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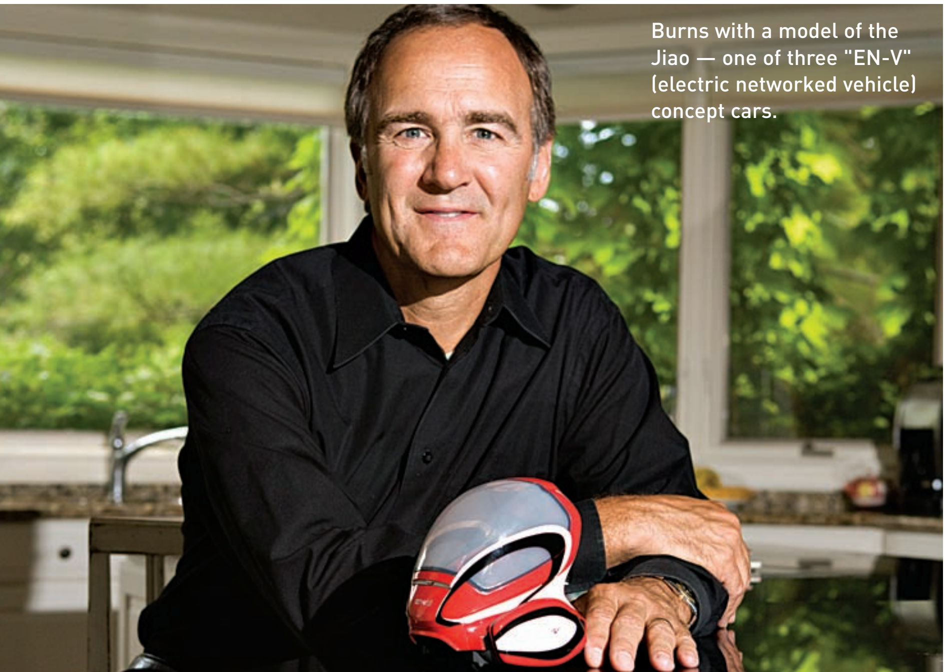

Burns with a model of the Jiao — one of three "EN-V" (electric networked vehicle) concept cars.

Photograph by Jeffrey Sauger

Nobody doubts that the automobile industry is destined for significant change. Given the imperative of climate change; the challenge of finding cheap, reliable, and secure supplies of petroleum; and the prospect of hundreds of millions of people in the developing world joining the ranks of car buyers, something's obviously got to give. But what will the future of personal transportation be? And how will we get from here to whatever that is?

Lawrence Burns, the former head of research and development at General Motors Company (GM), has a compelling vision of that future — specifically, what the future of automobiles might look like in cities, where 50 percent of the world's population lives today, and where an ever-increasing percentage will live in the future.

Burns's vision builds on changes that are already under way and seem likely to continue, such as the trend toward smaller cars, the increasing use of onboard computers, and the development of alternative fuels. But it goes much further. Burns thinks cars will be *way* smaller and lighter — 75 percent lighter, with 90 percent fewer parts — and that they will be connected by a weblike communications infrastructure, which will enable a range of new driving capabilities, conveniences, and features. In this future automotive landscape, Burns predicts that the energy problems we face today will diminish dramatically, as will many of the problems of urban congestion and road safety.

But it won't be primarily for those reasons that these ultra-small cars will succeed, in his view. They will significantly improve the fundamental value proposition that made automobiles wildly popular in the 20th century: their ability to enable us to go wherever we want, whenever we feel like going there, in an affordable manner.

One of the reasons Burns's ideas are so interesting is that he's a car guy, first and foremost — not a moonlighting energy specialist, economist, or urban planner. He was born and raised in Pontiac, Mich., best known as one of General Motors' major factory sites, and as the namesake for one of its most famed former brands. He bought his first car as a high school junior in the mid-1960s — a brand-new Volkswagen Beetle, for US$1,300 — and paid off the loan by working in his dad's diner.

Burns joined GM at age 18, under a program in which he studied for an engineering degree at General Motors Institute (now Kettering University) in Flint, Mich.; students alternated every six weeks between their studies and work at the company. His scholarship was sponsored by GM's research laboratory (the lab he later ran as head of R&D), and he went on to earn a master's degree in engineering and public policy from the University of Michigan and a Ph.D. in civil engineering from the University of California at Berkeley. During his 40-year career at GM, Burns played an increasingly central role in the company's many innovations and experiments in auto technology and design. He is currently a professor of engineering practice at the University of Michigan and director of the roundtable on sustainable mobility at Columbia University's Earth Institute.

