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GM's Billion-Dollar Bet

The hydrogen car has been a long time coming. GM is betting $1 billion that the end of internal combustion is near.

By Dan Baum

VIEWED from the proper angle, Detroit's Renaissance Center — six medium-high office towers surrounding a cylindrical 73-story giant — is a mighty glass hand giving the finger. Hulking by the iron-gray waters of the Detroit River, this is the führerbunker of the tired old industrial economy: the headquarters of General Motors.

These days, the company is on a PR tear to tell the world it is "reinventing the automobile." At the Detroit Auto Show in January, the company rolled out a radical prototype called the AUTOnomy, and a drivable proof-of-concept version debuts in September at the Paris Auto Show. How radical is it? It dispenses with just about everything that makes a car a car, such as the engine, transmission, steering wheel, and gas tank. Rather than spitting out carbon monoxide and other smog-causing gases, it emits nothing but water because it runs on hydrogen. With few moving parts, it will last for decades. It will generate more electricity than it uses and be equipped to apply the surplus to power the owner's house. Manufacturing will cost a fraction of what it takes to build a traditional car, because the AUTOnomy will contain many fewer components. And it will be ready for mass production by the end of the decade, which in the automotive world is a week from Tuesday.

Photo by James Westman

I park my rented Pontiac Sunfire in the Renaissance Center garage and open the trunk to retrieve my laptop. As I do, a slab of snow slides down the rear

window and straight into the open trunk. I stand for a minute contemplating this. The same people who are promising to reinvent the automobile can't figure out how to design a car that doesn't dump snow into the trunk. I'm reminded that, out of bullheaded arrogance, GM has lost more than half its 60 percent market share since the 1960s by making ugly, often slipshod vehicles. It missed the rise of the small car in the '70s and the SUV in the '90s. Now ponderous, elephantine General Motors is claiming not only to be able to read the post-gasoline future but to accelerate it as well. What's going on here?

WHAT'S GOING on is that after decades of tinkering with nonpolluting cars in a desultory, "chump change budget to satisfy the enviros" kind of way, GM is getting serious. To be sure, there is cause for skepticism. The hydrogen fuel cell has long been the miracle that remains perpetually 10 years over the horizon. *Wired* itself wrote in 1997, "Fuel cell momentum is now so great that its emergence as a predominant technology appears just short of inevitable." GM CEO Rick Wagoner is fond of calling the fuel cell car "the Holy Grail," which may be a truer assessment than he intends. "The Holy Grail is something you spend your entire life looking for," grumbles David Redstone, editor of the newsletter *Hydrogen & Fuel Cell Investor.* "The whole point is that you never find it."

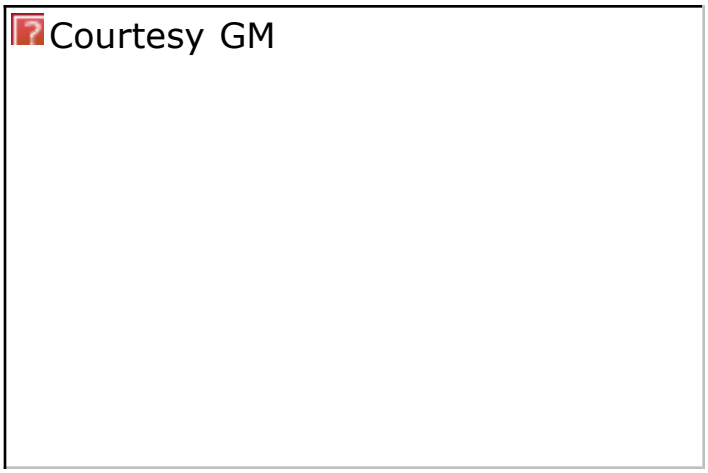
Detroit's eco-car efforts have been largely a matter of public relations. As they cynically wrap themselves in the Earth Day flag by promising hydrogen-powered cars, automakers have been using their muscle to keep federal fuel-efficiency standards exactly where they were when enacted in 1975. Freed of stringent regulation, the Big Three have reaped billions selling high-profit, gas-guzzling SUVs. Look at the window stickers on GM's current crop, arrayed in the Renaissance Center lobby - Chevrolet Avalanche: 13 city, 17 highway. GMC Denali: 12, 15. Cadillac Escalade: 12, 15. My Pontiac GTO got better mileage than this 33 years ago. Individual engines have become more efficient, but because "light trucks" (SUVs, pickups, and minivans) constitute half of all vehicle sales (54 percent for GM last year), national average fuel economy is at its lowest since 1980: 20.4 mpg.

