



Consumer Products Innovation 2007

Tesla Motors has totally redesigned the car, significantly improving it, revolutionizing the user's experience

by Mark Duncan, askmar, www.askmar.com

The MIT/Stanford Venture Lab meeting on February 20, 2007 was on product innovation, the art of taking an existing product and significantly improving it. For tonight's meeting, the lead speaker was Martin Eberhard, the CEO and co-founder of Tesla Motors www.teslamotors.com who discussed their motivation.

Martin's motivation for a new company was that it help address global warming and reduce the dependency on foreign oil. Realizing that passenger cars account for 51% of the oil consumed for transportation, this seemed a good area to focus on. In evaluating alternative sources of energy, he noted that there are three useful criteria:

- What is the net resource consumption per mile?
- What is the net production of carbon per mile?
- What is the net reduction in energy consumption?

In examining fuel cells, the first problem is that they run on hydrogen, and there are not hydrogen mines. If you produce hydrogen by electrolysis, than when you ask how many miles do you get from one unit of electricity, you have an overall efficiency of 70% electrolysis x 90% to compress the hydrogen x 40% fuel cell = 25% overall efficiency. In contrast, an electric car will go 3X farther than a fuel cell car.¹

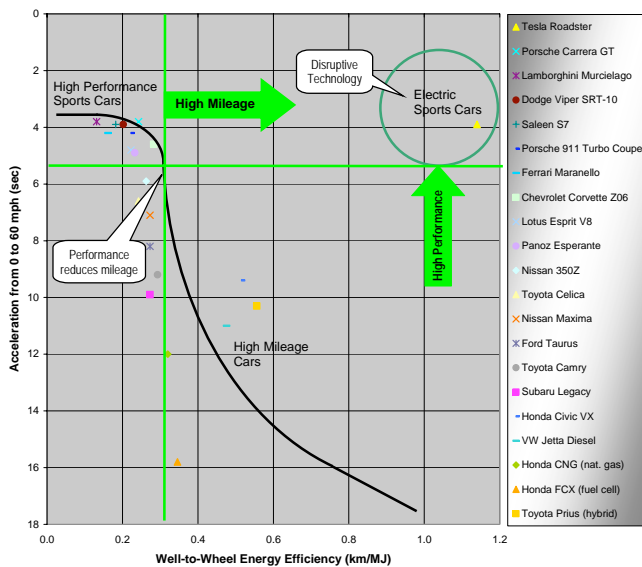
In examining biomass, you can use 1 ton of biomass to produce ethanol that will let you travel 2,900 miles. On the other hand, if you burn the biomass and generate electricity, you can travel 4,900 miles. Another way to think about this, is how many miles per acre? With biomass, you can get 20 tons per acre, that results in 58,000 miles. If you covered this same area with photovoltaic cells, you could travel 1,862,000 miles. You would have to plant the entire Midwest in corn to produce enough ethanol to provide the fuel needed for 50% of the vehicles in the United States. A much smaller area would be

needed for cellulose based ethanol, and a relatively microscopic amount for a photoelectric based solution.

A diesel engine provides about 38 miles per gallon, whereas a diesel electric generating plant can provide power that effectively enables 89 miles per gallon in an electric vehicle. For that matter, a home owner can install 2.8 KW of photovoltaic on their garage roof, it provides power to the electric grid during the times it is most needed, and the electric car is recharged at night when power is needed the least. In essence, the power grid acts as a large floating battery.

For an electric car to be successful, it must have wide appeal. Studies have shown that the average Toyota Prius owner has an income over \$100K, and the General Motors EV1 electric owners had incomes over \$200K. But it is not enough to have cool technology. Tesla Motors decided that its initial product would attempt to have the absolute best performance that could be achieved by an electric car. In a traditional car, there is a tradeoff between high performance acceleration and providing high mileage (well to wheel energy). With Tesla Motors, you can have both.

¹ The most efficient (52% to 61%) way to produce and compress large quantities of hydrogen is by reforming natural gas



The initial sports car has a 250 HP motor, a 200 kilowatt power supply, and a 55 kWh battery that operates at a nominal 375 volts. Initial production is Fall 2007. They have a motor plant in Taiwan, a battery assembly plant in Thailand, and the assembly of the cars will be done by Lotus in the United Kingdom. As of February 2007, they have sold 325 cars.