His vision is explained at length, and richly illustrated, in *Reinventing the Automobile: Personal Urban Mobility for the 21st Century* (MIT Press, 2010), which he coauthored with Christopher Borroni-Bird (GM's director of advanced technology vehicle concepts) and the late William J. Mitchell (who was a professor of architecture and media arts and sciences at MIT and director of the Smart Cities research group at MIT's Media Lab). The future may or may not unfold exactly as the authors outlined, but they have made a significant contribution by connecting the dots among the technologies, trends, and ideas that enable a very different — and less energy intensive — future for the automobile. Burns spoke with *strategy+business* in May 2010 at Booz & Company's offices in New York City.

> **"Safety is perhaps the most important sustainability issue faced by automobiles. However, energy and the environment get more play."**

S+B: You've framed a holistic conception of what the future might look like for personal transportation in major metropolitan areas. What motivated you to develop this vision?

BURNS: The challenges that we face related to how we move around and interact are pretty formidable, whether it's concern about the environment, running out of oil, or national security issues related to our dependence on imported oil. These issues — what's been called the sustainability debate — get a lot of attention, and are tremendously important, but other issues that get less attention are also important.

One is congestion. As head of R&D at GM, I thought a lot about what might make the automobile obsolete. I became concerned about congestion and parking problems in cities, where half the world's population lives. What happens if owning an automobile is no longer attractive? In Manhattan, 70 percent of the people don't own a car. That's a pretty compelling threat to the automobile industry.

Another is safety. About 1.2 million people a year are dying on roadways worldwide; that's epidemic in scale. Roadway safety is perhaps the most important sustainability issue faced by automobiles. However, energy and the environment seem to get a lot more play. I have always found this troubling. Not to say energy and the environment aren't important. They are very important. However, 1.2 million is a very large number of drivers, passengers, pedestrians, and bicyclists dying on roads each year.

One of my major concerns lies right at the heart of the fundamental value premise of an automobile. I've studied automobiles for my whole career, and there's a reason that there are 850 million of them on the planet, with 250 million of them in the United States.

Although people are concerned about the negative side effects of automobiles, there's nothing like the freedom they provide to let us go where we want, when we want, with the people we want to travel with. And the automobile has been an enormous economic engine for growth, not just in the United States but in many other nations.

When people look at the sustainability debate, they often conclude we have to give up something; we have to trade off something. I believe that the word *and* is better than the word *or*. *Or* means there's a trade-off. *And* means there's a synergy that we're trying to leverage.

My coauthors, Bill Mitchell

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and Chris Borroni-Bird, and I wanted to get a book out there that was positive and optimistic — a compelling vision of what might be possible, given the technology that exists today, if we put it together in a new and innovative way. We feel this vision can take our freedom to move around and interact to a greater level, to allow more people to enjoy that freedom, and at the same time get rid of the negative side effects. We felt this book needed to be written, because so many people were looking at this debate through the lens of a single issue, and maybe a single technology, when in fact the convergence of the technology and the connecting of these dots are creating an opportunity to do things that are transformational. We also wanted to present a picture of a future that drives economic growth and job growth.

S+B: There is a lot of innovation going on in the auto industry now, and certainly an expectation of more change in the future, but what we've actually seen seems slow and incremental. How does that affect your vision of transformational change?

BURNS: The auto industry has had the same fundamental technological DNA for about 120 years: Companies manufacture driver-operated, stand-alone machines fueled by petroleum. There haven't really been any disruptive innovations in all that time — and that's true of very few industries. In most industries, major upheavals have unseated incumbents, and enormous innovation has helped new players become very successful. Think of the dramatic changes in industries like retailing or computers.

I don't think it's a lack of innovation. The main reason upheavals haven't happened is that the automobile transportation system benefited from a tremendous self-reinforcing dynamic: the codependence between the roadway infrastructure, the energy infrastructure, and the machines that we created.

As cars became available in the early 1900s, you needed to build roads suitable for them, and the costs of the roads were paid with gasoline taxes. That was a stroke of genius by somebody. As more cars were manufactured, more gasoline was consumed; the more gasoline was consumed, the more roads were built. The more roads were built, the more valuable a car became. And as cars became more valuable, it led to more cars being bought. That growth dynamic was an enormous enabler. Next thing, you wake up and in the United States you have 250 million cars, and they travel on 4 million miles of road, 3 trillion miles a year.

