High-Tech Tools for the American Textile Industry

THE textile industry in the United States is huge—it employs more people than any other manufacturing sector and accounts for the most consumer sales among durable and nondurable goods. The U.S. leads the world in growing cotton and is very strong in the production of many kinds of fibers and finished cloth. But most sewing of finished apparel has shifted overseas, and overseas competitors are cutting into our predominance in fiber production and weaving. Over the last ten years, 400,000 American jobs have been lost to this intense overseas competition.

At first glance, a CRADA (Cooperative Research and Development Agreement) between the American textile industry and the Department of Energy's national laboratories might seem an odd match. It was born during a 1992 DOE-sponsored workshop on critical industries, when representatives from textile firms and DOE laboratories realized how much they had to offer each other. The laboratories have developed technologies in energy, environmental cleanup, and national defense that can help the U.S. textile industry improve its competitiveness in worldwide markets and create jobs as well by increasing quality, reducing costs, improving responsiveness and production times and by reducing the environmental impacts of manufacturing operations. Through its involvement in this CRADA, the DOE can obtain more information about market demands and needs in areas of communications, networked information, imaging, sensing, tagging and tracking, and environmental cleanup.

This partnership, known as AMTEX, began in 1993 as a collaborative program among DOE and eleven of its national laboratories and several textile research organizations. The entire textile industry is represented, including the retail, sewn products, textile manufacturing, and fiber production sectors.

Lawrence Livermore National Laboratory's contribution to the AMTEX partnership falls into five areas:

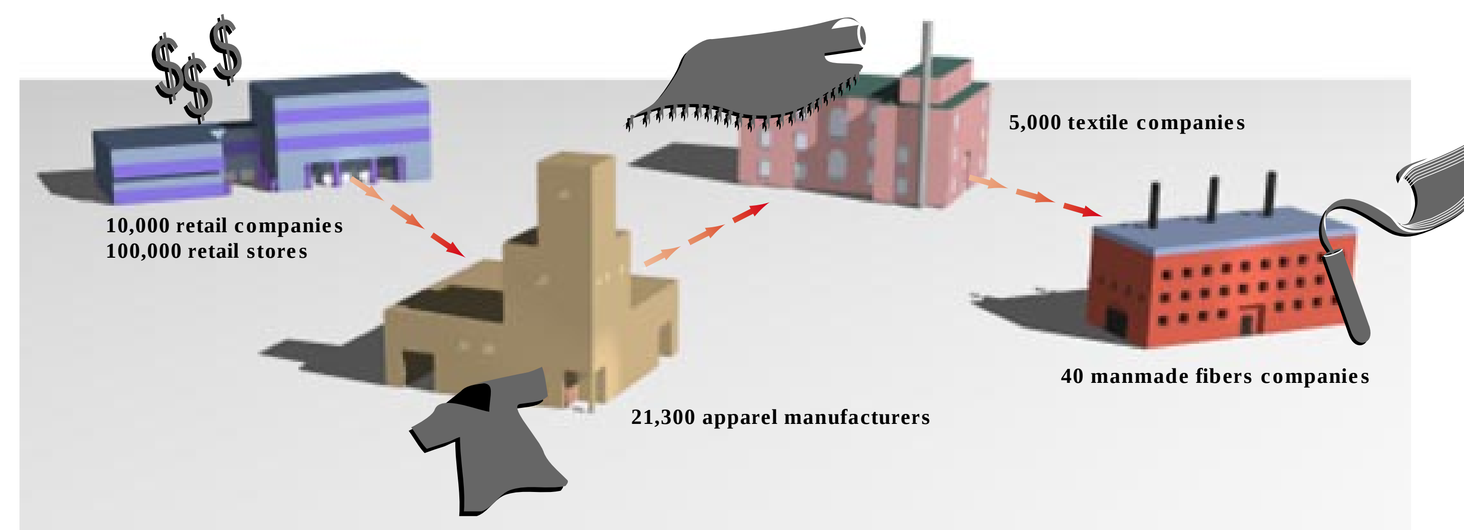
- Demand-Activated Manufacturing Architecture—For this project, Livermore is developing the first-of-its-kind client authentication software, which is discussed below.
- Computer-Aided Fabric Evaluation—Livermore-developed sniper detection technology is being applied to this project, which is discussed below.

