Sun flashes through leaves at Spectrolab in Sylmar, Calif.: This is the company's power source for helping Boeing go "green."

Shedding new light on solar cells

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Spectrolab is working on technology that could help cut fossil-fuel use

By Walter Polt

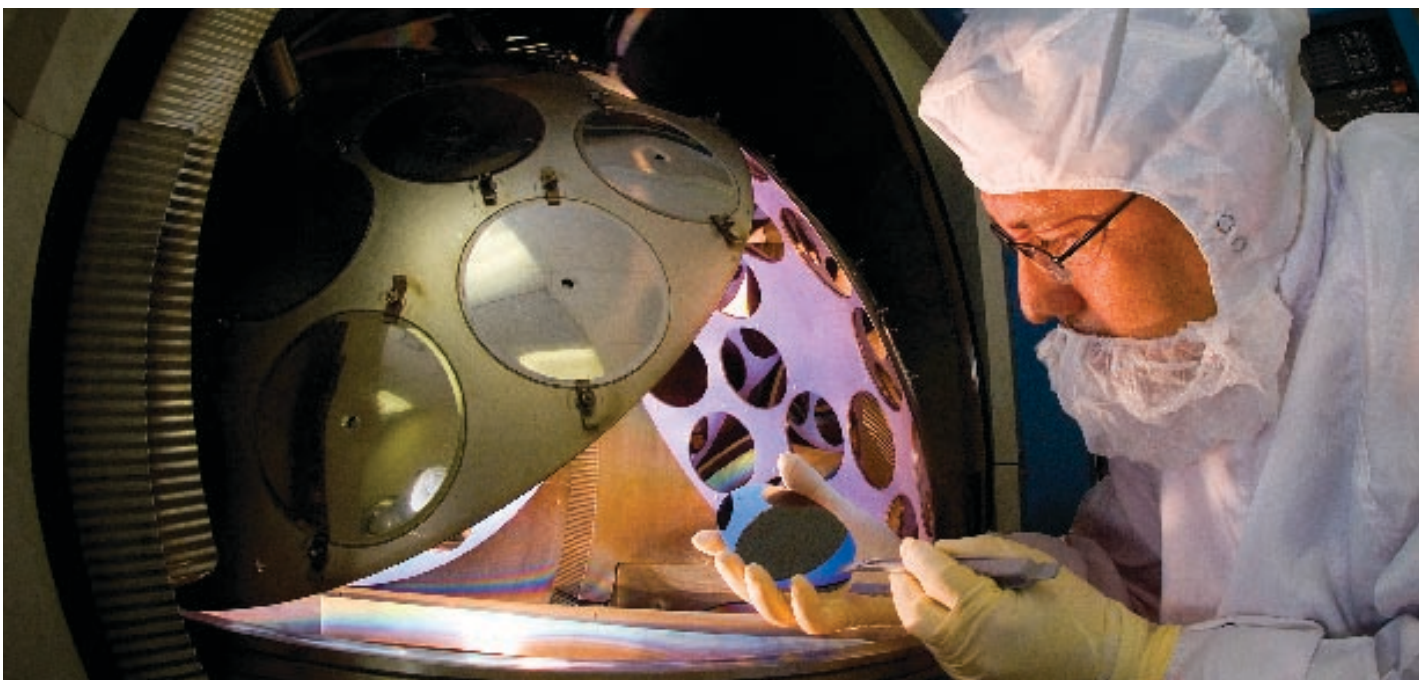
You thought satellite solar-cell technology was out of this world? "Boeing," said David Lillington, president of Spectrolab in Sylmar, Calif., "is bringing that space technology down to Earth." And that technology will be good for the planet.

The story, about one of the many things Boeing is doing to improve the environment, starts with translucent, amber chips that turn the sun's radiant spectrum of energy into electricity. This is the power that Spectrolab, a wholly owned subsidiary of Boeing since 2000, is using to leverage 51 years of expertise with spacecraft solar cells into a new product: miniature solar chips designed for concentrator systems on Earth. And these, if Lillington has his way, may end up on a Boeing rooftop near you, helping reduce dependence on fossil fuels—the use of which is at the heart of the today's global climate-change challenge.

