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Silicon and Lead

What we now see emerging is a remarkable symbiosis of two radically different materials–silicon and lead. C&D is leading the way.

The company owns no Nobel-Prize-worthy science, and isn't likely to be developing any. It's headquartered in Blue Bell, PA, not Silicon Valley. Its products begin with one of the most reviled materials in widespread use today. Not silicon, the semiconductor responsible for the rise of the information age, but an ancient metal responsible for poisoning the wine (and thus accelerating the decline) of the Roman Empire. They begin with lead, in lead-acid batteries. The silicon comes later.

Start back in 1906. Two high school buddies, Frank Carlile (C) and Leon Doughty (D), start a little business converting homes from gas to electric lighting. The enterprise grows; it gets into the manufacture of automotive batteries early on, but shifts to industrial systems during World War II. Allied Corporation buys it. In 1985, Allied spins out the battery division, which goes public as C&D Technologies (CHP) two years later. C&D emerges as a leading supplier of standby power systems to phone companies. It goes on to develop a broad range of similar systems for backing up computers, switchgear, process controls, and alarm systems.

Last year's market tagged C&D as another mere supplier to the telecom/datacom pariahs, and its shareholders got to ride the NASDAQ roller coaster alongside some of its major customers, the likes of Lucent, Nortel, Verizon, BellSouth, and MCI WorldCom. But as we've pointed out before, the high-9s demand is now as universal as the embedded base of networked silicon, which is already huge, which already needs much more reliable power than most of it is getting, and which will continue to grow inexorably, whatever the short-term profit outlook for manufacturers of chips and glass.

C&D's addressable market thus extends to everyone with a cash register, ATM, traffic light, or CAT scanner. And to the manufacturers of forklifts, airline ground support trucks, and other electrically powered industrial vehicles, which lose their connection to the grid every time they roll. And to anyone who would harness the most fickle power plants of all, the sun and wind, which turn off as regularly as the earth turns, and as unpredictably as the weather changes. And to utilities themselves–they buy C&D systems to keep the nuke's control room lit when all the rest of the power fails.

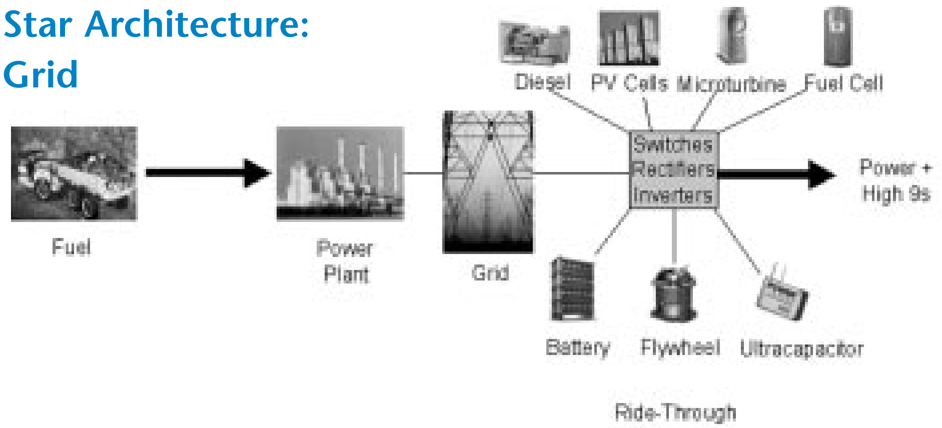
C&D is like Emerson Electric (EMR), only smaller; and it's focused exclusively on the heart of our space. Both were once old-guard "electrical" companies–but both anticipated and have adapted to the new demand for extremely reliable power. C&D delivers high-9s electrons for both stationary and motive power–no other company targets high-reliability power systems so consistently, and for such a wide range of platforms. As usual, most analysts don't even have a name for the new space, so they lump C&D in with "electrical equipment" vendors–manufacturers of alternators, motors, switches, washing machines, and light bulbs. One might equally well call C&D a "metal company," because it sells a lot of lead. But the business isn't in the metal, or even in the kilowatt-hours that an acid bath can squeeze out of it. The business is the systematized provision of high-9s "reserve power" to heavy-duty electrical clients.