A camera (inset) is mounted at the top of this A-frame structure, which is part of the demonstration unit for computer-aided fabric evaluation. Behind the A-frame is a closeup of the fabric that summer student Jessica Bayliss is inspecting.

- Electronically Embedded Fingerprint—Livermore worked on developing miniature electronic devices for permanent identification and inventory management. Manufacturers will be able to read and write information about size, color, style, process history, country of manufacture, etc. on a device the size of a grain of rice. This "fingerprint" may replace the bar code, which is not permanent and is limited in the amount of information it can store. A larger version of the fingerprint was originally developed by Livermore for permanent identification of weapons and other treaty-controlled items.
- Textile Resource Conservation—Livermore is developing and testing new processes to conserve the huge amounts of water used to dye and finish fabrics. Using less water in processing also means less downstream water treatment.
- Rapid Cutting of Textiles—Using its expertise in lasers, Livermore has developed a very-short-pulse, solid-state laser to replace the blade that has been used for decades to cut garment components from piles of fabric. The laser is faster than the blade and could be used for rapid custom cutting. The system is particularly useful for cutting very strong fabrics like Kevlar, which is used for sails and bullet-proof vests. Unfortunately, at present the laser cutting system is too expensive for small apparel manufacturing companies, which make up the bulk of apparel manufacturers in the U.S.

Demand-Activated Manufacturing Architecture

The two devils of the apparel retail market are undersupply and oversupply, both of which are dictated by consumer demand. Undersupply results in empty shelves and fewer sales, and oversupply in price markdowns, wasted resources, and lost profits. In either case, the retailer's bottom line is adversely affected. With an eye to improving the entire U.S. textile marketplace, AMTEX envisions a secure, Internet-based information system to link all sectors of the textile supply chain. The key to this project is securely and selectively communicating demand information from retail



The amount of secure "demand" data to be transmitted over the Livermore-designed TEXTNET data transfer system will be enormous. Ten thousand retail companies with 100,000 stores, each with 25,000 to 1.2 million stockkeeping units, generate 20 billion apparel and household textile purchases annually worth about $200 billion. That translates into electronic communication between apparel and textile manufacturers about the demand for 100 million industry stockkeeping units per year.

companies back to apparel makers, textile manufacturers, and fiber producers. From analysis of point-of-sale data and sophisticated simulations of the entire industry, decision makers will be able to bring the right products to market at the right time at a competitive cost. The underlying assumption is that the entire textile pipeline has to operate more efficiently if there are to be significant gains for each of the four sectors. The figure on p. 21 gives an indication of the size of the industry and the volume of data the industry generates.

Several pairs of industry partners have been electronically transferring purchase orders and advance ship notices for several years over proprietary networks. These are typically "push" transfers in which, for example, a retailer provides sales information about a particular brand of pants to its manufacturer. The provider of the information initiates the transfer to the client and determines what data will be transferred and when.

Livermore is working with Idaho National Engineering Laboratory to develop TEXNET, which incorporates a demand-activated or "pull" transfer of data initiated by the client. For example, apparel manufacturers will have "trading partner agreements" with a multitude of retailers and will regularly request sales and other information from them. Perhaps weekly, Brand A pants manufacturer will request sales information about Brand A pants, and Brand B pants manufacturer will do the same about theirs. Users will be assured that the information is provided not just securely but selectively as well—Brand A manufacturer must not receive information about sales of Brand B pants. Such a system is currently impossible because there is no method for authenticating the identity of a client, i.e., for a retailer to electronically assure that the requester of information about Brand A pants is really Brand A manufacturer and not someone else.

Livermore is developing software for client authentication, which will make possible secure, selective transfer of data among multiple users. With the advanced encryption codes incorporated in this software, a data provider will be able to electronically assess a client's identity and validate its trading partner agreement before releasing client-specific information. The major challenge in designing the system has been the development of tools for implementing necessary security mechanisms.

Livermore is designing the whole TEXNET data transfer system, of which client authentication and management of trading partner agreements are parts. Because a client is receiving only a portion of the total data available, the bandwidth required for data transfer can be narrower than if all the data were to be transferred. Storage and processing requirements for the transfer system are also relatively small because only selected pieces of data are transferring at a time.

TEXNET is designed for the real-time exchange of virtually any type of information and may be customized by its users. Using the Internet, information can securely flow in any direction in the textile pipeline.