These multijunction solar cells, like their space counterparts flying on more than 65 satellites, use a core Spectrolab cell technology that captures energy from more colors of the spectrum than ordinary silicon cells. A typical silicon solar cell converts about 15 percent of sunlight to energy. The concentrator cells Spectrolab ships to customers average 35 percent conversion efficiency. The target for future Spectrolab products is 45 percent, and champion cells already demonstrated in a lab setting have converted 40.7 percent of sunlight into electrical energy—a world record confirmed by the U.S. Department of Energy's National Renewable Energy Laboratory.

Credit goes to the scientists and technologists at Spectrolab, who have received numerous scientific awards for their achieve-

David Lillington, Spectrolab president, holds a semiconductor wafer made by his company. A single one of the 50 terrestrial solar cells to be cut from this many-layered wafer will yield 15 watts of electricity in a concentrator solar system, converting 35 percent of the light spectrum. By comparison, a standard five-inch-square (13-centimeter-square) silicon cell yields 2.5 watts with around 15 percent efficiency.



German Rivera inspects a semiconductor wafer freshly coated with an antireflection surface in a Spectrolab vacuum chamber. The coating will enhance transmission of concentrated sunlight into multijunction photovoltaic cells cut from the wafer.

Ana Escobar uses a vacuum wand to place concentrator photovoltaic cells during the process of welding interconnects to them. Robotic welding will soon free her to do other work in the factory.

How terrestrial concentrator chips are different

If you let pure sunlight fall on semiconductor materials, its photons ("packets" of energy) start knocking loose unstable electrons. Provide a complete circuit, and the electrons flow as electricity. That's the "photovoltaic effect."

Boeing's photovoltaic (light-to-electricity) cells, both in space and on Earth, are putting to use this power-generating process. They are cut from 4-inch (10-centimeter) germanium wafers that have some 25 layers of additional semiconductor materials "grown" on them in Spectrolab's semiconductor manufacturing facility. Some layers are only a few atoms thick. Arranged in three groups, the layers form a triple-junction cell: It captures the most potent photons available in the color spectrum—variations of red at one junction, of green at the next, and of blue at the next.

The wafers are imprinted with a fine grid, mostly of silver, that establishes the circuit for carrying the electricity. For Earth use, the wafers are cut into cells the right sizes for various concentrator systems—50 or more chips smaller than your fingernail from a single wafer.

And on Earth, concentrator-system makers do something not so feasible in space: they use curved mirrors or different kinds of lenses to concentrate sunlight on the chips. One customer, for example, uses a sheet of Fresnel (pronounced fray-NELL) lenses (flat magnifiers) to focus golf-ball-sized patches of sunlight onto pinhead-sized (1-millimeter-by-1-millimeter) chips.

Concentration puts the chips in, well, a whole new light: In addition to pouring more photons on a spot, it boosts the efficiency of the photovoltaic effect. So it might take 1,000 times as much silicon as concentrator cell material to get the same output. A surprise bonus on Earth: The conversion efficiency of multijunction solar cells on Earth is higher than in space, because our atmosphere obligingly filters out some colors that the solar cells cannot readily convert into electricity.

—Walter Polt

ments, including R&D Magazine's R&D 100 Award in 2001 and 2007. The company's accomplishments were supported by development funding provided by the Department of Energy, channeled through the National Renewable Energy Laboratory and the U.S. Air Force, which have funded space multijunction cell development for more than a decade. Support also has come from Boeing's White Space organization, which has promoted the application of space technology for terrestrial applications.

