors through the Research Competition award. Congratulations to the team, which has been working diligently in this area for the last year and a half."

— Venky Narayanamurti,
VP-Research 1000

"We like to point out that Sandia is both a science and an engineering laboratory. This award helps solidify our reputation as a laboratory that can do outstanding fundamental science, as well as engineering, and therefore can provide a broad, integrated spectrum of technical work.

"In the case of the flux-flow transistor, the materials development is what makes possible the device application. It's a strength of Sandia that fundamental work takes place in a setting that can quickly use it for a technological result. This kind of interplay, along with our multidisciplinary interactions, makes our work stronger and more efficient."

— Fred Vook,
Director of Solid State Sciences 1100

To Using High-Temperature Superconductors

Magnetic Properties Are the Key

Superconductors are materials that allow electrical current to flow without resistance — that is, without dissipating energy. Generally, that requires cooling the material to a low temperature.

As recently as the mid-1980s, no known material became a superconductor at a temperature above about 25 K — equal to -248°C, or -414°F. (The temperature below which a given material is a superconductor is called its critical temperature — T_c — or superconducting transition temperature.)

Then, in 1986, Johannes Georg Bednorz and Karl Alex Müller of the IBM Zürich Laboratory found that certain copper oxides had T_c values higher than 30 K — a discovery that won them the 1987 Nobel Prize. Since then, materials have been developed that become superconducting at much higher temperatures.

The thallium-containing materials being studied at Sandia — first reported in 1987 by Allen Hermann (then at the University of Arkansas)— generally have T_c values above 110 K (-163°C, -261°F), and may range up to 125 K (-148°C, -234°F), which is the highest T_c to date.

Their high transition temperatures mean that the new superconductors can be cooled with liquid nitrogen — at a temperature of 77 K (-196°C, -321°F) — instead of more-expensive, harder-to-work-with liquid helium.

Magnetic Flux Moves Easily

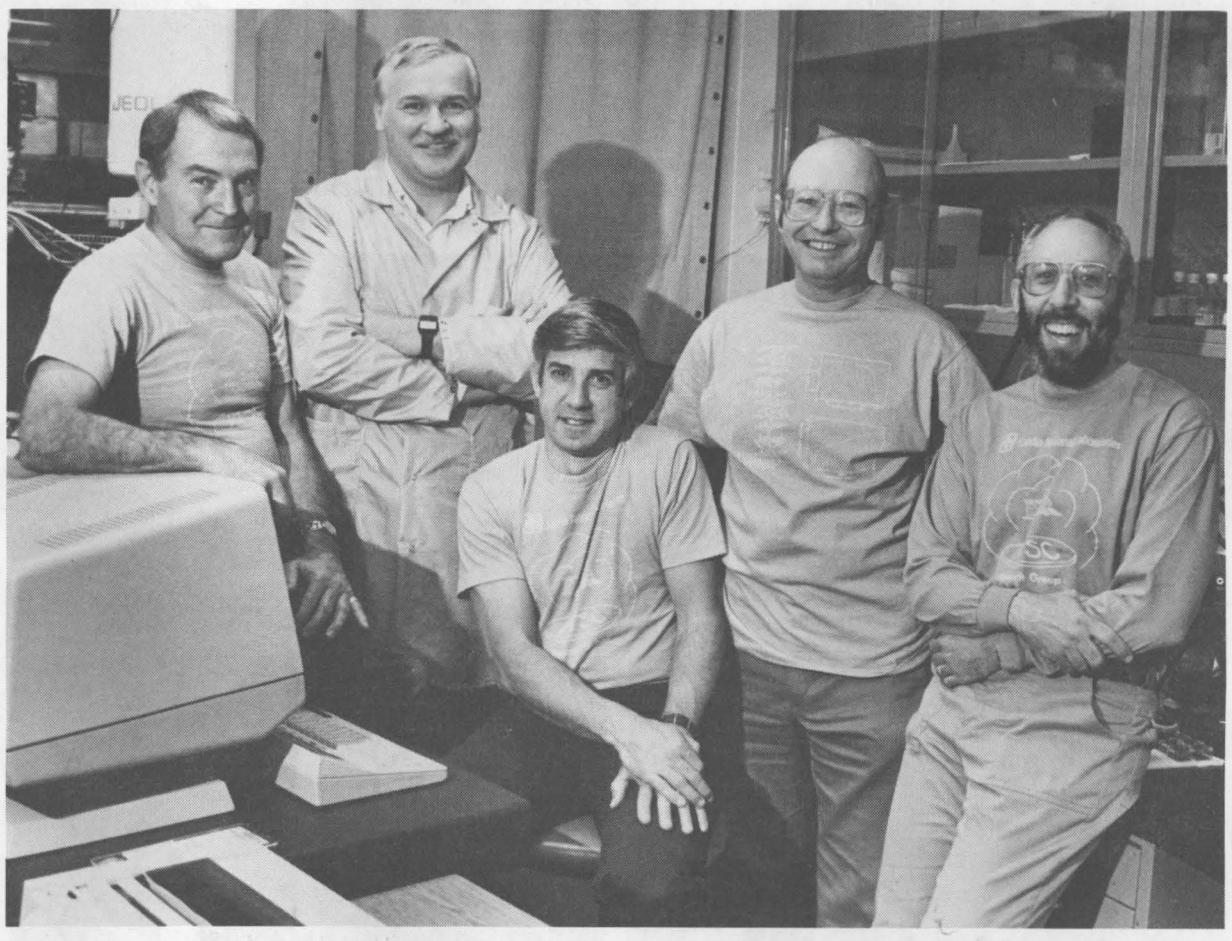
High-temperature superconductors — which along with some conventional superconductors are classified as Type II (see main story) — are unusual in their response to a magnetic field. Most materials allow a magnetic field to penetrate uniformly, but in Type II superconductors, the field is confined to narrow cylindrical cores, called flux lines.