Computer-Aided Fabric Evaluation

Several years ago, Livermore developed a sensor that can track the path of a bullet as it flies through the air. This sniper detector can read the bullet's unique signals two hundred times a second from any direction and then track the bullet's path back to its source.

This same real-time, image-processing technology is being used for computer-aided fabric evaluation. Instead of looking at a bullet flying through the air, a camera and computer look for flaws in patterns being printed on fabric or in knitted fabrics. The system can not only detect defects in printing or knitting but can also immediately classify the defect and signal the machine operator that a problem exists and how to correct it.

Quick detection and correction of flaws will bring huge savings to textile manufacturers. For example, high-speed, fabric-printing machinery can handle both narrow and wide fabrics and may print hundreds of yards of material in just a few minutes. Lightly glued to a mat to provide an unmoving, stable surface, the greige fabric (pronounced "gray" and meaning undyed, unfinished fabric) passes under a series of roller screens, each of which prints a different color onto the fabric. A screen could slip slightly out of alignment causing a "misfit" where the dye is shifted on the fabric, a screen could become clogged with dye creating an unprinted area, or lint or thread could adhere to a print screen, also resulting in an unprinted area.

The proprietary system developed at Livermore mounts a high-speed, line-scan camera, or series of cameras depending on the fabric's width, over the fabric immediately after the last screen. (See photos on p. 20.) As the first yards of printed fabric roll beneath the cameras, the computer to which the camera is attached digitizes and dynamically learns the printed pattern by creating a model of the repeated pattern. The computer, powerful enough to handle the huge amounts of data that the process generates, can then inspect the printing process on line.

As it detects and diagnoses flaws, the computer accumulates a history of defects, which the computer draws upon in its reporting to the machine operator. For example, a one-time flaw might not initiate an alarm, but a repetition of small flaws or a large flaw would. Based on the array of defects that are known to occur, the computer's program determines what the problem is and what the operator's response should be. Depending on the particular setup, the operator is notified of the problem by bells, lights, or a printout on a computer monitor.

As the manufacturing facility's central computer accumulates data from the dedicated computers at the various fabric printers, quality control should improve considerably. Managers will have a record of problems with specific printing machines and with particular operators.

Livermore's system to detect flaws in knitted fabrics is very similar to that for detecting printing flaws. The flaws that crop up in the knitting process are different from those that appear in printing, but they can be dealt with by the computer in the same way.

By the time Livermore's work on computer-aided fabric evaluation is complete, pilot facilities will have been installed at the mills of several fabric manufacturers.

Key Words: AMTEX, computer-aided fabric evaluation, demand-activated manufacturing architecture, technology transfer, textiles, TEXTNET.

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Rock Mechanics: Can the Tuff Take the Stress?

HIGH school teachers and college students, working side-by-side with Laboratory geophysicists and geochemists, have had the rare opportunity to contribute to the field of geomechanics and to the study of how rocks fracture.

Obscure findings for esoteric studies of interest only to geologists, mining engineers, and rock hounds? Hardly.

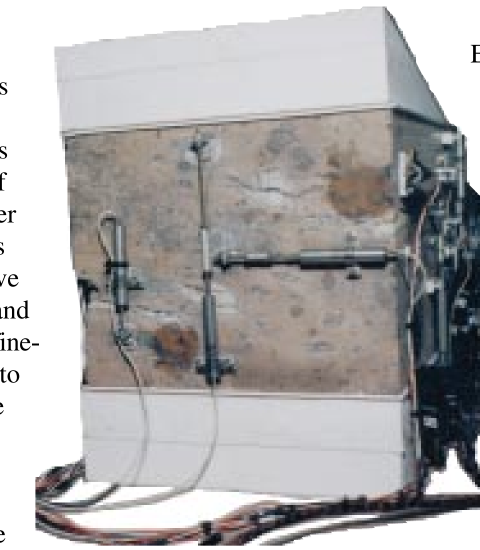
The results are critical to understanding the behavior of a proposed underground repository for high-level radioactive wastes. The Yucca Mountain Repository in Nevada could become a permanent storage site for as much as 70,000 metric tons of nuclear waste, nearly 90% of it spent fuel from commercial nuclear power plants.[1] Given the rigid federal, health, and safety regulations such a repository must meet, it is essential to understand how the surrounding rock behaves over time when exposed to heat and radiation generated by the nuclear waste.