INVESTIGATING IN INNOVATION

Boeing is playing a stronger role than ever in stewardship of the environment, because it's a priority for the company's customers, employees, communities and investors. Core to this strategy is to look for ways to reduce emissions of greenhouse gases caused by fossil-fuel use. As a technology leader, Boeing's biggest contribution is to invest aggressively in innovation—to pioneer new products with improved efficiency and environmental performance. Solar technology using Spectrolab's miniature terrestrial concentrator solar cells could be one solution, in a wide spectrum of solutions.

The solar cells illustrate how and where Boeing is examining environmentally progressive technologies. In fact, Lillington revealed larger possibilities: Boeing not just making the world's best solar cells, but taking the lead in benefiting from them. That could help Boeing sites reduce their reliance on today's major source of electricity—power plants that burn fossil fuels.

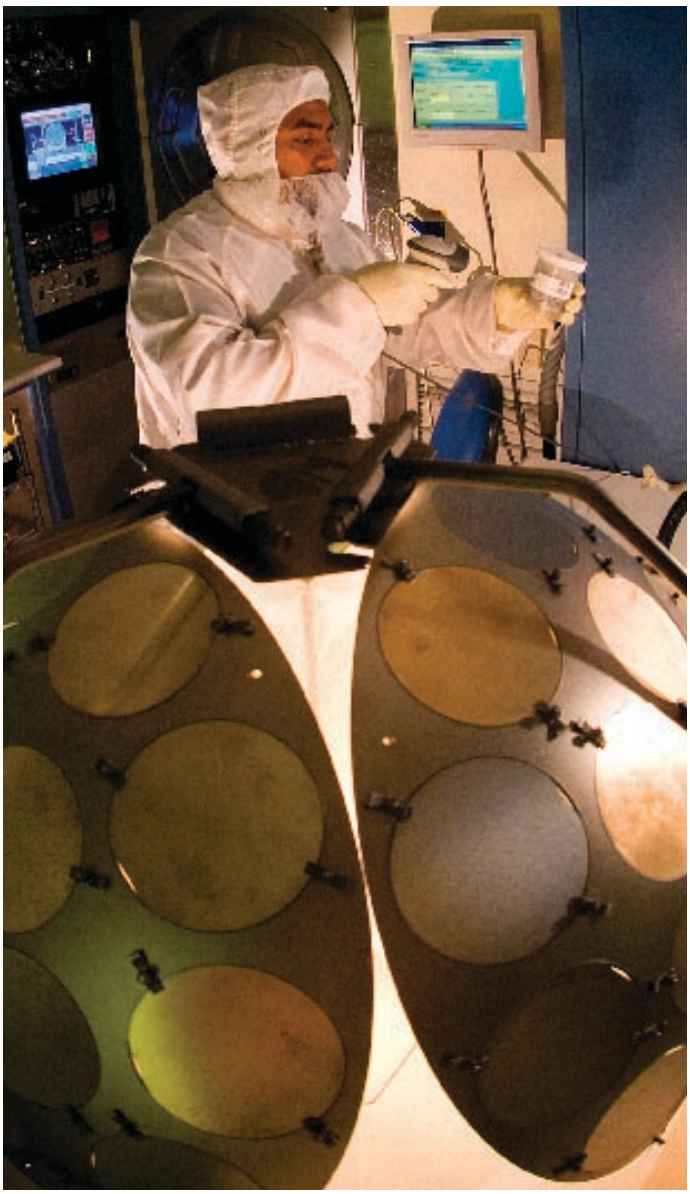
"Many large companies," he said, "are acquiring solar systems to reduce their carbon footprint and dependence on outside energy—so why not Boeing?"

The Spectrolab cells cost a little more. But replacing a standard conventional silicon solar panel system with a concentrator system provides more than twice the electricity over the system's lifetime. With worldwide electricity consumption forecast to double in 20 years, Lillington said these systems would be "an elegant way to get the cost of electricity down in widespread application—and help utility companies grow or supplement their production with affordable green energy."

Sun energy, unlike nonrenewable fossil fuels, keeps flowing—and with a zero carbon footprint. It will last forever—well, 4 billion years, anyway—and it's plentiful.