That's been wonderful because of the freedom it has provided, but the automobile transportation system has also created a lot of negative side effects, and they raise the question of sustainability. If the world isn't happy with these side effects — and it appears the world isn't — but the world still wants that freedom to move around and interact, which is important both for us as social people and for the economy in total, then something is going to have to change fundamentally.

So we thought about a new DNA for the automobile, but you couldn't create that just for the car itself. It has to operate within a new codependent system. How are you going to get the energy, and what are going to be the things that control the vehicle? We feel that the book makes two really transformational points: that vehicles in the future will be electrically driven, and that they will be connected via what we call the Mobility Internet. In fact, I believe connected vehicles, vehicles that talk with one another and communicate with everything along the roadway, will prove to be more transformational for the auto industry than different types of propulsion systems.

Cars That Don't Crash

S+B: You mentioned that safety was a major concern of yours. How did that influence your thinking, and how is it addressed by the future you envision for electrically driven and connected vehicles?

BURNS: It's central to the vision. Safety was something I had thought about since my student days studying mobility and transportation; throughout my career at GM, it was always in the back of my mind that someday we could build cars that didn't crash. Flocks of geese can fly in formations and not run into each other. Swarms of bees don't run into each other. If you watch pedestrians in metro stations or airport terminals, they can move around quickly, even when they're closely packed together. Without even consciously knowing what we're doing, we have a built-in algorithm that lets us know how to bob when the other person weaves, and somehow we don't run into each other either. Yet, for 120 years, the world has accepted the fact that cars will run into each other.

So, in 2003, I put a simple question to the research engineers at GM: If cars didn't crash, how would you design a car? And no one knew how to do it. They all went, "Oh my gosh, we haven't thought about that." And as they answered the question, it turns out that it changes a lot of things about how you would design a car.

The two biggest changes are the size, or mass, of the vehicle, and the way it's controlled or driven. A lot of the mass in a modern car is built in to protect an occupant in the rare instance that it crashes at a pretty high speed, and it is capable of very high speeds. You find that more mass begets more mass as you look at the physics of both mass and acceleration. But when we looked at where the world was heading, with the population moving increasingly to cities, and at the average speeds that cars travel in cities, it dawned on us that if we could design a car that didn't crash, it could be significantly smaller and lighter. It also dawned on us that we could design cars that could drive themselves.

By making cars that don't crash, you can take the mass from 3,000 or 4,000 pounds down to below 1,000 pounds. And if you're designing them for major cities where the average speed is less than 20 miles an hour, you can say that a top speed of 35 miles an hour may be sufficient.

Once you've determined that a car can weigh less than 1,000 pounds, that it needs to have a top speed of only 35 miles per hour, and that it doesn't crash, you start looking at how many parts and how much mass you can take out. And lo and behold, you find that lower mass begets lower mass. You find yourself chasing it down, and start thinking about the minimum machine that can meet the requirements of moving around and interacting in cities in a better way than we have today.

S+B: Other than safety, were there certain key developments and ideas that influenced your thinking?

BURNS: There were several developments that were transformational. One was the development of OnStar, GM's on-board telematics system that uses GPS. When it was first developed in the mid-1990s, we thought the main applications would be tracking the car if it were stolen, deploying the airbags and sending an emergency signal in the event of a crash, or unlocking the doors if you locked your keys in the car. The technology to include the kinds of navigation systems that are common now didn't exist. But as the technology evolved, it enabled the increasingly sophisticated GPS

The Xiao EN-V concept car

navigation systems that have become so enormously popular.

But the real insight was when we realized that once you have two vehicles with sophisticated GPS systems like that, you can determine their proximity to each other within 1 meter, and if you then share the data from their stability control systems, you can predict where each will be within the next 20 milliseconds. And once you can do that, you can program the cars' systems to prevent them from running into each other.

Another transformational moment was the DARPA [the Defense Advanced Research Projects Agency] Urban Challenge in 2007. It was a contest in which teams had to enter a driverless car that could complete a 60-mile course in less than six hours, obeying traffic rules and safely avoiding other traffic and obstacles, held at a military base in Southern California. We formed a team with Carnegie Mellon University, and we won the competition. Out of 85 vehicles entered, three others finished the race. That showed that you could design a car that could drive itself — and it was done without using GPS for navigation. Once you add GPS and the idea of the Mobility Internet, it becomes much less complicated.