The critical factor is the batteries. Lithium ion batteries have 6X the volumetric energy density of lead-acid batteries. By using commodity lithium ion cells they are able to leverage the steadily decreasing costs of these batteries. However, there were many challenges of durability, safety, interconnects, monitoring voltage, temperature, and charge balancing that required implementing a computer network, with a node in each cell. The design is such that no single-cell failure, including a cell catching on fire, will propagate. As a result, the implementation has considerable redundancy, failures of single cells do not affect overall reliability. Liquid cooling insures that all 7,000 cells remain at 25 degrees Celsius, maximizing battery lifetime. *(The battery pack consists of 6,800 cells and has a mass of 450 kg)*

Tesla Motors next product will be a sports sedan called the White Star. It is targeted to have an end user price of under \$50K and be produced at the rate of over 10,000 cars per year. It will carry 4 to 5 adults, have a 250 mile range, have relatively low mass and drag, with effective mileage of 110 miles per gallon. It will be manufactured in Albuquerque, New Mexico beginning in 2009.

While the initial sports car uses a carbon fiber exterior, the sports sedan will have a metal exterior. The third model that will be produced in our roadmap will be priced at \$30K to \$40K. You get the cost per car down by investing in tooling, but the tooling is expensive.

How do hybrid cars compare to electric cars?

We think of hybrids in much the same way as fuel injection, it gives you an extra 15% improvement in mileage. While plug-in hybrids at first sight appear to be a solution, the problem is that the batteries that they use are the limiting factor. When you only can run for 40 miles per charge and you only get 500 charges, this means you have to replace the battery pack after 20,000 miles which is unacceptable.

Many dealers obtain 80% of their revenues from service. How do you deal with this?

At Tesla Motors, we want to have a very close relationship with the customer. We need to be able to sell directly to the customer. Today, the buyer often knows a lot more about the car than the salesperson. However, states like Texas have laws preventing the manufacturer from bypassing the dealer. This is why we are not selling in Texas. The automotive dealer network is a 50 year old concept. The cost structures that work for an internal combustion automobile are not appropriate for an electric vehicle.

We are not selling franchises. We do a lot of work with focus groups and customer studies, with the objective of having as good a customer experience as possible.

What is keeping General Motors from running all over you?

This is the Innovator's Dilemma². The companies that seemingly are best able to compete with you, would have to obsolete their current product line in order to compete.

We are on everyone's radar. Virtually every car company has come calling us.

Quite frankly, what Ford and other Detroit companies are doing, is not working. They should state that by 2010 or 2011, that 10% of their cars will be electric.

Why are you making your own powertrain?

Car companies consider this to core technology that they don't license. In any event, we can't make more than 2,000 cars in 2008, and we only plan to make 10,000 cars in 2009.

What will it take for you to become a leading car manufacturer?

We believe that by 2015 we will be able to offer an electric car with a 500 mile range.

Have you thought of racing Testa cars?

It is expensive and time consuming. But we don't have to do anything. We have enthusiasts at Tesla that are

² Clayton Christensen, "The Innovator's Dilemma", Harvard Business School Press, 1997. (See Appendix for summary).

investigating what is needed to do a stripped down Roadster.

Any thoughts on the Reva electric car?

The Reva was developed in Southern California, but when they realized they couldn't meet U.S. safety standards, they decided to go to India which has more lenient safety standards.

How do you retrain consumers as to the dangers of a silent vehicle?

While you can add fake engine noise, ultimately it is the responsibility of the driver to drive in a safe manner.

What other considerations are involved in batteries?

Currently we offer a 100,000 mile, 5 year warranty on batteries. In large part, this is because laptop batteries are only intended to last 5 years before the laptop is obsolete. However, when we start building 10,000 cars a year, each using 7,000 lithium ion batteries, we will be consuming 70 million batteries a year, which is more than Dell. This will give us tremendous buying power as well as leverage in obtaining features that will provide greater lifetime. Used lithium batteries have a substantial value to the recycling market, so they won't get thrown away.

Sling Media

Dave Mathews, director of product innovation at Sling Media <www.slingmedia.com> spoke briefly. He noted that the genesis of the company occurred two years ago, with the realization that implementing a video website required many very fat pipes in order to scale it. In contrast, by making an appliance that incorporated a Texas Instruments DSP and Windows Media Player, enabled each home to operate a peer to peer network, distributing the video bandwidth requirements.

At Slingbox, we have used industrial design to get attention, even when it was impractical!

We have people around the world working for us. We use Skype as our means of determining who is up and running, so we are aware of who we can ask questions.