At Lawrence Livermore, geomechanics expert Stephen Blair is a principal investigator conducting fundamental studies of the rock that would form the Yucca Mountain repository—Topopah Spring tuff. (Tuff is formed of compacted volcanic fragments welded together.) In his quest for answers, Blair has enlisted the skills and talents of eight high school teachers and college students, most of them recruited through the Laboratory's various education programs.

Stephen Blair (left), John Kelly, and Patricia Berge (rear) at work on a study of the effects of high temperature and intense compression on the tuff from the Yucca Mountain, Nevada, area where a potential nuclear waste repository may be located.

Questions that they are examining include: What happens when this rock is exposed to radioactivity over tens of thousands of years? As the temperatures increase and water in the pore spaces of the rock evaporates, how does that water move and what happens to the fractures and the rock itself? Blair and others have been conducting tests to better understand the structure of tuff and to develop and fine-tune computer models that will be used to determine the performance of the entire repository for hundreds of centuries.

"We began with small rock samples, about the size and shape of a roll of quarters, looking at what happens at the pore level, basically the size of a grain of sand," said Blair. Three studies involving students and teachers focused on the behavior and structure of rock at this level. A fourth study examines how blocks of tuff a half-meter on a side behave under increasing temperatures and pressures.



A block of Topopah Spring tuff a half-meter on a side outfitted with diagnostic instruments to study the material's responses to high temperatures and pressures.

Grains and Pores

The properties and behavior of the tuff depend on its grain-scale structure and characteristics. Chris Pena, a graduate student in environmental engineering at San Jose State University, and Brian Johnson, a high school teacher now at Susanville, California, helped analyze the tuff microstructure. They used an image processing method—developed by LLNL's Blair, James Berryman and Patricia Berge—in which the microstructure of rocks is measured statistically. Under Blair's guidance, Pena used image-processing software to examine images of cross-sections taken from tuff core samples from Yucca Mountain and to determine the rock's porosity, isotropy (directional dependence of material properties), and general structure. Among her findings, which she presented at the American Geophysical Union meeting in December 1995, was that the tuff material was dominated by small pores with cross-sectioned areas of less than 10 square micrometers.[2]

Knowing the rock structure in such detail is important, Blair noted, because it is on this microlevel that cracks and fractures begin.

Cracks and Fractures

The grains of material that make up a piece of rock come in different sizes, shapes, minerals, strengths, and distributions. Even the most uniform rock is diverse at the grain scale, and this diversity affects the processes of rock fracturing under stress. Under heat or pressure, tiny cracks form and merge to form larger fractures. These fracture processes are not well understood and are the subject of an ongoing study.

"One of the things that might happen at elevated temperatures and stresses in an underground nuclear repository is that cracks may form in the rock and the rock's properties might change," Blair explained.

Using a two-dimensional statistical computer model developed by Blair in 1994, Diablo Valley College student Austin Woffington and San Lorenzo high school teacher John Kelly simulated what happens when rock is compressed. In the model, the rock is represented by a lattice of grain centers that can be either "strong" (breaking only under high compression) or "weak" (breaking easily under moderate compression).

This model is being used to estimate the amount of cracking that will occur over time and at the high temperatures expected in the proposed repository. The results will aid in predicting the long-term integrity of the repository tunnels.

Radiation and Rock Strength

The tuff forming the repository must endure centuries of exposure to radioactive waste. What effect, if any, might this have on the rock? Will the rock weaken? Will it fracture more easily?

"We want to be sure radionuclides will stay in the repository," said Blair. "We need to better understand the effect radiation has on tuff and whether exposure to radiation will alter the mechanical strength or other geomechanical properties of the rock near the waste. Until now, there have been no data describing the effect of radiation on tuff from the potential repository."

A controlled study was performed to examine the effects of radiation on the strength of tuff. For this project, Blair enlisted the help of several high school teachers, including Kelly.

"We applied up to 160 megapascals—about 10 tons of force—to rocks the size of a roll of quarters, some of which had been subjected to gamma radiation," Kelly said. "The results were impressive to watch. Samples with pre-existing cracks just crumbled. With others, nothing happened until they failed catastrophically at high stresses."