In January, the Bush administration scrapped a $1.5 billion Clinton-era program to develop an 80-mpg car by 2004. Instead, the White House launched FreedomCAR (the "CAR" stands for cooperative automotive research), promising $125 million next year plus more later to help automakers in pre-competitive hydrogen power research. The initiative set no hard goal or deadline for producing an H_2-powered car, so environmentalists see it as a Big Oil/Big Three/GOP plot to distract the public from the need to mandate immediate, radical increases in fuel efficiency. *The New York Times* wrote that the only freedom that FreedomCAR will bestow is on "the manufacturers, now relieved of the obligation (absent strong new fuel economy standards) to produce serious breakthroughs in the next few years."

Which may be true. Point is, though, it doesn't matter. Even if Bush's hydrogen-car initiative is a cynical ploy, even if the Big Three are hiding behind hydrogen promises to prolong the reign of the V-8 and oilmen secretly want to strangle the fuel cell in its cradle, simple geology is carrying us toward a post-gasoline future. Petroleum's days are numbered. GM executives themselves understand that. Some say the oil will last 20 more years and some say 50, but nobody says forever. "The internal combustion engine is an incredibly efficient source of power, but we've wrung the towel,"

Wagoner concedes.

That's why every automaker in the world has a merry band of H_2istas who are developing fuel cells. At least eight major companies have drivable prototypes, most of them designed around fuel cells built by Ballard Power Systems of Vancouver. Even so, most automakers seem to see their fuel cell projects as a grudging long-term hedge against the dark day when the recoverable oil runs out, and they talk in terms of 20 or 30 years before putting such cars in showrooms.



Courtesy GM
Power is built into the chassis, which is like a blank slate for body styles and interiors. Seats don't have to lie in rows. A trunk can run the length of the car.
The AUTOnomy Chassis:
Body attachments (center): Mechanical locks secure the body to the chassis.
Control system (right center): The central processor controls the drive-by-wire functions, telematics, and electrical system.
Fuel cell propulsion System: Hydrogen is processed through the fuel cell stack -- built inside the chassis itself -- producing electricity that powers the car.
Motors: Electric motors, located in each wheel, propel the vehicle.

GM executives, on the other hand, promise to deliver the AUTOnomy in less than a decade, and sometimes find themselves rather giddily wishing the gasoline would end sooner rather than later so they can start making real money. GM is the only US automaker developing its own fuel cell in-house: at the company's Warren, Michigan, research facility; at a 300-engineer skunk works near Rochester, New York, that recently expanded by 80,000 square feet; and at a third center in Mainz-Kastel, Germany.

But GM is different in a more important way. Most carmakers see the combination of a fuel cell with a big electric motor as a simple replacement for the internal combustion engine: DaimlerChrysler's fuel cell Voyager looks and drives like a Voyager and Ford's fuel cell Focus looks and drives like a Focus. That puts the fuel cell at a brutal cost disadvantage to the internal combustion engine, making a fuel cell car economically impossible.

GM took a radically different approach. Realizing that a fuel cell system could allow for an utterly new shape, the designers tossed out the design requirements of a conventional engine and devised a car from scratch. Once GM walked through that door, a universe of possibilities opened up; except for the familiar four wheels, the AUTOnomy bears almost no resemblance to a traditional auto. The implications go way beyond design and deep into the economics of manufacturing. By replacing most of the hardware in today's cars with wires and circuits that will be standard across multiple models, the AUTOnomy will allow GM to streamline its production system and drastically cut costs. That's the trick that might make the fuel cell car a reality in eight years instead of 30. Moreover, GM sees this as a way to extend car ownership to the 88 percent of the world's population that can't afford one today, opening the door to exponential increases in profits. It turns out that concentrating on the car, instead of just on the fuel cell, makes all the difference. And nobody is more surprised than General Motors.

