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INNOVATION FOR A NATION

NNSA Laboratory Directed Research and Development Symposium in Energy Security

National Nuclear Security Administration

CONTENTS

INNOVATION FOR OUR NATION

Authorized by Congress in 1991 to fund leading-edge research central to the national laboratories' core missions, the Laboratory Directed Research and Development (LDRD) Program is a key research component at all Department of Energy (DOE) Laboratories, but is especially significant at the three National Nuclear Security Administration (NNSA) laboratories, whose history of addressing national security needs dates back to the Manhattan Project in 1943. In this era of diminishing fossil fuel supplies and climate change concerns, our dependence on foreign oil and natural gas reserves has brought energy security into the forefront as, certainly, one of the most-pressing national security concerns faced by our nation. With their depth and breadth of research and development experience across the natural sciences, the NNSA Laboratories, and in particular, the strength of fundamental national-security-directed inquiry exhibited within their LDRD programs, have been increasingly called upon to address aspects of this energy-security dilemma.

> "…our dependence on foreign oil and natural gas reserves has brought energy security into the forefront…"

On September 18, 2008, as part of the annual program review, the NNSA and its three national laboratories — Los Alamos (LANL), Sandia (SNL), and Lawrence Livermore (LLNL) — held a symposium on energy security designed to present some of the specifics of this issue and spotlight key ongoing LDRD-funded research initiatives designed to address it. This report presents a summary of the oral presentations delivered by the symposium's keynote speakers. Poster presentations by trilaboratory scientists are featured in the Symposium Brochure, available at https://ldrd.llnl.gov/pdfs/LDRDSymposiumBook.pdf

PRESERVING AN OUTSTANDING INVESTMENT

Jamileh Soudah,
NNSA LDRD Program Manager

Reminding her audience of about 150 that "stockpile stewardship is not an easy task," and that it "requires a strong base in cutting-edge science and technology, NNSA LDRD Program Manager, Jamileh Soudah kicked-off the Second Annual LDRD Symposium in Washington, DC, on Thursday September 18, 2008.

In conjunction with the theme of "Energy Security," Soudah emphasized that the Symposium was part of the larger NNSA Annual LDRD Program Review, at the same time giving customers and other interested individuals an opportunity to gain insights emerging from the work of NNSA national laboratory scientists and engineers, "offering customers new ideas to solve national security mission challenges."

In reviewing the remarkable rate of return on investment for the tri-laboratory LDRD programs, Soudah pointed out the quite rigorous project-selection process, by which only 10% of the submitted ideas by laboratory staff ultimately receive LDRD funding. The outcome for the Nation is well-illustrated by the issued trilaboratory patent numbers, over 35% of which derive from LDRD-funded research against only an 8% investment in laboratory budget funds. Even more-impressive is that this 8% investment generates about 60% of the tri-laboratory R&D100 awards, an

internationally recognized measure of scientific and technical inventiveness and ingenuity.

"I'm very protective of this program," Soudah understandably told her diverse audience, offering the view that LDRD investments were comparable with those made for R&D in both other federal agencies (such as DoD) as well as in the corporate R&D world, the overarching difference being that all LDRD research is directed toward the solution of national security challenges. Furthermore, she repeatedly emphasized the critical nature of cutting-edge LDRD research in attracting high-caliber research talent to the laboratories, the national and international competition for such talent continually increasing. She underscored this point with the statistic that 53% of trilab postdocs worked on LDRD-funded projects, with 71% of new hires deriving from this postdoctoral pool.

"The Nation expects the Labs to provide a response to emerging threats," Soudah emphasized. As was obvious from the day's presentations and posters, the threat posed by energy security loomed largest as the issue most in danger of jeopardizing our national security, what Soudah characterized as "the critical issue facing our Nation."

LIGHTING THE SPARK OF SCIENTIFIC CREATIVITY

Thomas D'Agostino, Undersecretary for Nuclear Security and Administrator, National Nuclear Security Administration

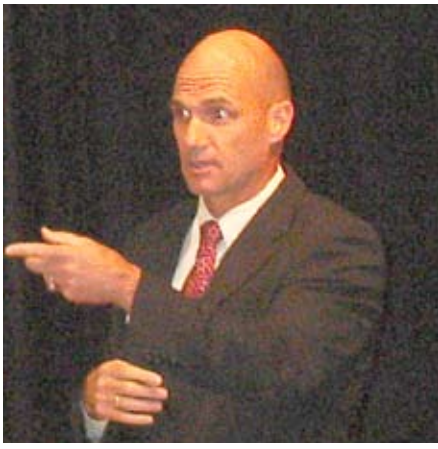
From the outset, Undersecretary for Nuclear Security, Tom D'Agostino, drew his audience into an empathic mode by way of the personal story of an eight-year-old boy visiting the Nevada Test Site (NTS), who found himself astonished by the "coolness" of a rocket engine.