If you happen to find yourself trading CHP on the floor of the Exchange itself this summer, when the rest of Manhattan is blacked out for lack of power, thank C&D. Its products help keep the NYSE ticker ticking when the grid power fails.

From Spaghetti to Star

The old grid–from the wires leading out of the power plant, to the meter outside your home–that's spaghetti. And the old car–all the stuff under the hood, from the gas tank to the wheels–more spaghetti. Or, if you prefer, spaghetti and one big meatball. The meatball is the single power plant that burns coal or gasoline. It pumps power down through a tangle of wires, shafts, belts, pulleys, transformers, gears, switches, and valves–the spaghetti.

Star Architecture: Grid



The architectural alternative is a star—multiple units that generate and store power, arrayed around a fast, intelligent central power unit that controls where the power is drawn from, and where it's delivered to, and its voltage-current profiles, and the AC/DC conversions. Why prefer Star to Spaghetti? Star Power is taking over the grid, because it improves reliability–it adds 9s. It's taking over under the hood of the car, because it improves performance and lowers cost. And if you happen to be mainly interested in saving the planet, Star Power is also the architecture that opens the door to the solar cell, windmill, or cogeneration gas turbine on the grid, or the fuel cell under the hood of the car. For fuller elaborations of these points, see *Reliably Green*, the special report that accompanies this issue, together with *Broadband Power* and *The Silicon Car*, our reports published in December 2000.

Until recently, the transforming of Spaghetti into Star was a haphazard process. Early phone companies added huge banks of batteries to keep the phone lines lit when the bulbs went out. Very early on, car manufacturers stuck a battery under the hood to relieve drivers of the dangerous chore of cranking their own engines. The World War II submarines got batteries to supply power under water, where you couldn't burn diesel. Manufacturers of forklifts and carts added batteries to keep the air clean in the warehouse, and the afternoon quiet on the golf course. The batteries themselves weren't hard to find.

Then came the hard part—connecting the grid or the gasoline engine to the battery, to convert and shuttle power back and forth, through starter motors and AC/DC charging systems. With grid and car alike, the shuttling gets progressively harder as you add additional points to the Star—a backup diesel generator, turbine, flywheel, or bank of ultracapacitors–and move more power to serve bigger loads. To control the multiple points of a Star intelligently, the controller has to know a lot–usually more than the points will readily disclose. The grid generally doesn't give twenty-four-hour warnings before it fails, except in California where failure itself is now being systematized. Diesels take time to get up to speed, and generally won't send you an e-mail in advance if someone forgets to change the oil or fill the fuel tank. Batteries–still by far the most common second point on the Star—are notoriously reticent about just how much power they're prepared to deliver, and how fast they can deliver it.

With no general-purpose technology on the market built specifically to address such problems, each major product vendor developed its own tangle of electronics, switches, alternators and generators to juggle its own particular mix of Watts and horsepower, voltages, currents, torques, and duty cycles. To this day, most vendors of auxiliary power systems still custom-design their own power controllers. Capstone builds one into the top of its 30- and 60-kW microturbine (*July 2000 DPR*). Active Power does the same for its 250 kW ride-through flywheel (*August 2000 DPR*). FuelCell Energy is pursuing its own custom power architecture (*September 2000 DPR*). An uninterruptible power supply (UPS) comes with its own power controller optimized to bridge between grid and batteries for high-9s AC applications. A silicon power plant does the same for DC loads (*June 2000 DPR*). The charging system, battery, and starter motor in a car are a specialized UPS on wheels, bridging the motor and the battery (*December 2000 DPR*).