LAWRENCE BURNS is GM's vice president of R&D and planning; this being GM, I expect a square-headed fossil in a charcoal suit — something along the lines of Donald Rumsfeld or Bob McNamara.

Burns jumps out of his seat as I walk in, looking more like a leonine yoga instructor in a tight black turtleneck, his outsize head wreathed in boyish blond curls. He's a car guy from way back, having started in GM's R&D department at age 18 while getting his undergraduate engineering degree at General Motors Institute. At 51, he's a high priest of the internal combustion engine, yet all he wants to talk about is hydrogen. "We've been working on internal combustion engines for a hundred years, and conceptually they're the same as they ever were," he says. "The fuel cell is as big a change from the internal combustion engine as the internal combustion engine was from the horse."

Burns is one of 15 mandarins on the so-called Automotive Strategy Board that charts the course of the world's third-largest company. Because GM leadership has undergone several shake-ups since the early '90s - when the carmaker bottomed out — Burns and his fellow top execs can blame GM's legendary mistakes on "the old regime."

While the company was recovering in the mid-1990s, it began developing a fuel cell system that would extract hydrogen from gasoline on board a vehicle; the prototype was unveiled last August in a Chevy S-10 pickup. The engineers knew gasoline fuel cells would be an interim technology on the path to a pure-hydrogen cell, but it would be cleaner and more efficient than a conventional engine and take advantage of the existing gas station infrastructure. In 1998, the year the Strategy Board was formed, GM opened the Global Alternative Propulsion Center, an in-house organization to advance fuel cell technology.

The basics have been understood for a long time. The first fuel cell was tested in 1839, and improved versions powered the Apollo spacecraft of the '60s and '70s. Think of the fuel cell as an atomic sieve: The nuclei of hydrogen atoms pass through a coated plastic membrane, then combine with ambient oxygen to form water - the only emission. The electrons, meanwhile, are siphoned off as electricity.

There are problems, of course. Because fuel cells are wet inside, they tend to freeze and stop working in cold weather. Because they are delicate, they aren't suited for bumpy roads. Because they require rare metals such as platinum to coat their membranes, they are expensive. It currently takes more energy to extract hydrogen from natural gas or other fuels than the hydrogen itself delivers. And researchers have yet to figure out how to store enough hydrogen on board a fuel cell car to deliver the obligatory 300-mile range.

Beyond the technological roadblocks, there's a huge chicken-and-egg quandary: Nobody is going to create a network of hydrogen fueling stations comparable to the existing 175,000 gas stations in the US until enough cars on the road require them, and nobody is going to buy — or build — a hydrogen-powered car until it can be refueled anywhere.

Fuel cells for stationary applications — backup power for computers, home generators, even laptop batteries — could appear within a couple of years. Nextel, for example, is beginning to test fuel cells made by Hydrogenics of Toronto as backup power for cell phone towers. But while cars may be the most difficult application of the fuel cell, from the point of view of the environment and national energy independence they're the most important — two-thirds of the oil consumed in the US goes to transportation, mostly to cars and trucks.

The ascent of fuel cells has been oversold in recent years, yet it's also true that a rough variant of Moore's law has applied. In the past decade, their power density (output per weight) has increased by a factor of 10; they've gone from being bus-sized to fitting in tiny cars; and their cost has dropped from a thousand times more expensive than the gasoline engine to only 10 times more.

Like every other car company, GM's dream originally went only as far as dropping in a fuel cell and a big electric motor where a gasoline engine once stood. Then, in June 2000, Burns hired Christopher Borroni-Bird, a frustrated British physicist from DaimlerChrysler's engineering department, to be the director of design and technology fusion.