On that day, the eight-year-old D'Agostino decided that he wanted to "do something like this," and he generalized that personal story into his view that "the curiosity and inventiveness of the human spirit are universally ingrained in our nature." In that context, he spoke about the "mystery at the leading edge of science," which many people find irresistible, some don't understand, and still others "don't want to pay for." But he was effusive in declaring the necessity to fund and encourage that curiosity, creativity and research, tracing the roots of NNSA back to the science and technology underpinning the Manhattan Project in 1943, that S&T now every bit as relevant to NNSA's nonproliferation and other national-security initiatives.

"Maintaining critical skills is crucial," and the critical skills for nonproliferation "cannot be learned at universities," but rather, "must be practiced," D'Agostino stressed, and LDRD serves as a "forcing function" to attract the talent needed to "shift from cold war nuclear weapons to Twenty-first Century national security." And in that context, he saw LDRD as resting on the concept of allowing scientists and engineers freedom to follow their ingenuity to provide new solutions and applications in addressing current and future national security challenges.

"At NNSA, we *want* LDRD to be laboratory-directed," the undersecretary emphasized. "We want to captivate the minds of young people . . . these are the people who will protect us in the future,"

Jamileh Soudah



Tom D'Agostino

came the reasoned discourse, which, he maintained, depended on strategic partnerships and the development of fundamental scientific and engineering capabilities in LDRD-funded staff that could be "flexibly drawn upon," as laboratory directors focused calls for proposals to match the Nation's needs, at present, energy security representing such a pressing concern.

> "We want to captivate the minds of young people . . . these are the people who will protect us in the future . . . "

D'Agostino closed by coming full circle to his opening story of his youth. He called for a ten-to-twenty-year effort to "get young folks interested in science and math," urging parents to "light the spark" in their children, just as his own father had done for him.

Dr. Raymond Orbach

TRANSFORMATIVE, NOT INCREMENTAL SCIENCE AND TECHNOLOGY

Dr. Raymond Orbach, DOE Undersecretary for Science

"We'll never get there by doing the same thing — we need a transformational approach," declared Raymond Orbach, DOE Undersecretary for Science. "There" is, of course, energy security, the symposium's theme, and motion along the path to "there," by necessity had to be propelled by a strengthening and ongoing revitalizing of core scientific competencies, a key component of all national laboratory LDRD programs.

"It's terribly unfortunate that LDRD has become a political issue," Orbach lamented, in declaring his support for the notion of "getting beyond" that road-blocking dilemma and using the LDRD program as its designers have always intended: "it is critical that NNSA maintain the LDRD structure for core competency," Orbach urged.

Orbach's view was that "the country has grown up," in the sense of the broader recognition that energy security is as important to national security as "any other part of the national security portfolio." He went on, however, to point out that although coal-burning effluents include neurotoxins such as mercury, in addition to the obvious carbon dioxide burden, even with a carbon tax, coal still is less expensive per kilowatt than solar photovoltaic.

I don't believe in energy independence," Orbach emphasized in arguing for transformation; "we are a globe," he explained, logic dictating that when it comes to energy generation and its effect on climate, there is no room for provincialism. Additionally, Orbach reminded his audience that the continuum of basic and applied research in the same location, at one point in time, occurred in industrial labs. However, "the only thing we have left is you," he supportively told those in the audience who work at national laboratories. "National laboratories are the only resource where we can work at scale — grand challenges to marketplace; it's terribly important that this message get out . . . no one else is capable of this scale . . . we have a responsibility to the country . . . our ability to work from nanoscale to macroscale is crucial."

Orbach reviewed numerous examples of the type of work that was both ongoing and necessary to bring forth the desired transformation, from biofuels to the nuclear fuel cycle through hydrogen and nanostructured substitutes for

photosynthetic sunlight-harvesting centers. He called for "a crescendo of support" for basic research. "If we don't do it, the consequences are clear; it's up to you to make your voices heard," Dr. Orbach urged his audience — and by implication, the nation at large.