Many complex engineering systems do evolve haphazardly; Spaghetti is as common in engineering adolescence as acne is in teenagers. But standardized products and orderly architectures eventually replace the tangle when the right technology comes of age. And now it has, with the arrival of the general-purpose powerchip. What is now emerging at the center of the star is a cleanly integrated unit, that can plug and play electric power from multiple different sources, in whatever format they may supply it–AC from the grid, DC from

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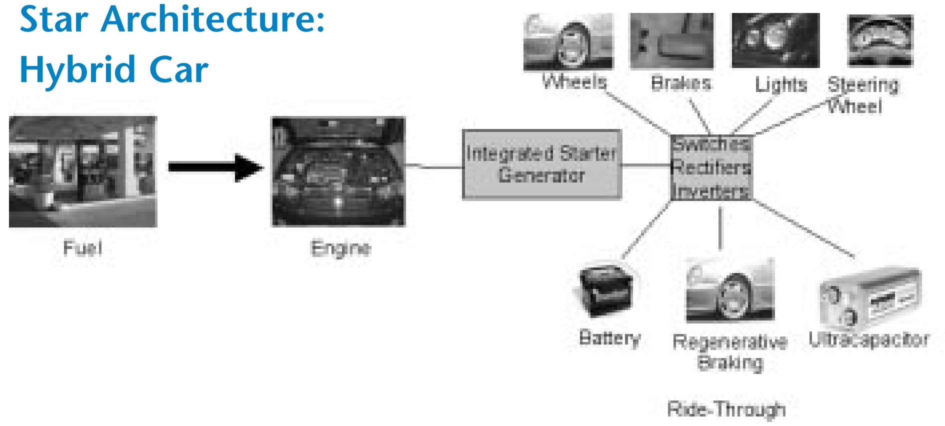
batteries, and lower quality, more variable power in between, from flywheels, solar cells, windmills, or other sources. Call it the "central power controller" (CPC).

Star Architecture: Hybrid Car



Xantrex and SatCon

A Pakistani refugee from Idi Amin's Uganda, Mossadiq Umedaly spent five years at Price Waterhouse, then eight years as one of the prime movers at Ballard Power Systems (BLDP). In 1997, Umedaly was appointed to the board of Xantrex, a privately held company headquartered in British Columbia; he then left Ballard, and in 1999 became Chairman of Xantrex. Ballard builds fuel cells–a new point on the Star. Xantrex builds CPCs—the electronics in the middle. Xantrex has emerged as an OEM supplier to Applied Materials, Ballard, Compaq, and Siemens, among many others. It also sells to the retail market through Canadian Tire, Costco, US Marine, and others. Its revenues now exceed $120 million; when IPOs return to favor, Xantrex will be among the first in line.

"I'd rather be rich than right," Umedaly remarked, when we suggested that demand for one of his products would be a lot higher than he had forecast. Most of the time, he's both. Founded in 1983, Xantrex began with a handful of products developed in-house, including some path-breaking DC power supplies. Umedaly has since built Xantrex into a CPC powerhouse, by rolling up the right technologies and the right companies. He bought Statpower in 1999, for its DC/AC conversion products. Then Trace Engineering (Arlington, WA) and Trace Technologies (Livermore, CA) in April 2000—they were leading manufacturers of 1-kW to 1-MW power electronics developed for solar, wind, and other "alternative" sources of power. Then, two Seattle-based companies, Heart Interface and Cruising Equipment–major suppliers of power inverters and instrumentation for recreational vehicle and marine markets. The common theme: a steady focus on the largest, fastest-growing, low-power edge of the Star Power revolution–small businesses, homes, cars, and boats, smaller loads, and smaller sources of power, including, inevitably, solar, wind, and fuel cells.

Built around a rechargeable battery, Xantrex's xPower series starts at $150 and runs a wide range of AC or DC electronic products. Ranging from 2 to 5.5 kW, Xantrex's Vesta products link directly to electrical panels in homes or small businesses, to provide power switching and connections to the grid, banks of batteries, and backup generators—or, if you prefer, fuel cells, solar arrays, and windmills. A plug-in energy management module, currently under development, will provide complete, user-programmable control, including the ability to sell excess power back to your utility when regulators and utilities get around to buying.

SatCon (SATC) is in much the same business, but targets higher-power industrial and military applications. The company was formed in 1985, by a nucleus of earnest (and very smart) MIT researchers, who were mainly interested in pursuing government R&D contracts in motion control, control software, and electronics. Working on the government's dime, SatCon built up a varied base of remarkable engineering IP in magnetics, motor/drive technology, digital signal processing, and high-speed electronics. In 1996, SatCon introduced its first commercial product–an "Inertial Battery," i.e. a flywheel. Beacon ((BCON) *August 2000 DPR*), a company that SatCon spun off last year, now sells that 2kWh storage device to Verizon, Cox Cable, and Century Communications.