Another series of insights came from the development work we were doing on new concept cars. In the late 1990s, I worked with Byron McCormick, who headed our fuel cell program but was also lead developer of GM's stability control system. He knew a lot about the four corners of the car — that little patch of traction, torque, steering, chassis dynamics, and braking where the rubber meets the road. He got me passionately interested in the idea of using software to control what's happening at that point of interface with the road, and what electric drive would enable in terms of changing the driving dynamics of the car.

"It dawned on us that if we could design a car that didn't crash, it could be significantly smaller and lighter."

At about the same time, Chris Borroni-Bird joined GM, and we teamed up to build a concept car called the Autonomy, based on drive-by-wire designs like those used on airplanes, controlling electric motors at the wheels. It had a skateboard-like chassis, with electric wheel motors powered by a fuel cell, with a body that docked onto it the way a laptop fits into a docking station. I had the honor of unveiling it at the 2002 North American International Auto Show, and there was a collective gasp from the audience. It was inspiring to realize that people were looking for something like that, and that no one had really visualized for the world what you might be able to do with a whole new design palette and what it could mean for the future of the automobile. In 2005 we built the Sequel, a car that embodied all those ideas, which we drove 350 miles from Rochester, N.Y., to New York City on a single tank of hydrogen.

In May 2010, GM, in partnership with Shanghai Automotive, began demonstrating three EN–V [electric networked vehicle] concept cars at the Shanghai Expo. These are two-wheel, two-person cars that use Segway stabilization technology and are powered by lithium-ion batteries. They are fully networked, are capable of autonomous driving, and have accident avoidance technology.

S+B: As you think about mass adoption of cars like these, are battery capacity and the ability of people to recharge the batteries a problem?

BURNS: No. The problem with batteries today isn't really the batteries themselves; the problem is the vehicle that we're putting them in. To power a typical car today, you need a battery the size of one or two Sumo wrestlers, and it takes eight hours to recharge, so you need charging stations in garages or on the street. For the 750-pound class of vehicles that we envision, the battery could someday become small enough so that you could easily bring it into your house or apartment to recharge, and it would recharge in just three hours.

The Market Tipping Point

S+B: What about the argument that by shifting emissions from tailpipes to the electric power grid, you are trading one set of problems — those associated with petroleum — for another, since 50 percent of electric power is currently produced by coal-fired power plants, which are the major source of greenhouse gases?

BURNS: Based on my analysis, in the U.S., for example, you can get all the energy you need for transportation purposes by producing electricity and hydrogen from three domestic sources: natural gas, biomass, and wind.

The energy challenges that the world faces aren't going to be solved by focusing on energy alone. To solve these challenges, we must focus more broadly on how people live their everyday lives and what they find desirable, along with how people and companies make money.

Until you change consumer behavior and get manufacturers and suppliers to align with a new set of alternatives, you're not going to solve the energy problem, because the solution requires such scale. The problem is embedded right in the fabric of the way the world works, and the world doesn't work around energy in isolation. Energy is an input to the economy.

The solution lies in reaching a market tipping point for vehicles that use energy differently and more efficiently. For this to happen, consumers must like the new solution better than what's been available to them in the past, and its value must exceed its price so that they will want to own one. In addition, the price must exceed the cost so that companies can make money by building it, along with the supporting infrastructure. It's very simple. That's where the tipping point will be. But to do this you have to deeply understand consumers, and a lot of people who weigh in on the energy debate — the ones who tend to jump to the conclusion, superficially, that improving battery technology alone or developing a new fuel is the key to the future — just do not understand consumers.

Inside the Xiao

S+B: Is there an alternative vision, in which cities invest massively in public transportation instead? Could it be that individual personal mobility was a 20th-century idea tied to the automobile, but it isn't suited to the 21st century?

BURNS: Part of the answer is what we discussed earlier — that ever since people could walk, the ability to move when they want and where they want is something people have found very compelling, and that's what drove the development of the automobile and its supporting infrastructures.

Three major impediments get in the way of public transportation. The first is routes. A public transportation system can't go everywhere, so people have to have a way to get to and from the stations. The second is schedules. You can't leave exactly when you want to, so you have to arrive before the public transit system arrives to pick you up, which has major impacts on how people schedule their lives. And unfortunately, those schedules aren't always predictable, so you have to buffer. The third is that since people have to shift modes from how they get to the station — whether it's in cars, on scooters, or on bicycles — to the public transport mode, you create a need for parking.