A DISCOVERY PROCESS LEADING TO STRATEGIC PLANNING

Paul Bollinger, Deputy Assistant Secretary of the Army

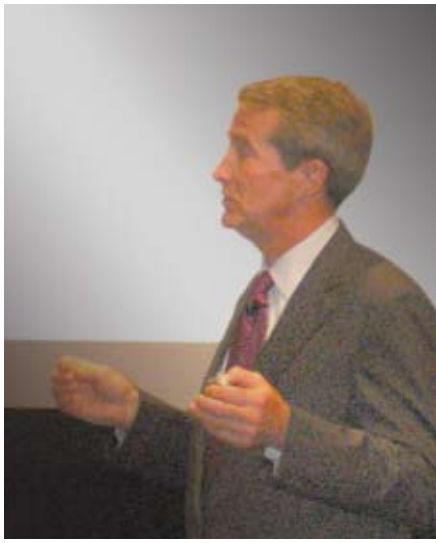
Vulnerabilities to long fuel chains and to failure of the grid: these are but two of the issues facing our armed forces with respect to their energy security during both peacetime and on the battlefield. Deputy Assistant Secretary of the Army, Paul Bollinger, provided a fairly in-depth look at what a recently constituted Army Energy Security Task Force has accomplished and is accomplishing in this area of military energy security.

Bollinger reviewed a diversity of energy-conservation solutions ranging from foamed tents, which significantly reduce energy consumption with respect to cooling in desert climates, to water-driven microturbines, which serve to locally generate electricity both for military and local civilian use.

"We're not looking to reinvent the wheel," Bollinger said, in emphasizing that there were technological advances in the private sector that the army was striving to adopt, and that relevant LDRD-directed research at NNSA Labs had quite a willing and eager test site in the military.

Acting on the Task Force recommendations, the army has moved in several direction: accelerating its use of renewables, increasing the level of energy metering at all installations, controlling and reducing consumption at forward operating bases, and altering acquisition and procurement practices.

Bollinger addressed the army's current investigations into several different forms of alternative electricity generation, solar, wind, geothermal, biomass, and nuclear. The army possesses six nuclear plant certificates and is years ahead of private industry. A geothermal power plant is operational at Hawthorne Army Base, and projects involving solar panels for the individual soldier and vehicular hydrogen and fuel cell power are also underway.



Paul Bollinger

URGENCY OF ACTION WITH A RAY OF HOPE

R. James Woolsey, VantagePoint Venture Partners and Former Director of the Central Intelligence Agency

Analogizing our addiction to fossil fuel burning (with CO_2 generation) to heavy smoking, former CIA Director R. James Woolsey assured his audience that, although we could not pinpoint the critical point for climate change (or irreversible lung damage), we could be reasonably sure that we were substantially increasing risk in each instance. The related, and certainly more-immediate threat derives from the fact that, when we light up that petroleum cigarette, it's not labeled with a domestic tax stamp; most of what we burn is imported from nations who do not view us with a particularly friendly eye. In fact, in Woolsey's view, "oil creates as big a security problem as this country has ever seen; not only are our enemies fanatics, but they're as rich as Croesus."

R. James Woolsey

> "... oil creates as big a security problem as this country has ever seen..."

But there is a solution, in Woolsey's view, and it is analogous to the fate of salt at the end of the 19th Century. A provocative resource for the preservation of meat, which fueled regional conflicts and wars, the advent of electricity and refrigeration destroyed salt as a strategic commodity, breaking its stranglehold on the food industry. In Woolsey' view, we need to destroy oil's stranglehold on transportation, in this instance, by progressing to an all-electric economy, where electricity generation is fueled by anything other than imported fossil fuels — solar, wind, geothermal, biodiesel, ethanol. By encouraging domestic automakers to manufacture hybrid, flex-fuel vehicles, convertible to full-electric mode, such "plug-in hybrids" could result in a 25-30% reduction in CO_2 emissions, as well (Chevrolet plans the large-scale release of such a model in 2010).