What are you doing about HDTV?

You need 27 Mbps for HDTV. Today, you get 4 to 8 Mbps download speeds and 1.5 Mbps uplink rates, sufficient for T1 performance, but certainly not for realtime HDTV. There is some work by what was known at the Venice project to do a Bit Torrent video aggregation, but they have yet to enable this distributed network model yet. There are some copyright issues in doing this.

Any new developments?

As you may be aware, we hired the team at MTV that developed Overdrive³. We are trying to build an ecosystem for user generated content, enabling them to create a video in a few clicks, that can be pushed to the web, yet still give the proper credit to the network that originated the content.

Dash Navigation

Robert Acker, Senior Vice President of Marketing at Dash Navigation <www.dash.net> spoke about their Internet-connected automotive navigation system.

Consider the problem of trying to decide what roads are slow? Dash Media takes your local GPS data and combining it with two way communication, is able to tell you for three different routes, how long it will take for each route. They are now adding a new feature set layer, adding Yahoo local search to routes, to be able to tell you what interesting restaurants are on a given route, in case you want to stop to get a bite to eat due to the traffic delays.

If you don't get the usability of your device right initially, the consumer won't use it.

IDEO

Dave Blakely, director of technology strategy at IDEO <www.ideo.com> spoke about how they help companies innovate and design new products and services.

Everyone talks the walk, but many companies find it difficult to walk the talk, when it comes to defining good design. Good design requires reaching out and emphasizing with a diverse community in order to obtain the necessary inspiration. As an example of what not to do, we participated in Microsoft's Zune team, that sought to define the features necessary to compete with the Apple iPod. But we resigned after a week, when we realized that in the 19 person team, there were only 2 women and one black. Yes, the nature of the Valley is that it is male, engineering centric; but you get better results when you have diverse inputs.

What changes do we see happening in cars?

Small, flat panel displays are increasingly being used for maps, video, and to display car status information. Over the next three to four years, people are going to start to figure out how to get data to and from these screens, outside of the car. While heads up displays are starting to occur, the jury is still out on whether or not they are useful. For example, putting gear shifts on the steering wheel is not a generally useful feature.

³ MTV Overdrive is a broadband video channel that provides live performances, music videos, artist interviews, etc.

To what extent is sustainability becoming a design factor?

This is really a sea change occurring in our clients and customers. It has caused us to form a group at IDEO that crosses all units to address this.

Any overall design advice?

Often, doing a few things, very well, and simply, gives you tremendous advantage in the market. The iPod is the leading recent example of this.

A Sports Car with No Gas Tank

Bay Area firm says its electric roadster does 0-60 in 4 seconds — but it's not cheap

By Michael Taylor, San Francisco Chronicle Staff Writer, August 9, 2006

Rocket ship. Silent rocket ship. It's a black blur, streaking down a back road in San Carlos, cowing its muscle-bound, gas-gulping brethren.

This could be the future of electric cars.



For The Chronicle / Erin Lubin

Marc Tarpenning, co-founder and CFO of Tesla Motors, front, and Martin Eberhard, co-founder and CEO of Tesla Motors, rear, stand next to a Tesla Roadster electric sports car Tuesday. Chronicle photo by Erin Lubin

The car is a Tesla Roadster, and it looks remarkably like a Lotus — no surprise, because the Tesla is built on the Lotus assembly line in England. The surprise, though, is how much it is also like a small Ferrari and how utterly quiet it is.

We tend to associate sports cars with finely tuned, sexy exhaust-noise gasoline engines.

The Tesla is nothing like that. It is quiet and quick. The Tesla people say it will do zero to 60 mph in four seconds and will top out at 130 mph. And if its creators have their way, it will be a permanent niche in the eclectic and rarely successful field of electric-powered cars.

A handful of firms is out there, trying to build cars for this new, expensive niche. So far, it appears that Tesla is the closest to actually getting some cars on the road — the Silicon Valley firm says 40 well-heeled customers have paid \$100,000 each for a car, even though they won't get their new toys for at least a year. The buyers appear to be captivated by the fact that these electrics

are completely different from relatively stodgy electric vehicles of the past.

And, indeed, they are different from the current darlings of the environmental set, the Toyota Prius, Honda Civic and other like-minded hybrids. A hybrid is a combination of gasoline engine and electric motor. The Tesla is a pure electric and has no tailpipe emissions.

