Good morning. I would like to discuss two major thrusts in the Advanced Energy Technologies program, namely portable power and energy harvesting.

I will highlight some near term demonstrations and discuss future opportunities.

Batteries have provided the power to the military's portable electronic equipment for decades.

New visions of future warfare include emerging technologies such as robotic vehicles and exoskeletons.

In most cases batteries can provide adequate power for proof of principal demonstrations but they will not have sufficient energy for real missions. In order to address the energy issue we need to develop efficient energy conversion technologies.

Two major approaches to energy conversion are fuel cells and heat engines.

Fuel cells and static thermal systems are favored for man-portable systems due to their simplicity and low acoustic signatures. (Lawn mower engines will not work as a viable power source for the soldier).

Fuel cells convert the fuel efficiently to electricity and are likely to provide near term energy solutions for some missions.

The major issue for using fuel cells is the fuel source, which I will address in a moment.

In order to assess the effectiveness of small fuel cells in an operational environment we supported demonstrations with the Marine Corps and the Navy.

In the Marine Corps exercise, fuel cells, secured aboard a Humvee, provided power to radios and laptop computers at a retransmission site.

The estimated cost savings using fuel cells exceeded $800 per day per site.

In a recent joint Navy/Marine Corps/United Nations humanitarian exercise, fuel cells were used to power laptop computers, ham radios, and repeaters in a remote, hostile environment.

The photograph illustrates a fuel cell powered repeater station that provided Internet access to a remote mock refugee camp.

On a weight basis small fuel cells outperform batteries for energy-intense or long duration missions. We recognize that compressed hydrogen is not an ideal fuel for portable soldier systems so we have developed small hydrogen generators and direct methanol fuel cells.

While the direct methanol fuel cell provides an attractive option for portable power applications, direct conversion of hydrocarbon fuels offers twice the energy content of methanol. Efficient conversion of these fuels has been realized for large systems. We are now asking--

can we approach these efficiencies in portable systems without posing a safety hazard or generating unacceptable thermal signatures? Recent results have shown that liquid hydrocarbon fuels can be converted directly into electricity in a solid oxide fuel cell.

There are major challenges ahead to turn this exciting preliminary result into a practical portable system.

Some of the challenges associated with small energy conversion devices, whether they be fuel cells or other concepts, will be addressed with new materials and thermal integration concepts.

Porous super-thermal conductors and advanced aerogel materials can be used to transfer or isolate heat, respectively.

In addition, cascading systems could be used; for example, waste heat from one energy conversion technology could pass through a second device such as a thermoelectric module to generate additional power before being rejected to the environment.

If innovative materials and fabrication methods are used, these approaches could lead to greater efficiencies than simply the sum of the individual efficiencies of each component.

We are initiating a new program called "Palm Power" that will focus on power generation in the 20-Watt range using high-energy content fuels.

We anticipate the need for highly interdisciplinary teams to address the issues associated with this challenging project.

In order to facilitate teaming we will be hosting a workshop this fall, the details of which will be posted on the DARPA website and published in the Commerce Business Daily.

Finally, I would like to comment on our energy-harvesting program, which is intended to increase mission endurance by harvesting energy or fuel from environmental sources. We are exploiting mechanical, biological, chemical and thermal gradients, and solar energy for energy harvesting.

Two projects utilize novel materials that convert mechanical energy to electrical energy directly. In the first example, energy is extracted from heel strike during walking.

We expect that 1-2 Watts per boot will be generated without encumbering the wearer. (We don't want the soldier to feel like he or she is walking through molasses). The system can be used to recharge batteries or provide power to devices co-located in the boot such as an inertial navigational system or chemical sensors.

In the second example an energy- harvesting eel has been developed that captures the energy of flowing water. The eel will provide power to an undersea sensor and acoustic modem that will transmit the data to a nearby buoy having a satellite link.

Finally, I would like to talk about biological energy harvesting.

Small biological motors powered by adenosine tri-phosphate or ATP have received considerable attention recently.

An example of a biomolecular motor is the ATPase motor in which the gamma subunit (the bowling pin in the middle) rotates as ATP is consumed (or synthesized).

The top portion of the motor can be isolated, modified and attached to a substrate. A single molecule ATPase motor can generate sufficient torque to move man-made objects. The generated force is equivalent to a person spinning a 50-foot telephone pole under water at a rate of one cycle per second. Macroscopic molecules and materials have been tethered to the gamma subunit of the motor in order to observe its movement and characterize its performance.

Recently, Carlo Montemagno's group at Cornell attached a one-micrometer nickel rod to a single ATPase motor and imaged it with an optical microscope in real time.

^ROLL VIDEO

If you look closely you can see a blender-effect as the vortex created by the motor draws larger objects into its spinning path.

We are interested in understanding the fundamental force production mechanisms of biological motors as a function of fuel consumption and to be able to integrate these motors with man- made nanostructures that will lead to useful devices.

The ultimate applications of these motors are presently unknown but the convergence of biomolecular engineering with nanotechnology offers unprecedented opportunities and some very thought provoking possibilities such as single atom or molecule detection.

I hope that this brief overview of the Advanced Energy Technologies Program will stimulate your thinking in this area and I would welcome the opportunity to discuss any ideas that you might have that support our program goals.

Thank you very much for your attention.