"We're within striking distance of things we can do," Woolsey asserts. He counters the argument against ethanol, whose critics claim that more energy goes into its production than comes out (is liberated) in its combustion; but Woolsey asserts, they are counting the sunlight in, which costs nothing. And although buses and other large transportation vehicles can reasonably continue to run on natural gas, the family car would face the problems of refueling infrastructure; hence ethanol can readily serve as a combustion fuel as the economy shifts to all-electric mode. Eventually, this is the only sane destination for our nation, to ensure our security. And although such liquid biofuels may still not be ultra-inexpensive, the hybrid and all electric alternatives are a shielding factor: "If the Saudis can't drive the price of oil down to that of electricity, then electricity can protect alternative liquid fuels," he maintains.

Woolsey made the arguments compellingly, and he left his audience, if not convinced, then certainly more apt to consider taking the first step by purchasing a hybrid vehicle.

NO GREATER MANDATE THAN SAVING LIVES

Chris DiPetto, Deputy Director, Office of the Undersecretary of Defense Acquisition and Technology

Presenting both the challenges and initiatives in DoD's energy policy, Deputy Director Chris DiPetto framed his presentation with a vignette about Marine Corps Maj. General Zilmer, who, at one point, pleaded with the DoD to help him save lives by providing him with renewable energy systems, simply because of the vulnerability of his convoys to attack while sustaining supply lines to trek back and forth for liquid fuel.

This story underscored both the "supply security" and the "assured distribution" aspects of DiPetto's message, the third member of his thematic triad, taking the form of "demand reduction." This last item is highlighted by the statistic that of DoD's $13B direct energy costs in FY07, fully 75% was expended on transportation costs to deliver fuel into theaters of battle.

This statistic highlighted the need for, and formation of an Energy Security Task Force, tasked with the development of a strategic plan. Essentially focused on developing and implementing alternatives, the specific messages were quite similar to those framed by previous speakers, with the proviso that for DoD, the sense of urgency was and is

heightened by the need to save the lives of its military personnel in the field.

Some exemplary alternative energy projects included the Navy's China Lake Geothermal facility, capable of generating 270 MW and Nellis Air Force Base, whose 14MW of solar-generated electricity provides 25% of the base's power. Both the Army and Air Force are developing advanced turbines with a 25% increase in efficiency, and remarkably, we will soon see a B-52 flying on a 50-50 blend of jet fuel and synfuel.

Lighter armor, higher energy-density fuels, improved business processes — all these and more, add-up to significant gains in energy efficiency and energy security at DoD. As echoed by every one of the symposium's keynote speakers, the time is now, the reward is great, and the failure to act is an unacceptable choice.

THE NNSA LABORATORIES' PERSPECTIVE

An Extraordinary Challenge

Dr. Terry Wallace, Associate Director for Science and Engineering, Los Alamos National Laboratory

"These are truly national-security issues," emphasized Dr. Terry Wallace, Los Alamos Associate Director for science and engineering. The disturbing statistic that $750B of US capital is, at current oil prices, annually transferred to OPEC countries, combined with an exponential energy consumption curve on a planet whose middle class is exploding in size, led Wallace to refer to these facts as "the main driver for our national security in the next one-hundred years."

Dr. Wallace reviewed an often-glossed-over piece of the climate-change puzzle, namely the fact that with increasing CO_2 level, the dissolving of CO_2 in oceans and lakes will produce increased quantities of carbonic acid (H_2CO_3), thereby potentially lowering pH. With 80% of planetary oxygen (O_2) produced not by terrestrial organisms, but rather by phytoplankton such as algae, serious disruption of photo-synthetic productivity is possible. Hence, technologies such as clean coal "must still figure out a way to capture and sequester CO_2."

"There is no magic bullet, no single transformational technology," Wallace emphasized, reminding his audience of the problems of scale in real world environments. Another emphasis was the necessity for investment in electricity infrastructure, given a grid "designed cleverly . . . in 1955 terms." On a related topic, nuclear energy, he called for better understanding of the actinides, specifically with reference to uncertainties associated with 5f electrons, in which LDRD research, particularly at Los Alamos, has played an important role in the progression from applying such fundamental nuclear physics understanding toward technological progress in closing the nuclear fuel cycle.