The flux lines are quantized, each one containing the same amount of magnetic flux. The flux lines are frequently located at defects, impurities, or grain boundaries. A typical laboratory magnetic-field strength of one-tenth tesla (some 2000 times the earth's magnetic field) results in 10 billion flux lines per square centimetre. Because each flux line is less than one-millionth of a centimetre in diameter, however, the lines are well separated. At very low temperatures — well below that of liquid nitrogen — the mutual repulsion of the flux lines causes them to form a regular hexagonal array, called a flux lattice.

A combination of superconducting current flow and the magnetic field exerts a force on the flux lines. If the temperature of the material is increased, "bundles" of flux lines begin to move in response to this force. Because of the unique physical properties of the new superconductors, the flux lattice begins to "melt." At liquid-nitrogen temperatures, the flux lines move easily.

If superconductors are to be lossless carriers of current — for instance, in highly efficient power transmission — flux motion is unacceptable, because it is a mechanism through which energy is lost. A solution to that problem would be to intentionally "pin" the flux bundles at structural defects or impurities in the material. Current research at Sandia and elsewhere involves the controlled introduction of structural defects through special processing of the superconductors or through irradiation by high-energy ions or neutrons.

Some applications of high-temperature superconductors, however, capitalize on the rapid motion of flux lines. An example is the newly developed flux-flow transistor. In this device, current passing through a control line creates a magnetic field that induces flux motion in the superconductor. Varying the current causes the transistor to switch rapidly between the lossless and "flux-flow" states. The flux-flow transistor promises to become the primary building block of a large number of new high-speed, low-noise analog and digital devices.



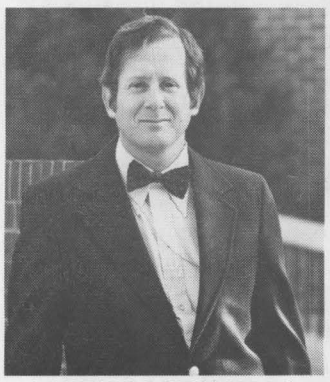
SANDIA'S WINNING TEAM in the 1989 Materials Science Research Competition: (standing, from left) Dick Baughman (1144), Jim Kwak (1152), Bruno Morosin (1150), Dave Ginley (1144), and (seated) Gene Venturini (1152). Most are wearing the high-temperature superconductivity T-shirts designed by Dave's wife, Lucy.

Supervisory Appointments

LARRY COSTIN to supervisor of Geomechanics Analysis and Testing Div. 6314.

Larry joined the Labs in July 1978, and was a member of the Geomechanics Research Division until 1986, when he transferred to the Geotechnical Design Division. His work included studying the fracture mechanics of rock, micromechanics of rock deformation, and oil shale *in situ* processing.

He has bachelor's, master's, and PhD degrees in mechanical engineering, all from Brown University. Before attending graduate school, Larry was a member of the US Navy Submarine Service. He's a member of the American Society of Mechanical Engineers (vice-chairman of the New Mexico Section), the Society for Experimental Mechanics, and the International Society for Rock Mechanics. In 1987, he received the US National Committee for Rock Mechanics Award for Basic Research in Rock Mechanics.

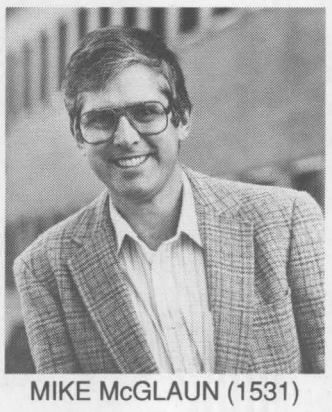

LARRY COSTIN (6314)

Larry enjoys shooting, hunting with a muzzle-loader, and fly-fishing. He's active in the US Practical Shooting Association. He and his wife Priscilla have one son and live in the NE Heights.

* * *

MIKE McGLAUN to supervisor of Computational Physics and Mechanics Div. I 1531.

Mike joined Sandia in July 1976 as a member of Firing Subsystems Div. III, where he modeled compressed magnetic field generators using a two-dimensional, magnetohydrodynamics computer code. In June 1978, he transferred to the Code Application Division, where he worked in development and application of software systems for strong-shock modeling. In May 1982, he transferred to the Thermal/Hydraulics Analysis Division.


MIKE McGLAUN (1531)

He has a BS in mechanical engineering from Texas A&M University and an MS and PhD in continuum mechanics from the University of Kentucky.

Mike enjoys board-sailing, skiing, jogging, weight-lifting, and juggling. He and his wife Kathy live in NE Albuquerque.

* * *

LORAINE McCUTCHEON to supervisor of Military Manuals Composition and Computer Support Sec. 3152-2.

Loraine joined the Labs in November 1979 as secretary of the Central Computer Network Division. In 1981, she was promoted to department secretary in the Safeguards Applications Department. Loraine joined the Office Systems Division in 1982 as a senior clerk in the word-processing center.


LORAINE McCUTCHEON (3152-2)

In 1983, she was promoted to MA-V and worked on office-automation and voice-messaging projects.

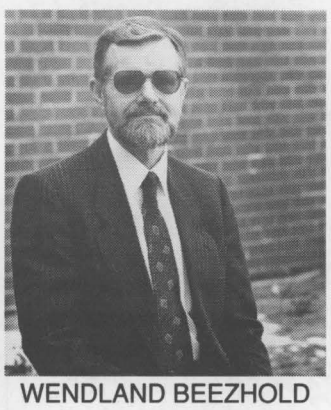
She has a BA in business administration from the University of Albuquerque. Before coming to Sandia, she worked for the Bank of New Mexico in Albuquerque.