Like Xantrex, SatCon has spent the last several years rolling up a number of smaller vendors that design and manufacture the complementary components and modules that are now converging in the CPC. The company recently purchased the IP and tooling from a unit of Northrop Grumman that builds power electronics and electric drive trains for microturbines. Though SatCon is still working out its transition from R&D government contractor to commercial enterprise, the company's revenues have tripled (to about $30 million) in the last five years; about 70 percent of its revenues now derive from the sale of commercial products.

SatCon's business remains squarely centered in power electronics. SatCon builds elegant magnetic bearings that effectively replace lubricants and hardened steel with silicon and electricity–SatCon technology levitates and spins the plates that move silicon wafers through chip fab ovens, for example. SatCon also manufactures servomotors for factory automation, industrial machinery, automotive markets, and a 1.5-ton industrial-scale shaker used for heavy-duty stresstesting. It builds power converters, amplifiers, and controllers, as well. SatCon's MegaVerter, for example, is a 200 kW to 5 MW inverter designed for use in connection with commercial-size fuel cells and microturbines. Among its customers: FuelCell Energy (FCEL), which has contracted with SatCon to develop power electronics and control software for FCEL's MW-level molten carbonate fuel cells.

What interests us most in SatCon's product line-up are its CPCs. SatCon's PowerGate is nominally a CPC for residential fuel cells–but it doesn't have to be a residence, and it doesn't have to be a fuel cell. The company's GridLink CPC is designed to provide a seamless, general-purpose interface to the grid for just about any power source—diesel, microturbine, flywheel, battery, photovoltaic, windmill, or fuel cell. Like Xantrex, SatCon is also developing features that would allow sales of power back into the grid, when utilities and their regulators are ready.

Batteries remain the overwhelmingly dominant second-source of power

It's too early to make confident calls on whose CPCs will end up dominating which sectors of the power market. Various engineering conglomerates, including Eagle-Picher Technologies, United Technologies, SAFT, and Hughes Power Control Systems, manufacture their own, impressive, CPC products in-house. But the commercial inevitability of this new family of products is no longer in doubt. The CPC will become as ubiquitous as the circuit breaker box, in businesses, homes, cars, boats, and almost every other system that handles serious amounts of power. Its destiny is to control the flow of power in all the places where our digital-electric hardware lacks sufficiently reliable power today—which means almost everywhere that such hardware currently relies on the grid alone to power it, as well as on all off-grid platforms where power begins with batteries, motor-generators, solar cells, and other alternatives.

Lead and Acid

The CPC is the gateway to supplementary sources of power, and the electronic bridge between spinning shafts and flowing electrons. Greens hope that the "supplementary" will some day become "alternative," with the CPC serving as gateway to solar, wind, and fuel cell. Perhaps some day it will. For now, however, lead remains a better bet than sun or wind.

Are we happy about that? No we are not. Do we wish the lead would go away? Yes we do. But we try to keep this letter anchored in present reality and the reasonably foreseeable technological future. The lead isn't going away, it's piling on. Yes, the small turbines and flywheels, along with larger molten carbonate fuel cells, are already multiplying around larger businesses; we've already set out our views on these very promising technologies in prior issues. As we've emphasized, their biggest opportunity is to cut into the huge battery market. But the Californian who buys a house-sized CPC from Xantrex or SatCon is most likely to connect it, first, to a rack full of lead-acid batteries.

As we discussed in our flywheel issue (*August 2000 DPR*), batteries remain the overwhelmingly dominant second-source of power. If you're using any kind of off-grid power today, it most likely comes from the shoe-box-sized UPS that sits directly behind your personal computer, or some larger equivalent that backs up your office network. And when the UPS can't draw power from the grid, the next thing it looks to, most often, is lead.