"If you populated a chunk of California desert just 150 kilometers square (93 miles by 93 miles) with 35-kilowatt solar dishes using Spectrolab's high-efficiency concentrator solar cells," said Jeff Peacock, vice president of Spectrolab Photovoltaic Products, "you'd generate about 4 million gigawatt hours annually." That's almost as much as last year's total U.S. electrical usage, according to the Department of Energy's Web site.

Gabriel Rivas uses a bar-code scanner to keep a record of silver used on a batch of semiconductor wafers (foreground). The wafers—which will be cut into smaller photovoltaic cells—were imprinted with a fine grid composed of silver alloyed with other precious metals. The metal lines collect the electric current generated by light absorbed in the solar cells.



It's our future

Actions cited in this story show how employees are applying concepts of the Boeing Management Model to support the company's business strategies. Here's how.

- **Growth and productivity: Lean+, through replicating production efficiencies implemented on the manufacture of a similar product.**
- **Leadership attributes: Finds a Way, Lives the Boeing Values.**

To learn more about the Management Model, visit http://bmm.web.boeing.com on the Boeing intranet.

For space use, Spectrolab makes chips and places them in big fan-like arrays to power satellites; for use on Earth, it just makes the chips. "As merchant-supplier to the industry," Lillington said, "we supply chips to about 10 concentrator-system companies. There are about 30 around the world, all looking at our products—plus there's the Boeing team that is working in support of the U.S. Department of Energy's Solar America Initiative." SAI is a push to make solar electricity competitive with conventional sources by 2015.

GETTING COMPETITIVE

In order to slash chip cost, boost production—by orders of magnitude—and satisfy the mounting demand for nonpolluting power, the Sylmar factory is continuing technology and process development, and increasing automation.

"Automation is part of our work under the Solar America Initiative, and it's part of our capitalization plan," said Jim Hanley, director of solar panel operations and chief of staff to Terri Cavicchi, vice president and general manager of operations.

"We're borrowing and adapting ideas from our space-cell production for terrestrial-cell manufacturing; and by expanding our robotics into welding, testing, piece handling, and packaging," he said, "we expect in 2010 to be making 200,000 of these pieces every week. In several years more it could be 2 million. And we'll be reapplying everything we learn about cost reduction to space–solar cell manufacturing." This replication of efficiencies supports Boeing's Lean+ growth and productivity initiative.

Spectrolab is projecting a $150 million terrestrial-cell business within four years, growing to more than half a billion by 2016—and supplying a conservatively estimated capacity of 1.8 gigawatts of power to concentrating system manufacturers. That's 4 percent of projected worldwide renewable electricity production. Plus, by then some of that clean, multicolored sun energy may be in the electric power that lights your workplace, thanks to Spectrolab. ■

walter.j.polt@boeing.com

Green products, green workplace

Making miniature solar chips that will help convert more of the sun's light into energy isn't the only thing Spectrolab is doing to help the environment. The Boeing subsidiary not only works on green products, but it strives to improve environmental practices in its workplace.

Collectively, the crowning "green" contribution as a work force of 400-plus factory workers, engineers and other professionals is the high-technology terrestrial solar chip. Yet "individual Spectrolab employees do things for the environment every day," said Jeff Peacock, vice president of Spectrolab Photovoltaic Products.

For example, some drive hybrid cars. Others have notes on their e-mails indicating: "Please consider the environment before printing this e-mail."

Also, Spectrolab's Sylmar, Calif., facility does more than just use high-efficiency light bulbs and recycle 100 percent of its semiconductor waste material. "We keep strengthening our recycling and reclamation streams," said Holly Baez, Spectrolab's manager for Environment, Health and Safety. "We reengineer our processes."

Terry Cavicchi, vice president and general manager of operations, said those efforts have accomplished a lot: "Today we use half as much electricity processing semiconductor wafers as we did in 1995."

—Walter Polt