Loraine enjoys camping and bowling. She and her husband Bern have two sons and live in NE Albuquerque.

* * *

WENDLAND BEEZHOLD to manager of Simulation Technology Dept. 9340.

Wendland joined the Labs in January 1970 as a member of the Ion Implantation Physics Division. His work at Sandia has been primarily in experimental and theoretical studies of radiation effects within electronic systems and materials, and developing and applying both pulsed- and DC-radiation sources.


WENDLAND BEEZHOLD (9340)

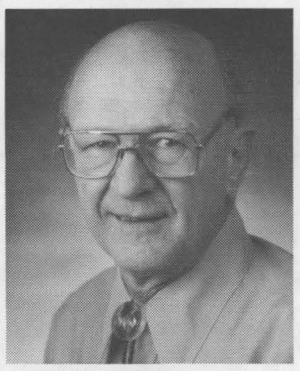
From 1975 to 1977, he was on leave of absence from Sandia to serve as director of Montana State University's magnetohydrodynamics and energy research program.

In 1977 he was promoted to supervisor of the Beam Source Applications Division, and was part of the team that developed Sandia's Saturn and STL simulation facilities. Wendland was supervisor of the Simulation Technology Research Division when he was recently promoted.

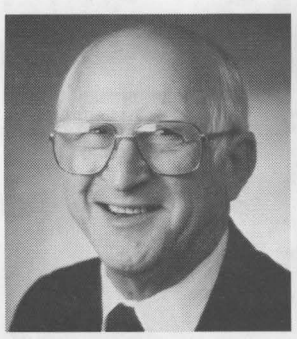
He has a BS and an MS in physics and a PhD in solid-state and nuclear-magnetic-resonance physics, all from the University of Washington. He worked for Boeing before joining the Labs. Wendland also taught physics as an adjunct professor at Seattle University from 1964 to 1969. He's a member of the steering committee of the Hardened Electronics and Radiation Technology Society.

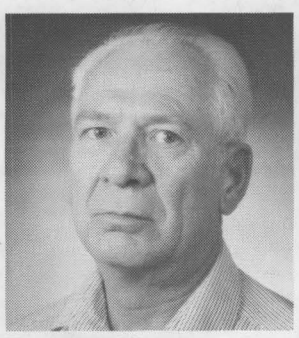
Wendland enjoys sports, backpacking, running, music, and church activities. He and his wife Jeanne have two grown children and live in the NE Heights.

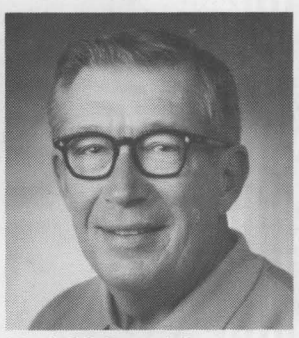
Recent Retirees

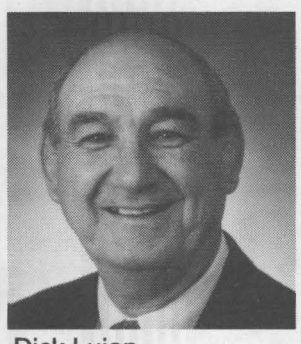

Jesse Rehberg (9214) 40

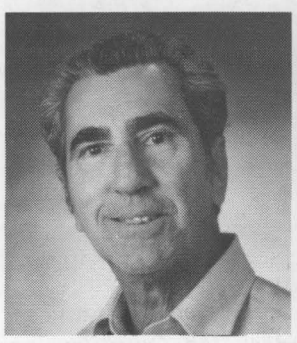

Margaret Ebaugh (3716) 23
Wayne Ebaugh (5214) 30

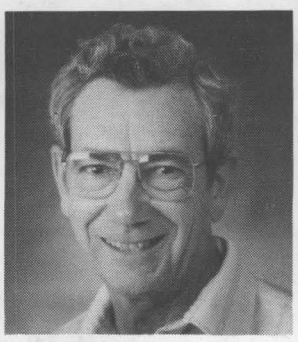

D. H. Weingarten (2552) 32

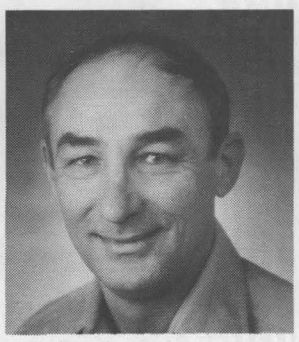

Thaddus King (2543) 38

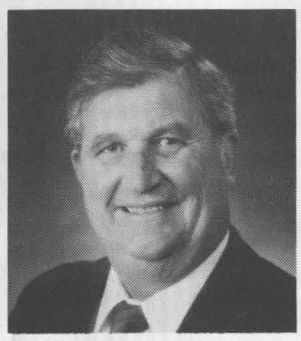

M. J. McLaughlin (1200) 35


Dick Lujan (3741) 38


John Stathis (3734) 32


Larry Dyer (7522) 33


Bill Jacoby (3432) 31


W. B. Norwood (122) 38

feedback

Q. Now that copying machines are available everywhere, why do we still have both purchase orders and expense vouchers with many pages? Users know they can't make their copies readable, so they copy the first page. Most secretaries won't — and reasonably so — type them. Someone with arthritis could not possibly use enough pressure to make even the second copy readable. Cost should not be the only consideration.

A. Multi-part forms serve many purposes that a single-part form, reproduced, cannot. Changes to information appear on all copies. Color coding on the different plies facilitates distribution of the form to all concerned organizations. Divisions using large quantities of these forms do not have to get extra help to spend hours at copying machines. Because of these reasons, Sandia will continue to use multi-part forms.