Manufacturers of batteries for PDAs, cell phones, laptops, and other portable applications chase lithium, cadmium, nickel, silver, and zinc. These exotic materials offer very high power densities, and that's what the portable customer wants: really light, durable batteries, whatever they cost. The other main option at this end of the market is the alkaline disposable—which ends up expensive, too, in most applications, but offers the convenience of (effectively) instant recharging, when you throw away the old and slide in the new. Disposables still dominate the low-power battery market as a whole with over 2 billion units—100,000,000 *tons* worth—sold last year in the United States.

That leaves a huge space at the other end of the performance curve–much worse, in terms of energy stored per kilogram, but much better in terms of energy stored per dollar. Lead and acid are heavy and cumbersome, but they are also affordable. No other battery chemistry has yet come close to beating them. From the grid itself, $1000 will buy you 10,000 kWh–about a year's worth of electricity for a typical home. The same money will buy the same home a few hours worth of storage in lead-acid batteries. Or a couple of minutes worth in the lithium battery used in a cell phone. Or just seconds worth from a satellite's nickel-hydrogen cell.

About 70 percent of C&D's sales come from what the company calls "reserve power systems"–batteries tightly bundled with electronics. C&D builds lead-acid batteries for systems designed to deliver serious quantities of stored energy–not just *ride-through* power for the seconds or minutes it takes to start up the diesel generator when the grid goes down, but true *energy storage*, for applications where there's no diesel on the premises at all. It has three major competitors in the non-automotive lead-acid market–Enersys (formerly Yuasa), East Penn (private), and Exide (EX). The major battery buyers we've consulted agree: C&D is the undisputed leader in this huge segment of the battery business. Both its "flooded" and its absorbed-gas-mat valve-regulated lead-acid (VRLA) batteries are the best on the market.

C&D's Round Cell battery, for example, is of the venerable flooded design and was originally patented by Bell Labs. C&D has manufactured Round Cells for AT&T, Lucent (after the spin-off) and now Tyco (after the Lucent sell-off) since 1972, and has been the exclusive manufacturer since 1982. Flooded cells store about 20 percent more power than other designs, and when properly maintained, they can last indefinitely–the Round Cell is said to be good for forty years. The ugly part of the traditional flooded design is that it vents hydrogen and oxygen (an explosive mixture), and that it has to be watered periodically (although increasingly with reliable automated systems) to replace what's been vented as gas. Technicians, in other words, must hover around.

VRLA batteries, by contrast, are designed to run sealed–they recombine the electrolytic gases within the battery, rather than vent them. These units can go pretty much anywhere, safely–in enclosed cabinets, office environments, and basement homes–without full-time technicians on hand to nurse them along.

There are two VRLA basic designs. The absorbed glass mat (AGM) battery uses a thicker electrolyte absorbed and immobilized in a sponge-like glass mat. The gel-based VRLA depends on mixing a pure form of silica with the electrolyte to form a gel between the lead plates. Cracks that form naturally within the gel when it dries channel the oxygen back to recombine with the hydrogen. Both designs include a safety vent/flame arrestor that prevents sparks from entering and maintains sufficient pressure inside the cell to recombine the gases during normal operation, but provides a safe release during abnormal operation. Like others in the industry (particularly in Europe), C&D has systematically improved the catalysts that are used to help promote the hydrogen-oxygen recombination inside the cell, while minimizing the ancillary self-discharge problem that can be aggravated by the recombination process. The catalyst is incorporated into the vent assembly.

Between their patented catalysts and improved (proprietary) lead alloys, VRLA battery life has roughly doubled in the past decade. C&D's VRLA units now have a twenty-year design life. Getting to that kind of performance is mainly a matter of persistent, incremental progress, advancing a very old technology year by year to meet the ever more stringent demands of the new digital marketplace. By lead-acid standards, C&D batteries run cleaner and cooler, provide higher power density, and can tolerate more hostile (especially hotter) environments. C&D also sets the industry standard on design and service details—front access to the battery terminals for rack-mount installation, after-market technical support, just-in-time delivery programs, strategic warehousing, emergency shipment, and 24-hour emergency service worldwide.