Preliminary results indicated that whereas radiation had little or no effect on initially unfractured samples, it did affect samples with pre-existing open fractures. These irradiated samples failed at stresses only half those applied to the non-irradiated samples.[3]

"One explanation is that radiation weakened the cementing material in the cracks," said Blair. "We need to do additional studies to say for certain. However, if this is a real phenomenon, it has significant implications. The radiation is expected to penetrate only a few centimeters into the rock. But this rock will also experience high temperatures, stresses, and humidity. If the fracture-filling materials are weakened, more pieces might break off over time. In addition, changes in fracture properties—such as fracture shear strength, compressibility, and permeability—could also occur. The rock mass may be affected in unanticipated ways, including movement of rock blocks along fractures."

Next Step Up

Blair's next step is to take a block of tuff a half-meter on a side (basically the size of a large computer monitor), subject it to increasing pressures while varying the temperature, and measure the deformation.

One block has been tested so far. San Jose State student Owen Pine did the data reduction and analysis on the first block of the series. Those results indicated that almost all the deformation in the block occurred across fractures and voids.[4] Additional tests were completed recently.

"The results have significant implications for the flow and transport properties of the rock," said Blair. "For instance, it appears that cracks, fractures, and other open spaces perpendicular to the maximum principal stress will close over time. That means the rock will become less permeable in this direction. In addition, the tests show that pre-existing hairline cracks parallel to this stress may open over time. That will increase the permeability of the rock in that direction."

In the next test, Blair and his colleagues will add water to examine how water flow through the blocks of rock varies with pressure, temperature, and time.

The Benefits of Collaboration

Blair is one of many Laboratory principal investigators who occasionally employ students, teachers, and faculty through the Laboratory's Education Program.

"I've found that for certain projects—particularly ones that are limited in time, effort, and money and that have general tasks—students and teachers can fill a niche. The radiation tests are an example. Teachers and undergraduate-level college students have the broad skill sets we need, and I believe they get something from the experience too," he said.

High school teacher John Kelly and college students Chris Pena and Austin Woffington agree.

During his Science and Engineering Research Semester at the Laboratory, Woffington increased his knowledge of geology, worked with a variety of software programs, and learned to give effective technical presentations.

"The networking with other scientists and students was extremely valuable to me," said Woffington. After getting to know scientists in the Environmental Programs Directorate, he developed an interest in groundwater modeling.

Chris Pena, now a graduate student at San Jose State University in environmental engineering, was introduced to the Laboratory through one of her SJSU undergraduate professors.

With Blair as a mentor, she honed her analytical and research skills and gained valuable experience writing technical papers and giving technical presentations. "I couldn't have gotten that experience elsewhere," she said.

John Kelly teaches mathematics at Arroyo High School in San Lorenzo. His summers at the Laboratory as part of the Summer Research Internship Program for teachers helped him become one of two technical "mentor teachers" for the San Lorenzo School District. "As a mentor teacher, I conduct technical workshops for other teachers and work on the district's Educational Technology Committee," he said.

Blair also sees a benefit in direct outreach to the public. "This is a way to get grassroots support for science and research," he explained. "Students and teachers talk about their Laboratory experiences and pass on what they have learned. Those who come to us are the ones who go the extra mile, who are ambitious and curious. They may be future leaders, and we have a golden opportunity to introduce them to the value of research and broaden their experience. Who knows? Some may work in our fields someday and be future collaborators as well."

Key Words: geomechanics, nuclear waste repository, tuff, Yucca Mountain Project.

References

1. For more information on the Yucca Mountain Project and the Laboratory's role, see "The Safe Disposal of Nuclear Waste," *Science & Technology Review*, UCRL-52000-96-3 (March 1996), pp. 6–16.
2. C. Pena, S. C. Blair, P. A. Berge, *Image Analysis of Tuff from the Yucca Mountain Project* (Abstract). 1995 Fall Meeting, American Geophysical Union, December 1995.
3. S. C. Blair, J. M. Kelly, O. Pine, R. Pletcher, P. A. Berge, *Effect of Radiation on the Mechanical Properties of Topopah Spring Tuff*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-ID-122899 (January 1996).
4. O. Pine, S. C. Blair, P. A. Berge, *Mechanical Behavior of a 0.5 m Block of Topopah Spring Tuff under Uniaxial Compression.* 1995 Fall Meeting, American Geophysical Union, December 1995.