Currently, these forms are produced from the best-quality NCR paper. As NCR paper quality improves, or electronic-forms technology becomes feasible, form readability will also improve.

Paul Stanford — 100

Take Note

Dana Powers (6422) has accepted an invitation from DOE Secretary James Watkins to continue as a member of DOE's Advisory Committee on Nuclear Facility Safety for a term continuing until March 1, 1992.

* * *

Peace negotiations continue in the effort to end the Battle of the Sexes. Gender equity specialist and newspaper columnist Amanda Smith ("The Sexes: Working Together," Scripps-Howard News Service) will present a one-day workshop about developing trust between women and men in the workplace on March 24 at the Albuquerque Convention Center, Taos Rm. The workshop is sponsored by the *Albuquerque Tribune* and Committed to Education Associates, a scholarship fund-raising association formed by Sandians Lorraine Elliott (2116), Mary Ann Lindsay, Betty Turk, and Berta Rodriguez (all 4000-1) to assist women needing help with educational expenses. Cost is $35 for all day or $25 for morning or afternoon sessions only. Registration deadline is March 17. Information is available from Lorraine on 4-7864, Berta on 6-4870, or Betty on 4-9081.

Financial Seminar

Daisy Johnson and Mary Mahoney of Financial Network Investment Corp. will make the final presentation of their three-part series, "Financial Puzzles," March 13 at the Coronado Club, 5-6 p.m. This presentation: "Can Risk Work for You: Using Probate, Wills, and Trusts." For information, contact Daisy or Mary on 291-8585.

UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS

Deadline: Friday noon before week of publication unless changed by holiday. Mail to Div. 3162.

Ad Rules

1. Limit 20 words, including last name and home phone.
2. Include organization and full name with each ad submission.
3. Submit each ad in writing. No phone-ins.
4. Use 8½ by 11-inch paper.
5. Use separate sheet for each ad category.
6. Type or print ads legibly; use only accepted abbreviations.
7. One ad per category per issue.
8. No more than two insertions of same "for sale" or "wanted" item.
9. No "For Rent" ads except for employees on temporary assignment.
10. No commercial ads.
11. For active and retired Sandians and DOE employees.
12. Housing listed for sale is available for occupancy without regard to race, creed, color, or national origin.

MISCELLANEOUS

WALTER HAGEN CLUBS, Spalding bag, caddy, $150; octagonal game table, $50; Rossignol skis, ST650, $25; wine rack, $5; Capehart AM/FM stereo, $25. Mason, 281-3052.

KENMORE WASHER/GAS DRYER, heavy-duty, almond, $450. Walton, 898-5042.

DESK, formica top, 2 drawers, 30" x 48" x 26-1/2" high, $65. Long, 294-4591.

ZENITH COLOR TV, 19", $135 OBO. Chandler, 821-3356.

NIKON N2020 SLR CAMERA, w/50mm AF and 70-210mm AF zoom, Nikkor lenses, $600 OBO. Kramer, 294-0488.

TWO ROUND-TRIP AIRLINE TICKETS, to New Orleans, leave Albuquerque March 15, return March 18, $100/ea. Hamilton, 294-5850.

AKC DACHSHUND PUPPIES, black/tan, $200/males, $300/female; 3-hp gas outboard motor, $110. Puccini, 255-0568.

PSE COMPOUND BOW, 45-60 lb., 29-30 in. draw, $100; brown floral-print sofa, chair, ottoman, $175. Montague, 281-4025.

BUILT-IN DISHWASHER, Caloric, white or almond, 2 wash levels, fits 24" opening, $150. McWilliams, 281-1224.

CHEST FREEZER, 22 cu. ft., $200; refrigerator, 14 cu. ft., $150. Benham, 881-2593.

FOUR RADIAL TIRES, 15", on white Jackman spoke rims, fits Chev., Toyota, Nissan trucks, $65/all. Lucero, 294-2546.

OAK DRESSER, w/6 drawers, mirror, $50. Stevenson, 299-3510.

WASHER & DRYER, Whirlpool, electric, $90/ea. Forrest, 275-3797.

CARPET, approximately 13' x 16' plus hall, medium shag, mottled blues and beiges, $50. Snodgrass, 268-8820.

MATCHING COUCH AND CHAIR, earth tones, $100; antique vanity, $50; portable dishwasher, $30; refrigerator, $200 or trade for freezer. Goodson, 275-7707.

DINETTE SET: 42" x 60" butcher-block-top table w/chrome legs, 4 vinyl-covered chairs, $100. Kidd, 256-1020.

BIRD-DOG-CROSS PUPPIES, male, 6 weeks old, free to good home. Hammond, 296-7985.

FREE-FORM SWAG, pale green w/small ecru flowers, 45" wide x 132" long, 3 pieces, w/copper rods. Wagner, 823-9323.

M-1 GARAND, late manufacture, carrying case, 1000 rounds ammo, $750. Foster, 281-3975.

HANGING LIGHT FIXTURE, Mexican wood and wrought-iron, 4 amber globes, rewired, attached 15' black chain, $50. Bland, 265-6286.

FULL-SIZE VIOLIN, appraised at $200. Holmes, 292-0898.

HEATH DUAL-TRACE SCOPE, $200; counter, $150; generators: function, $80, signal $45, audio, $40; other items, $10-$100. Levan, 293-0079.

PORTABLE COLOR TV, 13", remote control, stereo receiver, cassette deck, speakers, stand. Shortencarier, 293-8053.

BOAT TRAILER, Sears, for boats up to 14' long, winch, lights, spare tire, wheel, non-skid walkway, 1-7/8" coupler, $325. Hughes, 299-6674.

SOFA, $200; kitchen hutch, $125; microwave, $125; X-cargo carrier, $40; sink, $50; smoked-glass mirror, $50; chandeliers. Bonzon, 828-1066.