Nearly fifteen years ago, Southern California Edison along with EPRI and (surprise) the International Lead Zinc Research Organization set up the mother-of-all lead-acid load shifters. They put 8,256 telecom-type lead-acid batteries in a massive 10 MW array, fifty miles outside of Los Angeles. The utilities missed the point. If you're going to deploy 8000+ batteries, you don't want to pile them all up in one place, it makes much more sense to scatter them across Los Angeles. Most especially today, now that sealed batteries have advanced so far, and CPC electronics have grown so cheap. You want to keep the batteries under your own control, and well out of the utility's hands–nowhere more so than in the Golden State, where the utility is no more reliable than the political system, which is no more reliable than the San Andreas fault. But the utilities did get one thing right, and it still holds today: Like it or not, electron storage still begins mainly with batteries, and affordable batteries still begin and end with lead. And where reliability matters, mainly C&D's.

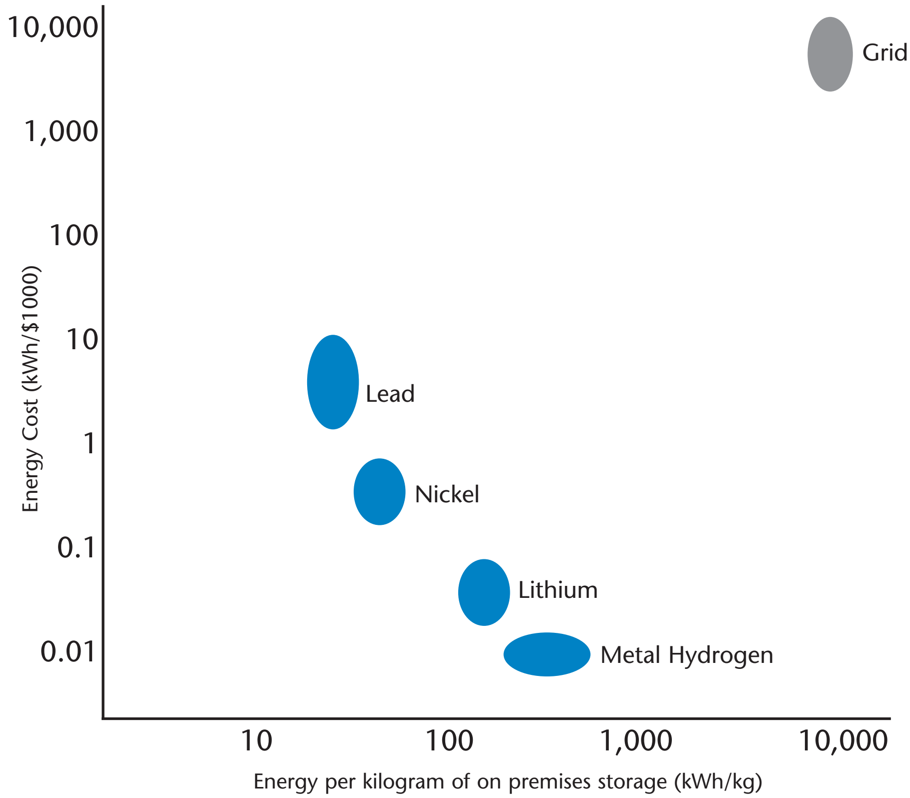
Silicon and Lead

The CPC plays an especially essential role when batteries make up one of the points on the Star—which they almost invariably do. Batteries supply power, when discharging, and consume it when charging. How long the battery lasts depends a lot on the quality of that power, both coming and going. Batteries are delicate. They remember. Charge or discharge them the wrong way, and they'll never forgive you. Bad power can crash the battery as easily as it can crash a silicon microprocessor. The battery, in short, requires its own kind of high-9s power, its own tight control of the voltages and currents that get thrown at it, or drawn from it—even as it helps supply more reliable voltage and current to the loads downstream.

This was recognized some time ago by the manufacturers of the exotic-material, lightweight batteries favored in portable applications. These batteries deliver terrific power density, but they overheat, and are easily damaged, when charged too fast or overcharged. Charge a lithium-ion battery too fast, and it may burst into flames. Some of the even more exotic designs will explode. The charge-control electronics thus occupy up to one-half of the sealed battery pack, and much of its cost. More effort goes into advancing the electronics to manage high performance than to advancing battery chemistry.