The other day, Tesla's vice president of marketing, Mike Harrigan, took a reporter for an exciting if brief ride in the industrial area of San Carlos that Tesla Motors calls home. It's a tight fit in this car, much like getting into a Lotus. And it goes like a Lotus, too, but without the noise.

"We're trying to build the concept that an electric car can be beautiful and can be fun to drive," Harrigan said, shifting the Tesla up from its first to second (and top) gear. The car and the firm were named for Serbian electrical engineer Nikola Tesla, who invented alternating current, among a few hundred other things. He died in 1943, half a century before the truncated age of modern electric vehicles.



For The Chronicle / Erin Lubin

Marc Tarpenning, co-founder and CFO of Tesla Motors, left, and Martin Eberhard, co-founder and CEO of Tesla Motors, right, stand next to a Tesla Roadster electric sports car Tuesday. Chronicle photo by Erin Lubin

The short and dismal modern history of electric cars can be roughly divided into three parts:

First came the home-built specials — shade-tree mechanics converted gasoline cars into anemic and ugly electrics that sort of ran but much of the time didn't.

Part Two was the costly effort by the big auto manufacturers in the 1990s to make cars that would adhere to the California Air Resources Board's dictum of zero emissions. The cars were made and, for the most part, were leased to consumers who, by most accounts, loved them.

But when the Air Resources Board weakened its zero emissions rule three years ago, the manufacturers just as quickly closed their tiny electric vehicle operations,

breathed a sigh of relief and lapsed into the comfort of their century-old internal combustion technology.

The third stage is what is starting to emerge now — tapping into the lucrative luxury sports car market with a car that will operate on a charge from household current (no \$3.50 a gallon premium gas) and won't require a multi-thousand-dollar periodic service.

Tesla was the brainchild of Silicon Valley entrepreneur Martin Eberhard and Marc Tarpenning, who co-founded the Rocket e-book firm.

"When you make a handheld electronic device," Eberhard said, "you're obsessed with the energy density of your batteries. I was also looking for my next car."

Eventually, he got in touch with Tom Gage, president of AC Propulsion, a San Dimas (Los Angeles County) firm that had already made the TZero, a brutally fast electric-powered sports car. AC had made only a few cars, and Eberhard says he invested in the company and drove its lithium ion-battery-powered car for about three months "as a daily driver."

"That convinced me that if you set about making a real production car," Eberhard said, "you could make a nice car, a great sports car and a very efficient car." Tesla eventually would use some of AC Propulsion's electronics under license.

Eberhard and Tarpenning wrote a business plan and set about raising money. The big windfall came in April 2004 when PayPal co-founder Elon Musk agreed to invest about \$30 million, half the \$60 million Tesla eventually raised to get itself into the bigger league world of making cars.

Fine. Got the money. Now what?

"We didn't have a lot of automotive experience," Eberhard said, "and so we were looking for a partner. Lotus was the best fit. They have a history of building cars for other companies." Eberhard likes to stress that the Tesla is "not a Lotus Elise," a \$43,000 gas-powered sports car, but concedes that the Tesla's "DNA comes from the Elise. We started with the technology of the Elise chassis and then re-architected it for our needs."

Eventually, Marketing Vice President Harrigan said, Tesla wants to sell 500 to 800 cars the first year and then ramp up to maybe 2,000 cars a year. Initially, Tesla says it will sell cars in five markets — Los Angeles, the San Francisco Bay Area, Chicago, New York and Miami. Harrigan says those five comprise 65 percent of the luxury sports car market. When it's time for service, a flat-bed truck will pick up a customer's car and take it to the shop, where it will have its tires rotated and its electric system checked out. No oil and filter change. No tune-up. No valve adjustment.

Down the road, Tesla plans a four-door electric-powered sedan that would sell for somewhere between \$50,000 and \$65,000. But Tesla isn't the only one out there pushing these costly electrics.

The king of the heap, pricewise, is the Venturi Fetish, a speedy little electric sports car handmade in Monaco and selling for more than \$600,000.

On a more reasonable front, firms in California and Washington state are developing a range of electric cars that they hope will cater to the burgeoning audience of people who are bored with their run-of-the-mill gas-powered Porsches and BMWs and will opt for something new and different.

Commuter Cars of Spokane, Wash., makes the Tango, something that looks like a four-wheeled motorcycle and was different enough to attract actor George Clooney as its first (and, so far, only) buyer. Commuter Cars Vice President Bryan Woodbury says the car will do zero to 60 in four seconds (like the Tesla) and, in the spirit of these exclusive wheels, costs about \$108,000.