REFRIGERATOR/FREEZER, GE Hotpoint, 20.7 cu. ft., 4 months old, cost $625, sell for $425. Guerra, 842-1491.

WAGNER POWER PAINT ROLLER, $30; 450 vacuum tubes, $45 OBO; '87 Toyota truck tires, w/rims, rear window, $80 OBO. Jesse, 296-1709 leave message.

WASHER/DRYER, Kenmore heavy-duty, porcelain tubs, almond, $350; wood-top Whirlpool portable dishwasher, $100. Packwood, 255-6644.

CAMPER SHELL, wired, aluminum, insulated, for small truck, $115. Gonzales, 898-5978.

WHEEL, 14" x 6" standard 5-hole, GM pattern; spare tire, 205 75R14, $25 OBO. Newman, 299-6018.

FOOD SLICER, electric, Rival model 1030V, $35 OBO. Liguori, 256-3613.

KONICA FT-1 CAMERA, 50mm and 70/200 telephoto lenses, 2x converter, haze and UV filters, padded case, tripod, $300. Jones, 299-1658.

WALL-TO-WALL CARPET, blue, 12' x 12', $50; desk, 40" wide x 19" deep x 30" high, $45. Navratil, 293-5527.

PROM DRESS, size 5, white, strapless, ribbed knit top w/10-layer ruffled nylon skirt, cost $150, sell for $60. McMillen, 881-6077.

HEATHKIT GR295 TV, Mediterranean cabinet, tube-type, weak picture tube and tuner, spare tubes and manual, free. McClintock, 294-4286.

BEDROOM SET: white, older style, 5 pieces, $105; Venetian blind, aluminum, almond color, $5. Koletar, 255-4751.

YARD SALE: guitar, flute, punching bag, misc., 8 a.m.-2 p.m., Saturday only (March 10), 3600 Espejo NE (near Comanche & Eubank). Komen, 299-8881.

TV/STEREO CABINET, glass door, $90; 5-shelf bookcase, $45; 3-shelf bookcase, $30; all wood-grain finish. Hietala, 296-3287.

DP BODYTONE 250 MULTI-GYM, $45. DeReu, 275-2336.

FURNITURE: 3-seat couch, recliner, chair w/ottoman, chocolate brown vinyl, no tears, $250. Hole, 255-1444.

MICROWAVE OVEN, full-size, temperature probe, $50. Jones, 292-1581.

COMMODORE 64 COMPUTER, 1541 drive, Epson adapter, Multiplan, Flight Simulator, Easyscript, Print Shop, $230. Goldenberg, 821-6209.

KNITTING MACHINE, w/lace & intarsia carriages, 30 cards, blank cards, card punch, professional lessons, $350; ribber, $250. Smith, 892-4041.

QUEEN-SIZE SEALY POSTUREPEDIC MATTRESS and box spring, used 2 years, $100. Miller, 883-0218.

MADAME ALEXANDER DOLL, Mary Cassatt, mint in box, $57; 2 stereo record players w/speakers, $15/ea. Van Deusen, 291-8196.

CRAFTSMAN 18" SCROLL SAW, tabletop model, $75. Adkins, 271-0025.

COUCH AND MATCHING CHAIR, brown, $195. Davis, 294-1048.

FOUR AUTO CAPTAIN'S CHAIRS, one needs repair, burgundy/gray upholstery, $100 OBO. Berg, 296-2695.

ABOVE-GROUND POOL, 4' x 18' diameter, $500 OBO. Greene, 292-1613.

TRANSPORTATION

YAMAHA 150 MOTORCYCLE, $185 OBO. Chandler, 821-3356.

'78 FIAT SPYDER CONVERTIBLE, model 124, 62K miles, new top, $3000 OBO. Stuart, 265-7315.

'82 HONDA NIGHTHAWK 650, fairing, seat rack, $750; woman's 18" Univega mountain bike, 3 yrs. old, $55. Goodson, 275-7707.

'83 DODGE PICKUP, 1/2-ton, 6-cyl., AC, PB, PS, AT, new tires, 36K miles, $3150. Andrews, 256-7328.

'85 COLT VISTA WAGON, FWD, AC, 50K miles, new tires, brakes, battery, $5000 OBO. Berman, 296-5640.

'78 TOYOTA LAND CRUISER, wide wheels and tires, winch, roof rack, more. Johnson, 898-8439.

'76 FORD CONVERSION VAN, 4-WD, fiberglass camper top, 85K miles, $3500. Siska, 298-1624 or 345-6212.

'61 PONTIAC BONNEVILLE, 4-dr. hardtop, 4-spd., AT, PS, PB, needs front fender, grille, bumper, $395 OBO. Daut, 255-2529.

'89 MERCURY GRAND MARQUIS GS, 4.1K miles, $15,000; '78 Cadillac Coupe DeVille, 61.7K miles, $2000. Garrison, 881-1851.

'86 HONDA XL250R MOTORCYCLE, 4-stroke, $650. Swahlan, 292-3598.

'83 ESCORT GL, PS, AC, cruise, AM/FM cassette, hatchback, 74K miles, $1900. Knewitz, 265-6092.

'87 TOYOTA PICKUP, 4x4, 5-spd., AC, PS, PB, AM/FM cassette, sport stripes, adult-driven, 56K miles, $7200 OBO. Zaorski, 281-9194.

GIRL'S BIKE, 20", $15. Gonzales, 898-5978.

'89 FORD AEROSTAR XL MINIVAN, 24K miles, dual AC, AM/FM cassette, tinted windows, $13,200. Clise, 271-2865.

'90 RANGER XLT PICKUP, 2K miles, AM/FM cassette, bed liner, undercoating, $10,200. Tessler, 293-5628.