In much the same way, for much the same reason, C&D designs and manufactures silicon systems to overlay on top of lead-acid batteries. Though the company sells both its batteries and its electronics separately, it is its complementary expertise in both dependable industrial-sized batteries and sophisticated monitor, control, and charge-discharge electronics that sets C&D apart. The electronics rectify or convert between AC and DC, and step down DC voltages to accommodate the elec-

Cost and Weight of Batteries



Lead and acid are cumbersome and heavy, but they are also affordable. No other battery chemistry has come close to beating them, except in applications that place a high premium on light weight. The grid costs least and requires almost no hardware on the end-user's premises.

tronic equipment served by a UPS, or the motors and peripherals in a forklift. The electronics simultaneously monitor and test the batteries, and control voltages and currents during charge and discharge. Across all the platforms its products serve, C&D acts as a single-source designer, manufacturer, and integrator of battery plus power controller.

And while the basic chemistry of the lead acid battery is old, the silicon overlay now accounts for very significant advances in a power-storage technology long thought to be too old, familiar, and well understood for much improvement. The powerchips that control charge/discharge cycles are getting smaller, cheaper, and more efficient. And it's now possible to pack cheap intelligence and data storage alongside, with smartchips instructing the powerchips what to do. With those capabilities now at hand, battery engineers have been able to significantly advance charge/discharge control algorithms, to optimize charging and performance for the specific applications at hand, and extend battery life. C&D recently patented its own system for sensing battery parameters, adjusting charging characteristics in response to the environment, and enhancing maintenance with remote signaling.

The total U.S. market for battery control systems—just one segment of the DC power electronics field—is forecast to grow from today's $1.8 billion to over $8 billion within the decade. C&D should capture a substantial share of it. There are many kinds of batteries, and many good battery manufacturers. But no other company is as well positioned to prosper from the little noted and widely overlooked convergence of silicon and lead.

Gasoline and Sunlight

Next up: get a free set of wheels with your UPS. Aura Systems (AURA) can retrofit an "AuraGen" on to your Chevy Suburban, or Ford Expedition, to provide 5 to 9 kW of continuous power at 120/240 VAC or 14–28 VDC. Other units, ranging from 12 to 25 kW are under development. The AuraGen bolts on to the vehicle's engine, and uses the engine in much the same way as a conventional alternator. An electronic control unit filters and conditions the power.

The company itself has had (to put it gently) a checkered and sometimes unhappy history. But the AuraGen is important for the concept it helps crystallize. Almost every red-blooded American already owns a good-sized motor with plenty of capacity to generate backup power for an entire home. Xantrex or SatCon can already supply the module that will use that motor to generate on-board power for peripherals used in the passenger cabin of a car (or boat). Other companies will inevitably emerge to deliver the power at off-grid worksites–and eventually from the driveway to off-grid homes. To most of California, in other words, if the politicians keep fiddling while the lights don't burn.

And it won't end with AuraGen. For about $20,000, Toyota's Prius and Honda's Insight will supply you with a gasoline generator, a bank of batteries, and 10 kW (Insight) to 33 kW (Prius) of power, along with a set of wheels to get the gas tank to the filling station when you need to. Both use nickel-metal-hydride battery packs; the Prius's delivers 274 VDC, the Insight's 144 VDC. When somebody gets around to it, it won't be hard to hook up one of the new hybrid electric cars to wiring in your home through a CPC. It will also get you to the baseball game, and win you the admiration of your green friends, and perhaps earn you a hefty tax credit too.

Honda and Toyota would certainly howl (and void the warranty) if any AuraGen-like company tried such a stunt without their permission. But someone will eventually get around to it anyway–and possibly the car companies themselves. Who, after all, supplies most of the portable and standby generators today? The builders of big trucks, small cars, motorcycles, and lawn mower engines–Caterpillar, and Honda itself. Honda will already sell you any number of neatly packaged units that can connect easily to the input socket supplied for just that purpose on Xantrex's Vesta Online unit or SatCon's GridLink. One way or another, the hybrid car will get connected to the hybrid home.