"It's the new high-power electronics that is making this possible," Woodbury said of the immense power he and other manufacturers are seeing in modern electric vehicle machinery. "Now you have electric cars blowing away Dodge Vipers on the drag strip. Electric cars are expensive and fast, because of better motor controllers and better batteries. People just aren't interested in slow cars."

In California, Universal Electric Vehicles of Thousands Oaks (Ventura County) makes a convertible sports car (the Spyder) that it says will, like the others, be doing that zero to 60 dance in around four seconds, according to Vice President Gregory Lane and will be relatively cheap — under \$70,000.

"This is a niche market," Lane said. "We're not after the general public. We have a list of potential buyers, and we're talking production of about 155 Spyderys by the third year." Lane's wife, Diana, says the firm is trying to secure funding.

Phoenix Motorcars in Ojai figures its niche is SUVs and SUTs (sport utility truck), using bodies made in South Korea and electric motors built in Torrance. The vehicles will sell for about \$45,000 each.

Perhaps the most ambitious project in all these may be the one mounted by Ian Wright, a New Zealander who used to work for Tesla and now has his own shop in Burlingame and is raising money.

"I want to build an extreme performance electric sports car," Wright said the other day, "faster than any production car you can buy for less than \$1 million. This would be zero to 60 in three seconds."

Who's going to buy this \$120,000 car?

“Those who like the latest tech toy,” Wright said, “people who want to be seen.”

“People have no idea. Once people who like fast cars get to ride in one of these, they say, ‘Wow! This is cool. Faster than my Porsche. Faster than my Ferrari.’ “

Just remember to plug it in after that ride.

Tesla by the numbers:

Tesla Roadster: Zero to 60 mph in 4 seconds. Top speed, 130 mph.

Where it’s made: Assembled by Lotus Cars, Hethel, Norwich, England, on same production line as Lotus Elise and other Lotus cars. Electric motor made by Tesla Motors in Taiwan.

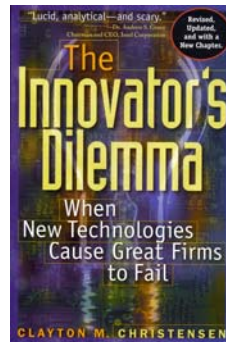
Range on a full charge: 250 miles on EPA highway cycle.

Charge time: With home charging, 220 volts, 3 1/2 hours for completely discharged battery.

Price: Base price, \$89,000; fully optioned (mobile charging, upgraded upholstery, removable hardtop, navigation system, additional cost for some colors), about \$100,000.

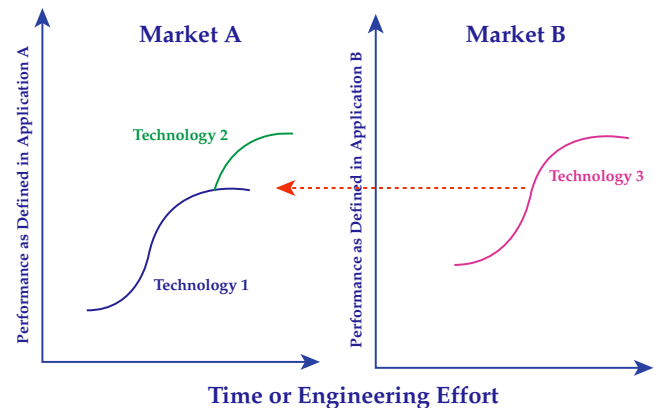
Sources: Tesla Motors

The Innovator’s Dilemma



Clayton Christensen is a professor at the Harvard Business School, who is the author of *The Innovator’s Dilemma* (1997), *The Innovator’s Solution* (2003) and *Seeing What’s Next* (2004). He observes that “Great firms can be undone by disruptors who analyze and exploit an incumbent’s strengths and motivations.”

A disruptive product’s first market is typically a non-consumer of the existing technology, a market segment not well served due to the existing product being too costly or large. Often this means focusing on the most commoditized, least-profitable portion of the market, and requires being sold through a different channel.



An example of a disruptive technology is flash memory. Although flash memory was more expensive per megabyte and could not be written on as many times as disk drives; they were well suited for use in digital cameras, cell phones, and modems, where disk drive were too large, fragile, and power hungry.

Flash memory has effectively eliminated low capacity disk drives from being competitive in size or cost for most applications.