'78 SEA RAY CABIN CRUISER, 24', w/flybridge, sleeps 5, loaded, Butte slip goes with the boat. White, 898-7646.

'85 FORD F-150 XL PICKUP, 302 V-8 EFI, AT, AC, AM/FM tape, w/custom topper shell, trade for camper trailer or $7500 OBO. Garcia, 293-3937.

'87 TORONADO, loaded, burgundy color, 22K miles, $11,800. Greenwood, 298-5268.

'87 NISSAN 300ZX, 21K miles, T-tops, 5-spd., electronics package, AM/FM cassette, cruise, champagne pearl, $13,500. Walker, 294-4087.

'81 HONDA ACCORD, 5-spd., 2-dr. hatchback, AM/FM, AC, 59K miles, passed emissions test, $2495. Kepler, 296-0402.

CHILD'S BICYCLE, 12", for 2- to 5-yr.-old, training wheels included, $35. Shirley, 821-0480.

'77 FORD BRONCO, 4x4, PS, 3-spd., 302 V-8, $3600; '80 Audi 5000S, new engine, tires, battery, electric fuel pump, $2600. Sanchez, 869-6423.

BUICK LeSABRE, custom 4-dr., 89K miles, one owner, sell below NADA retail for $3300. Moore, 345-4030.

FIAT X1/9 SPORTS CAR, convertible, removable hardtop, new tires, clutch, brakes, $1000 firm. Moss, 299-5149.

'84 MERCURY LYNX, 4-cyl., 5-spd., 2-dr., radio, 86K miles, $2000 OBO. Berg, 296-2695.

REPOS: '70 Olds. Cutlass, needs repair; '84 Pontiac Firebird, bids accepted through March 19, we reserve the right to refuse all bids, subject to prior sale. Sandia Lab FCU, 293-0500.

'77 OLDS. CUTLASS SUPREME, AT, PS, PB, 4-dr., white w/red velvet interior, new windshield and battery, $995. Farmer, 898-2340.

10-SPD. RACER BICYCLE, made by C. Itoh, $60. Jones, 843-9645.

BIKE, $30. Bonzon, 828-1066.

REAL ESTATE

80 ACRES, northwest of Datil in Sawtooth Mtns., $150/acre or trade. Harrington, 899-1277.

3-BDR. RIO RANCHO HOME, 1542 sq. ft., formal DR, FP, double garage, 1/4-acre, landscaped, $78,000. Wanya, 891-0018.

APPROXIMATELY 10 ACRES, below Sandia Ski Area, views; quarter-share condo, Colorado ski resort, sleeps 6, all or part. Clement, 299-2324.

3-BDR. PARADISE HILLS HOME, 1475 sq. ft., sunroom/study, landscaped, hot tub, open floor plan, near schools, $83,900. Deuel, 898-5836.

2-BDR. TOWNHOUSE, 1-3/4 baths, garage, refinance or take over payments, $38,000. Schindwolf, 831-1940.

3-BDR. MOBILE HOME, 2 baths, LR, kitchen, pantry, washer/dryer, 14' x 80', '84 Fleetwood Vogue, set up in park, $15,500 negotiable. Reed, 821-6315.

CABIN SITE in the Brazos near Chama, NM; 10 acres near Mora. Garcia, 293-3937.

MARLETTE MOBILE HOME, 12' x 60', completely furnished, at Elephant Butte, $5500, lot not included. Liguori, 256-3613.

ANGEL FIRE LAKESIDE LOT, has all utilities. Krahling, 294-2623.

TRIPLEX AND DUPLEX, NE Heights, triplex needs work, will consider all offers. Cook, 296-1020.

PAGOSA SPRINGS (Colo.) HOME, on 5 acres, w/garage and year-around access, $65,000. Mares, 884-4843.

3-BDR. HOME, Four Hills Addition, 1470 sq. ft., 1-3/4 baths, FP, 2-car garage, auto sprinklers, $86,500. Martinez, 296-9035.

4-BDR. HOME, on 2.5 acres in Cedar Crest, 1980 sq. ft., 2 baths, detached garage w/heated workshop, horse facilities, $135,000. Hurt, 281-3675.

WANTED

CAPTAIN'S BEDS OR BUNK BEDS, light color wood; skis for small children. Nimick, 281-3148.

SEMI-FORMAL or party dress, for teen size 14-18. Sanchez, 836-3060.

PORTA-BED w/mattress. Luna, 877-3137 after 5.

TWO BAR STOOLS, 20", swivel base, in any condition. Chandler, 821-3356.

PATIO SWING, reasonable. Long, 294-4591.

INFANT/SMALL CHILD CAR SEAT. Underhill, 294-5774 after 6:30.

KITTEN, cuddly, furry, friendly. Doran, 299-2635.

VACATION COMPANIONS, 2 women (age 40s) to join 2 women, Philadelphia, Pennsylvania Dutch country, Atlantic City, share expenses, March 22. Johnson, 296-1917.

DESKTOP ADDING MACHINE, w/printer tape, dependable, reasonably priced, simple. Barr, 821-5870.

CAMPER TRAILER, approximately 23', self-contained, w/rear bed. Garcia, 293-3937.

TRUCK, early model 4x4, crew cab/super cab, 3/4- to 1-ton, long bed, Ford or GM. Krause, 299-0931.

OVER AND UNDER TRAP GUN; reloading equipment. Beradino, 823-2105.

BASKETBALL GOAL AND POST SET, height-adjustable type preferred. Bonzon, 828-1066.

LAWN MOWER, electric rotary-type. Davis, 294-1048.

WORK WANTED

BABYSITTING, reliable 14-yr.-old girl, available Friday evenings, Saturday, and Sunday, far NE Heights area. Willan, 821-3011.