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For further information about the Laboratory's Education Program contact Eileen Vergino (510) 422-3907 (verginoes@llnl.gov).

Patents

Each month in this space we report on the patents issued to and/or the awards received by Laboratory employees. Our goal is to showcase the distinguished scientific and technical achievements of our employees as well as to indicate the scale and scope of the work done at the Laboratory.

Patent issued to	Patent title, number, and date of issue	Summary of disclosure
Richard H. Sawicki Terry W. Alger Raymond G. Finucane Jerome P. Hall	**Segmented Lasing Tube for High Temperature Laser Assembly** U.S. Patent 5,497,392 March 5, 1996	A ceramic lasing tube having a plurality of cylindrical segments of the same inner and outer diameters nonrigidly joined together in axial alignment; insulation of uniform thickness surrounding the lasing tube; a ceramic casing, preferably of quartz, surrounding the insulation; and a fluid-cooled, metal jacket surrounding the ceramic casing.
John M. Halpin	**Large Core Fiber Optic Cleaver** U.S. Patent 5,501,385 March 26, 1996	A device and method for cleaving optical fibers with core diameters greater than 400 micrometers to produce high-damage-threshold end surfaces. The device includes scribing means, a chuck assembly, and a fiber connector block. The fiber is scribed and then biased to apply cleaving tension.
Daniel M. Makowiecki	**Nano-engineered Explosives** U.S. Patent 5,505,799 April 9, 1996	An explosive and fabrication method having a plurality of very thin, stacked, multilayer structures, each composed of reactive inorganic components separated by an organic component such as carbon. Upon detonation, the separator material reacts with the inorganic components to generate high temperatures and produce a working fluid or gas.
Steven T. Mayer Fung-Ming Kong Richard W. Pekala James L. Kaschmitter	**Organic Aerogel Microspheres and Fabrication Method Therefore** U.S. Patent 5,508,341 April 16, 1996	The formation of organic aerogel microspheres ranging from about 1 micrometer to about 3 millimeters in diameter by inverse emulsion polymerization with agitation. The aerogel microspheres can be pyrolyzed to produce doped or undoped carbon aerogel microspheres. The size and structure of the microspheres are determined by the processing procedures and the chemical formulation.
Stephen E. Sampayan William J. Orvis George J. Caporaso Ted F. Wieskamp	**Flat Panel Ferroelectric Electron Emission Display System** U.S. Patent 5,508,590 April 16, 1996	A device that can produce a bright, raster-scanned or non-raster-scanned image from a flat panel by relying on electrons emitted from a ferroelectric emitter impinging on a phosphor. This device, unlike many flat panel technologies, does not require ambient light or auxiliary illumination for viewing the image.
Kurt H. Weiner	**Method for Materials Deposition by Ablation Transfer Processing** U.S. Patent 5,508,065 April 16, 1996	A process in which a thin layer of semiconducting, insulating, or metallic material is transferred by ablation from a source substrate (which is coated uniformly with a material of a desired thickness) to a target substrate by means of a pulsed, high-intensity, patternable beam of energy.
Clinton M. Logan	**Cooled Window for X-Rays or Charged Particles** U.S. Patent 5,509,046 April 16, 1996	A window that is capable of handling the thermal load from scattered x rays, electrons, or ions. The window offers good structural integrity and a very high capacity for removal of heat with minimum attenuation of the beam. The window has microchannels inside it through which coolant is pumped to cool the window.
Thomas E. McEwan	**Time-of-Flight Radio Location System** U.S. Patent 5,510,800 April 23, 1996	A method and apparatus for detecting time-of-flight of electromagnetic pulses from a transmitter on an object to a receiver by sampling the pulses with controlled timing such that the time between transmission and sampling sweeps over a range of delays. An equivalent time sample signal is produced that can be processed to indicate object position.
Thomas E. McEwan	**Homodyne Impulse Radar Hidden Object Locator** U.S. Patent 5,512,834 April 30, 1996	An electromagnetic detector and method in which a homodyne oscillator modulates pulses from a pulse generator and transmits them to a hidden object. Reflected pulses are detected by a receiver that includes a sample and hold circuit that is gated by the pulse generator to produce an averaged detected signal. The receiver includes an AC coupled amplifier and a rectifier connected to the homodyne oscillator to demodulate the detected signals.