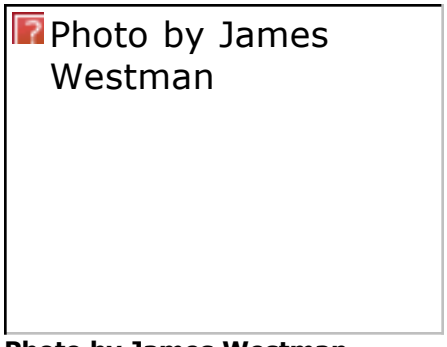


Photo by James Westman
Fuel Cell Testing Process:
Data center (top center, right):
Gauges and digital display monitors convey test results, including gas pressures and electrical output levels.

"At Chrysler, we tended to develop the shape of a car and then look in the parts bin to see how we could make it," says Borroni-Bird, whose spiky hair and slight build make him look younger than his 37 years. "I thought, why not create a group that fuses design and technology from the start?"

He got his chance at GM, where the fuel cell people weren't thinking of the design implications, and the design people weren't thinking about the fuel cell. At first, Borroni-Bird saw the technology as a way to free Detroit's designers from the constraints of a traditional car - unlike the internal combustion engine, fuel cells could be configured flat enough to fit into a car's floor. Eight months after Borroni-Bird took the job, a group of engineers from the Swedish company SKF gave GM a

Fuel cell (left): H_2 molecules hit the fuel cell's proton exchange membrane which extracts electrons and produce electricity.

preview of a project called Filo they were readying for the 2001 Geneva Auto Show. Though conventionally powered, Filo did away with mechanical steering, clutch, and braking hardware, replacing it all with wires and circuits controlled by a joystick. Combine a pure-hydrogen fuel cell with this kind of drive-by-wire technology and put an electric motor in each wheel, Borroni-Bird thought, and the last constraints on car design go out the window.

What emerged from Borroni-Bird's nine-designer shop early last year was the blueprint for a contraption that looks like a giant skateboard, with motors in the wheels and the power supply and controls built into the 6-inch-thick chassis - a blank slate upon which the permutations of body style and interior are endlessly drawn. Seats don't have to lie in rows. The trunk can run the length of the car. The driver can choose where to sit.

Borroni-Bird's big idea might have been shoved into a deep drawer full of futuristic concept cars, were it not for Larry Burns. Burns saw that its implications went beyond design and into manufacturing, and he had the muscle to make things happen. Look under a modern car at all the hardware that steers and brakes it. Look at the transmission. Imagine how many people and acres of factory floor it takes to design, machine, assemble, and ship all that iron. Then imagine all of it gone.

IT COSTS nearly a billion dollars to bring a new Chevrolet or Buick to market. Every engine GM makes requires its own factory, and every car model a unique set of running gear. Fuel cells, on the other hand, easily scale. "You can make a 25-kilowatt fuel cell stack and a 1,000-kilowatt stack in the same plant" by adding or subtracting layers of membrane, GM's Burns says. And the AUTOnomy has no mechanical running gear. Everything needed to power and control the car is built into the skateboard chassis. This means fewer factories devoted to manufacturing the car's power source, and no factories at all making steering and braking hardware. Moreover, a single chassis can serve as the basis of every GM model from sports car to SUV, which means economies of scale that Henry Ford could never have imagined. Even if the cost of the fuel cell never drops to the level of a gasoline engine, the car built around it might be economical enough to offset the greater expense. "It's adding drive-by-wire that really makes the fuel cell plausible," Burns says.

So the AUTOnomy might prove to be even cheaper than today's cars. But as Burns spins it, even if the AUTOnomy turns out to cost more than a conventional car, people might be willing to pay more because it will do things today's cars cannot - such as last 20 years. As it will have almost no moving parts except for the suspension, there will be little to wear out, and its owner could simply buy new bodies when styles change instead of trading in the whole car. Depending on how cleverly GM can engineer the hardware that will hold the body to the chassis, it's conceivable you could own both a summer convertible body and a winter hardtop, or even slap on the roadster for a Saturday drive and the pickup for a run to the dump. The AUTOnomy will accelerate like an F-111 because its electric motors will deliver instant torque to the wheels. It will be silent. The wheels will be controlled independently, allowing the car to swivel and move sideways, doing away with the cumbersome three-point turn. And like other fuel cell cars, the AUTOnomy will generate more than enough juice to

power a house, helping you reduce reliance on the power grid. "Perhaps they will be mortgaged instead of financed like today's cars," Burns muses.