LOST AND FOUND

GENIE GARAGE-DOOR TRANSMITTER, lost between Bldg. 880 and Gate 18 dirt parking lot on Feb. 14. Sanchez, 836-3060.

REVO SUNGLASSES, green lens, on Feb. 17, lost possibly along north fence of Nuclear Weapons Training Center. Winkelman, 271-0221.

SHARE-A-RIDE

FULL-TIME VANPOOL SEATS AVAILABLE, along N-14, Frost Rd., Tijeras, ride every day. Yelton (281-2893) or Burns (281-3922).

WANTED: anyone interested in starting a carpool from Santa Fe to Sandia. Flores, 1-438-0067.

Coronado Club Activities

Looking for a Swellegant, Elegant Party? Try Seafood Night/Wine-Tasting

PEOPLE SEARCHING FOR PISCINE PLEASURE hit the jackpot tonight, because the Seafood Night menu features both lobster tail ($13.95) and broiled salmon ($7.95). A wine-tasting session between 5 and 7 p.m. may help you select something to accompany your favorite fish dish. Free c/w dance lessons from 6 to 7 for those with dinner reservations, and Trio Grande strums the sagebrush-shuffle tunes from 8 until midnight. Reservations recommended (265-6791).

FAMILY FARE this Sunday (March 11) features the movie "Cheetah" on the big screen at 2 p.m. (free admission). Reasonably priced food is available starting at 1 p.m.

WESTERN NIGHT WRANGLERS have a chow-line treat in store March 16 (next Friday night) — New York steak ($7.95) or poached halibut ($7.95). Free c/w dance lessons (6-7 p.m.) for the dinner-reservation crowd; afterward, stomp to the tunes of the Isleta Poor Boys from 8 to midnight.

CELEBRATE WEARIN' O' THE GREEN at the St. Patrick's Day party on March 17. That famous son of Erin, Bob Banks (3531) plays the piano in the main lounge from 5:30 to 7:30 p.m.; here's your chance to sing along on your favorite Irish ballad. Featured on the menu is (of course) a corned beef/cabbage dinner ($6.95), which includes new potatoes, corn O'Brien, and a trip to the soup/salad bar. If you're not into corned beef, other selections are filet mignon ($8.95) and grilled albacore tuna ($7.95). Roland De Rose and his orchestra play dance music from 8 to 11:30. Early reservations are advised.

THE MARCH DISCOUNT is still in effect for those who join the brunch bunch on Sunday, March 18 (10 a.m.-1 p.m.). The goodies cost just $5.95/adults, $3.50/children from 4 through 11, and free/toddlers 3 and under.

CORONADO SKI CLUB MEMBERS get together for the last meeting of the season March 20, starting with a social from 7 to 7:30 p.m. Then it's election time: The schussboomers elect CSC officers for 1990-91. Lots of free goodies and great door prizes throughout the evening, which is a kind of belated Thanksgiving celebration in honor of all that fine February snow.

THUNDERBIRD ROADRUNNERS put the pedal to the metal again March 18-24. The happy campers travel to Patagonia Lake State Park, 12 miles northeast of Nogales, Ariz. For details, contact wagon master Harvey Miller on 268-5992.

More T-Bird news: The card sharks, with nary an ace up their sleeves, go back to the tables March 15, starting at 10 a.m. No doubt about it — this is one group that looks forward to the ides of March. Join them and find out why.

Retiree Deaths

Marjorie Michaud (72)	Jan. 2
Britt Marie Manrow (66)	Jan. 9
Gordon Bachand (69)	Jan. 11
Verna Thompson (78)	Jan. 13
Ernest Norton (75)	Jan. 15
Candido Montoya (68)	Jan. 17
Ralph Calvert (80)	Jan. 22
Jack Spence (82)	Jan. 24
Steve Drago (73	Jan. 27
Leandro Garcia (96)	Jan. 30

Sympathy

To Lawrence Anderson (7481) on the death of his wife in Albuquerque, Feb. 21.

To Ray Wood (5144) on the death of his mother in Albuquerque, Feb. 22.

Events Calendar

Events Calendar items are gathered from various sources. Readers should confirm times and dates of interest whenever possible.

March 9 & 10 — Classical Concert Seven: New Mexico Symphony Orchestra and Chorus perform Mendelssohn's "Elijah"; 8:15 p.m., Popejoy Hall, 842-8565.

March 9-18 — "The Beggar's Opera," John Gay's classic adapted to the Southwest in the 19th century by director Derek Davidson; music, comedy, and dancing girls galore; 8 p.m. Fri. & Sat., 6 p.m. Sun.; Vortex Theatre, 247-8600.

March 9-24 — "The Goodbye People," Albuquerque Little Theatre presentation of Herb Gardner comedy; 8 p.m. Thurs. & Fri., 6 & 9 p.m. Sat., 2 p.m. Sun.; Albuquerque Little Theatre, 242-4750.

March 9-31 — "The Wind in the Willows," Theatre-in-the-Making presentation of children's classic featuring Rat, Mole, and Mr. Toad by the riverbank, performed by the Youth Performance Workshop; 8 p.m. Fri. & Sat., CenterStage, 260-0331.

March 10 — "Best Voices of China," Asian Performing Arts presents recital of operatic arias, duets, and folk songs; featuring bass-baritone Tian Haojiang, tenor Zhang Jianyi, and pianist Wei Fugen; sponsored by the Han Chorale and New Mexico Chinese Assn.; 7 p.m. (reception follows performance), Central United Methodist Church (1615 Copper NE), 843-7620.

March 11 — Piano recital, Darby Fegan performs program of works by Schumann, Scriabin, and Barber, benefit for New Mexico AIDS Services, New Mexico Association of People Living with Aids, and the AIDS Emergency Project; 3 p.m., Unitarian Church (Carlisle and Comanche), 266-0911, 299-0342.