The Miao EN-V concept car

In the United States there's really only one place where the public transportation system overcomes all three impediments, and that's in Manhattan. In most other cities, the population densities are too low and the amount of subsidies needed to make it work are too high.

My coauthors and I thought about this, and compared what we're envisioning with public transportation. Think about the 750-pound vehicles that we're describing: If you put 32 of them in two rows of 16 side by side, they take up the same area footprint as a typical transit bus. As we did our research, we were intrigued by this fact, because it means you can move the same number of people with each approach. Then we said, "How much do 32 of these vehicles weigh?" They weigh less than the bus. And then we said, "How much do 32 of these vehicles cost?" They cost less than the bus. And when you look into the way these vehicles work in the traffic flow, you find that you can move more people through a tunnel, for example, faster and more efficiently than you can in a bus.

You could even look at these vehicles as a new form of mass transit. If you as a policymaker were going to buy enough buses to move everybody in your city, I would conclude you're going to spend more money and consume more energy and provide less mobility and convenience for your citizens than if you gave everyone one of these machines.

Testing the Concept

S+B: What are the steps to introduce these vehicles, test the concept, and convince consumers to buy them?

BURNS: When you look at an innovation of this type, you start by getting market foothold tests of the building blocks. Some of these, such as electric drive and vehicle telematics, as we discussed, are already pretty far along. And market foothold tests are already starting on different aspects of the Mobility Internet. Those will continue to evolve, and at some point it's a matter of hooking them together, either all in one step or in partial steps.

It's largely a matter of one place giving it a try, so that we can prove the concept. There could be opportunities to test it in restricted geographies, such as a college campus, a gated community, or an island. Another way it could come about would be in a nation like Singapore or China, where policymakers and private-sector leaders think differently about the relationship between public and private entities. One of the reasons the Prius became a success was in part how Toyota worked with the Japanese government to build the mechanisms and the supply base necessary to enable a technology to get out in front. Some people refer to that as industrial policy — and I know that can be an inflammatory phrase for some people in nations like the United States — but a nation that thinks differently may see the promise of systems like this and put together the implementation road maps to do something about it.

I'm not optimistic that this will happen first in the United States, and that concerns me, as an American, because the United States really drove the development of the Internet, and I believe that the impact of the Mobility Internet will be just as significant. There's no real barrier to entry for building the vehicles — it's like designing an appliance. But the Mobility Internet will be a different story. Think of the fortune that Microsoft made by creating the operating system that most of us use, and the business that Cisco built by creating the routers and the traffic management systems. Cities, regions, or countries will start building the infrastructure to allow this vision of the automobile to happen, and the companies that create that infrastructure will be enormously valuable some day.

You need to drive the innovation time line from invention, to laboratory proof of concept, to demonstration, and to first-, second-, and third-generation commercialization, so that you can get some experience and some data, and show people that this utopian vision is actually achievable.

S+B: If you and your coauthors had a perfectly free hand, what would you do to accelerate that time line and push the tipping point forward?

BURNS: I would demonstrate the integrated system in a controlled setting where there was policy support, and establish an "A-team" of companies and communities to work together to realize what's possible. I would fully engineer and build 5,000 to 10,000 small electric networked vehicles and create the foundation of the Mobility Internet. Then I would deploy what we developed in a few communities and learned from real consumers going about their everyday activities, and incorporate this insight into second- and third-generation system designs to be sure we have a mobility solution that consumers desire to own. I would continuously improve manufacturing processes and the overall operating system to reduce costs and enhance quality, and keep going until the system matures sufficiently to reach a tipping point.

I think you could do it in five years for less than $1 billion. You could have this demonstration going quite nicely somewhere at a scale that would allow you to learn, and that's what would be really important: measuring the impact on carbon footprints, energy consumption, travel times and their predictability, cost reductions, safety gains, and consumer satisfaction. Once you've provided those proof points — showing that this can work, showing that it's safe, and showing how inexpensive it would be — then consumers will demand it, and the market will take over.

Now, $1 billion is a lot of money, but it's not a lot of money given the issues we're trying to address. We need to find a way to take this to the next level. When we do, I think it will accelerate the implementation of the sustainable mobility solutions that I believe are within our grasp, and it will absolutely be transformational. +

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