Cars that last 20 years don't sound like a moneymaker for General Motors; however, GM could make up for lower repeat sales in the US by cracking the global markets long sought by the industry. "Just 12 percent of the world's population can afford to own a car or truck," Burns says. "We want to grow that penetration, and even if they were cheap enough you couldn't do it with the internal combustion engine. If you want to expand from the current 700 million cars in the world to even a billion, can the world sustain that? You have to get at emissions and affordability."

AUTOnomy's greatest untapped market might be in China, where there isn't already an entrenched gasoline network. In GM's dreams, the AUTOnomy becomes ready to debut at about the time China's billion-plus people are economically ready for car ownership. China builds a system to deliver hydrogen without ever having one in place for gasoline, the way some African countries are leapfrogging telephone cables and moving straight to cellular. Chinese farmers are given the chance to use a single chassis for both tractor and market truck, and, if they hook up to their houses at night, they make wiring rural China for electricity unnecessary.

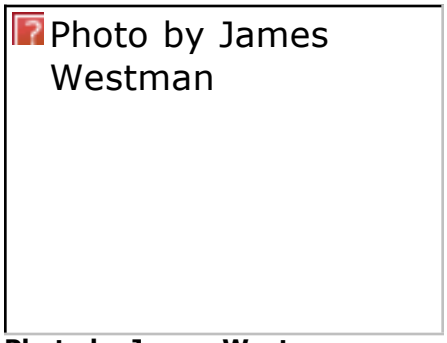


Photo by James Westman
The fuel cell is as big a change from the internal combustion engine as that engine was from the horse.

Sounds far-fetched, but GM is bent on pursuing this vision. The AUTOnomy has catapulted a back-burner, maybe-someday project of GM's H_2istas into mainstream play. Burns won't reveal his exact R&D budget but says fuel cells are "the biggest item on our budget by several orders of magnitude ... bigger by a long shot than improving the internal combustion engine." The company has spent "in the high hundreds of millions of dollars" on the fuel cell, which approaches the $1 billion it costs to bring an entirely new conventional car to market. In addition to its direct R&D investments, GM has been on a shopping spree, buying up shares in fuel cell-related concerns. In 2000, it took a 30 percent share of a new joint venture with Giner Electrical Systems, which made fuel cells for the Navy and NASA. Last year, GM acquired 24 percent of Hydrogenics; 20 percent of Quantum Technologies, a hydrogen-storage company; and 15 percent of General Hydrogen of Vancouver. (It has not disclosed how much it spent for these.) It has also launched a hydrogen fuel cell research partnership with Suzuki Motor of Japan and collaborations with ExxonMobil and Chevron/Texaco to develop the gasoline-powered fuel cell as an "interim strategy until a hydrogen infrastructure is established."

Burns says that for business reasons he's picked 2010 as the year the AUTOnomy will be mass-produced. "If we're not there by then, we'll have dug too deep a hole to recover the time value of that money," well over a billion dollars if the current rate of expenditure continues.

"We're coming up on the moment when GM is going to have to choose between the old and new ways," he says. "Investments in internal combustion engines last 15 to 20 years, so we're going to sit down in 2005 and decide whether to create a new

six-cylinder engine to appear in 2008 and still be used in 2020."

He sits forward and raises a finger. "Or," he goes on, "we will decide those resources are better spent on fuel cells. That will be a fascinating meeting, and it will happen during my career."