March 13 — Subscription Concert IV: Chamber Orchestra of Albuquerque presents the Chestnut Brass Company, featuring works by Haydn, Roussel, Schmelzer, and Foss; 8:15 p.m., St. John's United Methodist Church (2626 Arizona NE), 881-0844.

March 13 — "Vegetable Gardening," class presented by George Dickerson (County Extension Office); 7 p.m., Albuquerque Garden Center (10120 Lomas NE), 296-6020.

March 15-17 — Spring Craft Faire, 5-8 p.m. Thurs., 9 a.m.-6 p.m. Fri., 9 a.m.-3 p.m. Sun.; Willow Creek (Lomas and east Tramway area).

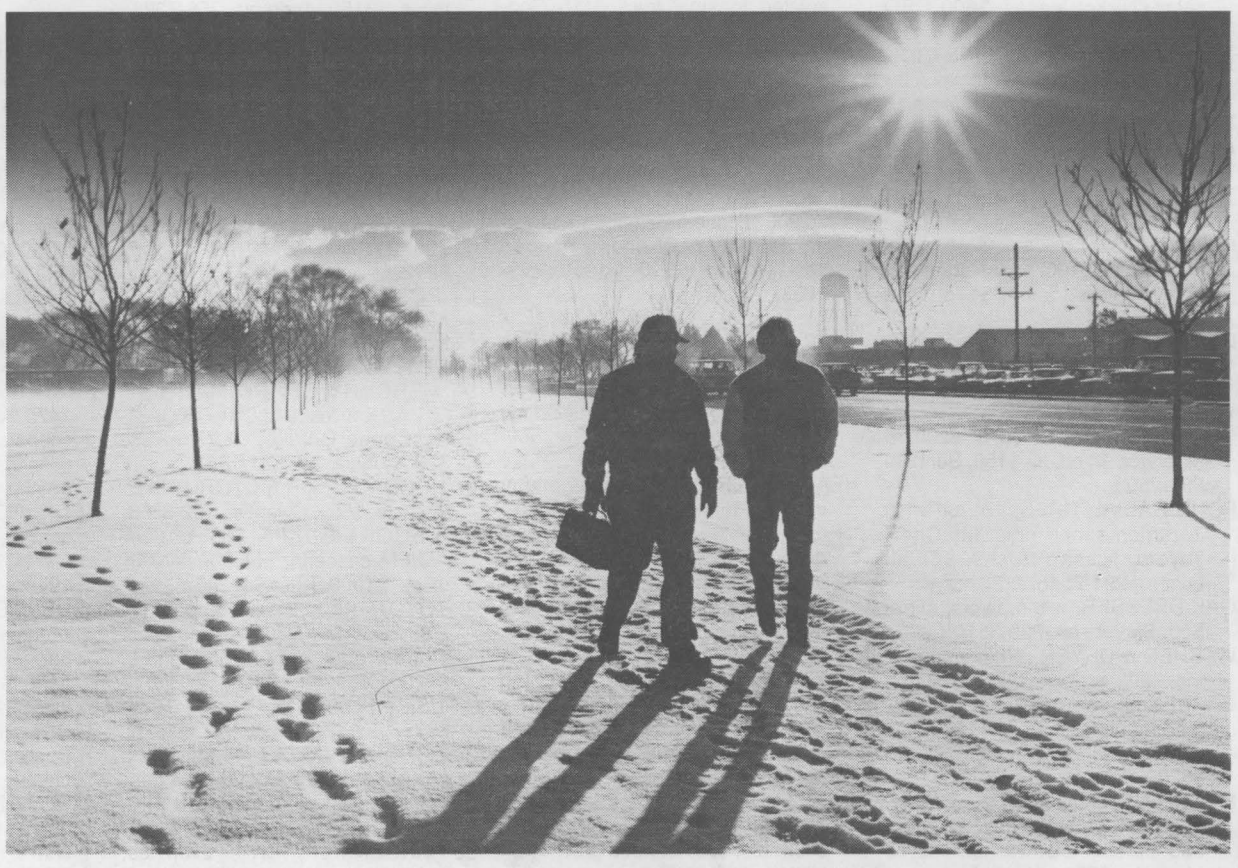
March 16-18 — "Dash of Spice," Southwest Ballet performance of classic and contemporary ballets from its Balanchine repertoire, plus a return of "Rhapsody" set to the lush music of Rachmaninoff; 8:15 p.m. Fri. & Sat., 2 p.m. Sun.; Rodey Theatre, 294-1423.

March 18 — Lecture, Jesús Bautista Moroles, sculptor of Albuquerque Museum's "Floating Mesa" courtyard fountain, presents a slide lecture of his work with commentary on his approach to sculpture; 2 p.m., free, Albuquerque Museum, 242-0434.

March 18 — Scholars of London, British vocal chamber music ensemble; 8 p.m., South Broadway Cultural Center, 848-1320.

March 21-April 1 — "Fences," New Mexico Repertory Theatre performance of August Wilson play about the quiet collapse of an ordinary black family in the '50s as the individual family members seem unable to fulfill seemingly ordinary aspirations; 8 p.m. Tues.-Sat., 2 p.m. Sat. & Sun. matinees; KiMo Theatre, 243-4500.

March 23-24 — "The Marketplace," arts and crafts show, more than 70 local crafters; 9 a.m.-6 p.m., Menaul at Juan Tabo (old Revco store on SE corner).



FEBRUARY SNOW still said winter on Hardin Field, but the sun promised Bob Lewandowski (left, 7476) and Jeff Smith (3521) that spring wouldn't be too far away. (Photo by Randy Montoya, 3162)