And for many greens, that will be a long-held dream come true. In their parallel efforts, Xantrex, SatCon, Toyota, and Honda are now bringing to market the infrastructure technologies that the "alternative energy" crowd has been pursuing for decades. Indeed, many of the companies that Xantrex rolled up started out trying to build CPC-like modules to support photovoltaic cells, windmills, and fuel cells. Some green futurists now discern a triumphant end to their quest: Wheels and home all beautifully integrated around high-efficiency, thermo-electric fuel cells.

Maybe some day. When CPCs are installed to back up the unreliable grid, they certainly make it cheaper to draw power from the unreliable sun, as well. Once a few million Californians have bought their CPCs and VRLA batteries, some fraction of the more affluent among them–the ones with the big roofs and yards and nice sunny views–are certainly going to put in some solar too, partly to trickle charge their batteries, and partly to feel good and impress their green friends. And vanity-green markets aside, the rise of the inexpensive CPC and silicon-encased VRLA battery will certainly improve solar, wind, and fuel-cell prospects at the many off-grid locations where these aren't mere "alternatives" to the grid, they're the only choices at hand.

So lots of alternative-energy companies will benefit. In solar, the likes of Evergreen (ESLR), Astropower (APWR), and Spire (SPIR)—if they can beat out Siemens, which just announced solar JV with Shell, or BP Solar, or Toshiba, which are all chasing sunbeams too. Or if you like wind, take a look at Vestas-American Wind Technology (California), Dutch Pacific, or The Wind Turbine Company (Washington state). And as for fuel cells–we've already named the couple we like–FuelCell (FCEL) and Proton Energy ((PRTN) *September 2000 DPR*), or take your pick among any of the hundreds of others favored by breathless reporters at the *New York Times* or on CNBC.

Notice, however, that the batteries tenaciously hang on, and the more "alternative" (and therefore "interruptible") your fuel, the more you need them. For many mid-tier applications, the lead and silicon may be all there is to the story, the second and last point on the Star. Many off-grid applications like forklifts remain in easy reach of a plug for periodic recharging, and even in California, the grid itself hardly ever goes black for more than a few hours at a stretch. Off-peak power from the grid is really cheap, as it should be–the expensive capital infrastructure is designed for the peak loads, and the rest of the time grid power isn't much more expensive than the marginal cost of the fuel. Batteries can time-shift electrons on the grid almost as easily as a VCR can time-shift Tony Soprano on your television. The cheapest, most reliable, most hassle-free substitute for grid power at 4:00 p.m. is grid power delivered to a lead-acid cell twelve hours earlier.

Batteries are now being integrated ever more tightly into the datacom/telecom universe. Duracell and Intel saw this coming almost a decade ago, and joined forces to promulgate a Smart-Battery Specification. It defines how data must flow across the bus between a smart battery, host, smart-battery charger, and other devices, to convey complete information on the battery's state of charge and remaining capacity, control its own recharging environment, and provide information on its own history—temperature extremes, charge-discharge cycles, and so forth. In 1999, Texas Instruments (TI) purchased the innovative Benchmarq Microelectronics, for its smart-battery IC technology, and as we were going to press, TI announced the release of a new programmable, monolithic IC for fast-charge management of NiCd, NiMH, and Li-ion batteries. ON Semiconductor (ONNN) and National Semiconductor (NSM) are likewise pursuing the silicon overlay for DC storage; National recently introduced a single-chip system of its own for managing high-end portable batteries.

The integration of silicon smartchip and metal power cell is already obvious and far advanced in the smallest and most expensive portable devices, and their tightly sealed packages of silicon, on the one hand, and nickel, cadmium, silver, zinc, or lithium, on the other. At C&D, the same art is being extended, for the same reasons, to the far larger market for silicon and lead. Lithium at least sounds fancy enough to be partnered with silicon; lead really doesn't. But what we now see emerging is a remarkable symbiosis of those two radically different materials. Lithium will continue its dominance in many portable applications. But silicon is everywhere else too, and the silicon needs the lead to supply electrons to higher-power loads when other sources fail. And the silicon simultaneously breathes new life into the lead itself, by meticulously controlling the flow of power in and out of the lead-acid cell.

C&D has been building those packages, for those applications, longer than anyone else. By all accounts in the industry, it also builds them a lot better than anyone else.

Peter Huber and Mark Mills
June 29, 2001