Dr. Wallace reiterated the theme introduced by Dr. Orbach, namely that "looking at these problems solely from a national perspective is not sufficient." Underscoring this view, he offered the projection that by 2020, China will import twice as much oil per day as the U.S., and opining what seems obvious to all, that the rest of the world desires to rise to the living standard of North Americans. Unfortunately, "at a minimum, we'd have to quadruple the energy available," Wallace emphatically projected. "An extraordinary challenge; I've never seen anything like it

Chris DiPetto

Dr. Terry Wallace

Dr. Terry Michalske

before," he concluded, offering the solution common to all speakers at the Symposium, namely that the National Laboratories should identify where they could provide solutions. As exemplary, he cited LDRD-funded research at LANL in climate, next-generation fuels, and carbon-neutral fuels.

Time to Stop Thinking of What We Might Do

Dr. Terry Michalske, Director for Energy Innovation Initiatives, Sandia National Laboratories

"Without the best people, we would be unable to maintain the core of capabilities that allow us to deliver on our mission." Sandia's Director for Energy Innovation Initiatives, Terry Michalske framed that "best people" message in the context of the LDRD Program and its critical role in maintaining Sandia's "health," by attracting superior staff personnel. Moreover, Michalske emphasized, it is the LDRD Program that serves an adaptive function when, in the interests of national security, any of the three NNSA laboratories is called upon to shift into a novel area of research. This partnership is "not static . . . we continually work with NNSA to address broader natural security issues," Michalske emphasized.

> "Without the best people, we would be unable to maintain the core of capabilities that allow us to deliver on our mission . . . "

One focus of Dr. Michalske's presentation was the immediacy of the threat from global climate change and the need to better understand the national security issues around it. Some of these are already evident, however there may also likely be unanticipated physical and biological changes, to which we must somehow be prepared to respond. "It's time that the country stop thinking of what it *might* do," Michalske emphasized.

Like Dr. Wallace, before him, Michalske addressed the need for a new grid, noting that reaching a goal of 30% of energy generation from renewables "isn't going to happen on the existing grid. Transitioning from a one-way to a two-way grid is a complicated systems problem; Michalske was quick to point out the important role for the NNSA laboratories in assessing and maintaining safety and security of such a transformed grid.

There was some good news, however: for example, Sandia's solar-to-petrol initiative, through which solar thermal energy is being employed to split carbon dioxide and water, ultimately utilizing the products to synthesize hydrocarbon liquid transportation fuels. If this project can achieve 10-percent efficiency, it "could make a big dent." Additionally, the possibility of employing algae as prolific oil-producers offers a more biologically oriented pathway toward the production of liquid fuels with sunlight as primary energy source. Both these initiatives have their roots in LDRD funding, as do projects in advanced nuclear reactor engineering.

Finally, Michalske called for some sort of national roadmap, a target defining "what we want to get to," citing Japan's national roadmap as exemplary.

Modeling the Macrosystem

Dr. Douglas Rotman, Director for the Energy and Environmental Security Program, Lawrence Livermore National Laboratory

For Doug Rotman, Lawrence Livermore National Laboratory's Director for the Energy and Environmental Security Program, climate change constitutes an enormous national security challenge, one that can and is leveraging LLNL's expertise with nuclear weapons modeling codes, turning that expertise, instead, to climate change assessment. His reiteration of the oft-articulated, "we need to act now," was completely understandable, given the system's complexity and associated uncertainty.

Rotman focused on LLNL's role as the assessor of the various extant global climate models, its major responsibility, ensuring the accuracy of the physics underpinning these models. He also discussed LLNL LDRD projects relevant to climate change, such as building a global-scale hydrology model, predicting optimal wind-farm siting, and understanding shear effects that shorten the life of wind turbines. LDRD investments were also bringing geological codes to bear on the challenge of coal gasification, as well as in modeling of CO_2 sequestration or "carbon storage."

Finally, against the backdrop of the thematic triad, "assess, mitigate, verify," Dr. Rotman discussed an initiative in emissions modeling, with the goal of a fossil-fuel emissions verification program that would, for example, be capable of distinguishing between CO_2 derived from fossil fuel combustion and CO_2 deriving from other sources.

Just as weapons designers required uncertainty predictions from their models, so do fossil fuel emitters, companies, nations, and the society at large require uncertainty characterizations from CO_2 emissions models — and climate models, in general. In some ways this brought the symposium discussion full circle, from NNSA Administrator D'Agostino's reminder that the national security mission of the NNSA labs hearkens back to the Manhattan Project to Dr. Rotman's message that the subsequent requirement to model uncertainty in weapons yield has been of great value in other modeling initiatives related to national and global security.

Dr. Douglas Rotman

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