BYRON McCORMICK, the phlegmatic 56-year-old physicist in charge of GM's program, has been working on fuel cell cars for decades, first at Los Alamos National Labs. He arrived at General Motors in 1986, but the company's fuel cell efforts date back to 1966 and an experimental, 7,000-pound two-seat behemoth called Electrovan. McCormick says the company is on its way to solving the problem of fuel cells freezing; by tweaking the design and reducing the amount of water inside the stack, GM's H_2istas can start up a fuel cell within 15 seconds at 20 below zero. The company is also experimenting with replacing the platinum on the membranes with hemoglobin, which would radically reduce their cost. "But the problem that keeps me up at night," he says, "is storage."

For all the talk of throwing away the rule book, GM executives are loathe to break this tenet: The Amount of Sacrifice Americans Will Be Willing to Make to Drive a Nonpolluting Car Is Exactly Zero. Any future vehicle — even one that pirouettes — must be able to go at least 300 miles between fuelings and take no longer than five minutes at the pump. GM's plug-in electric car, first offered to the public in 1997, could do neither of these things, and so, though it was quick, fun, silent, and nonpolluting, GM pulled it from the market in 1999. Now McCormick wonders how to get enough hydrogen on board the car to give it the 300-mile range drivers expect.

Pressurized tanks won't do it. Even if you could double their current pressure and wedge enough of them into a car, people would reject this approach for fear the tanks would explode. For a while, GM scientists experimented unsuccessfully with "nanotube" storage — microscopic tubes of carbon mesh that hold single rows of H_2 molecules lined up like billiard balls. The current hope is a variety of metal hydrides, blocks of specialized metal that soak up hydrogen like a sponge and release it on demand. GM's hydrides now store about half as much hydrogen as will be required to give the AUTOnomy a 300-mile range, and Burns concedes the 300-mile fuel cell may be as chimeric as the 300-mile battery.

So he and McCormick play the same game with AUTOnomy's price tag: They envision the future two ways. While genuflecting before the tyranny of consumer preference, they gingerly approach the unthinkable by wondering if they can change expectations. Specifically, if GM can't crack the storage nut, can it bring along other technologies to compensate for the inconvenience? What if you could make your own hydrogen out of water, right in the garage? The technology is already available; you electrolyze water by more or less running a fuel cell in reverse. At the moment, this takes more electricity than the hydrogen would ultimately generate. Giner Electrical, which GM just bought, is developing an electrolyzer the size of a dishwasher and GM wants to accelerate its refinement.

"If you can reform natural gas or electrolyze water at home, you can also do it at rest areas, gas stations, and McDonald's," Burns says. "If you can do that, will a 200-mile range do it?"

GM CEO Rick Wagoner is the yin to Burns' yang, the man who tethers the H_2istas' dreams to grim Detroit reality. "Consumers aren't in any way motivated to buy anything but the vehicle they want," Wagoner says, "and if you don't sell them what they want, they'll buy somebody else's." The plug-in-car experience, Wagoner explains, taught everyone the folly of asking the public to adapt to technology instead of the other way around.

As for government regulation forcing change, heaven forfend. "[Federal efficiency standards] are a failure for good reason," Wagoner says. "They force automakers to make small cars people don't want." He embraces only one government role: The Feds are the single entity big enough to break the chicken-and-egg problem by providing the incentives to build a hydrogen-fueling infrastructure. Gestures like FreedomCAR, modest as they are, indicate to Wagoner that Washington may be willing to step in when the time is right.

To Wagoner, the AUTOnomy — even without China — offers the chance to take the car industry into the post-gasoline future without consigning the world to bloodless little transport pods or, shudder, public transportation. "The payoff for us," he says, "could be huge."

Get real, I reply. From here atop the Renaissance Center, does it really look as though the future of General Motors is in something other than the internal combustion engine — the old-fashioned motor? Will the Pistons change their name to the Membranes?

"We're not betting the ranch," he says, leaning back and hooking his thumbs into his belt loops. "But if you want to be a big player in the auto industry," you have to embrace fuel cells in a real way. "And we're big. We wanna play."

Dan Baum (danbaum@pacbell.net) *wrote about intelligent transport systems in* Wired *9.11.*

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