Spearheading the EV revolution

Tesla's second major vehicle program is the Model S, a four-passenger battery-electric sedan target priced at $60,000. Production was originally planned for 2010, but capital shortfalls and wrangling with the state of California over a production site have delayed it until late 2011. Much of the car's initial-phase CAD and CAE work is being done by a dedicated Tesla engineering team located in Auburn Hills, MI.

JB Straubel

Tesla Motors' JB Straubel has built an engineering team that is challenging the traditional auto-engineering culture—and may be a blueprint for the future.

by ***Lindsay Brooke***

The words "tumultuous" and "auto industry" are synonymous these days, but it is not only the incumbent giants who are suffering. **Tesla Motors**, the fledgling Silicon Valley-based electric car maker, has seen more than its share of management upheaval, product and plant delays, expense slashing, layoffs, and government loan requests since the company's 2003 founding. No doubt Tesla's key investors are now quite aware that the century-old business of automaking is not as predictable as perhaps they once imagined.

But none of that detracts from the David-like role Tesla is playing. It has beaten the Goliaths to market with an attractive, high performance battery-electric car with acceptable (+200 mi/322 km) range. Despite a high price tag and low production volume, the Roadster already is considered a pioneer in the drive toward greater vehicle electrification. Next in the pipeline are a Tesla-designed lithium battery pack for **Daimler**'s 2010 **Smart** EV—part of the company's strategy to sell electric propulsion systems to other OEMs—and the svelte Model S sedan slated for MY2012.

The bold little start-up company has helped shift the technology frontiers in the automotive space. In the next decade and beyond, engineering and technology leadership "is really going to be in environmental and efficient transportation—solutions that address issues of CO_2 emissions, oil consumption, and energy security," said JB Straubel, Tesla's Chief Technology Officer.

"Wringing more and more horsepower out of a car was a leadership technology at one time, and it's still a difficult technical problem to solve. But I think it'll be less and less relevant," he said.

Energy storage is the defining technical challenge for mobility engineers going forward, Straubel believes. But the industry, along with **SAE International** and regulatory groups, has much work to do in establishing global standards and test criteria for batteries, particularly in critical areas such as abuse tolerance and safety.

"It feels a little bit like the Wild West right now, and that's not a joke," Straubel noted. "Technology stability is not yet in the EV and hybrid space."

Cost and product longevity are other major issues—both correlate to product design, he continues. "And how do you measure longevity, or quantify the [battery cell] degradation over time? What are the benchmarks for leadership? These are really important things Tesla and its competitors have to address, and we have to do it while we're developing and building vehicles."

A new breed of engineer

Straubel's own career illustrates how future auto engineers will likely be bringing diverse new personal interests, educational backgrounds, and work experiences into the transportation arena. As a kid growing up in Wisconsin, his father would take him on tours of electric power plants and substations, spurring JB's interest in electricity, energy conversion, and storage. But he also loved vehicles and when at age 14 he found a derelict electric golf cart in need of a rebuild, his passion for EVs ignited.

By the time he entered **Stanford University** as a physics major, Straubel knew he wanted to build a career involved with energy efficiency. Although the school did not offer a ma-

Lotus builds the Tesla Roadster as a 'glider' sans powertrain in the U.K. The car's electric propulsion system is installed at Tesla's Menlo Park, CA, facility. The car's success reportedly inspired General Motors Vice Chairman Bob Lutz to push for the Chevrolet Volt program.

jor in that field, the faculty was open to suggestions. So Straubel ultimately designed a new major called Energy Systems Engineering—a blend of electrical and mechanical engineering curricula, with a hefty dose of physics, chemistry, and basic science thrown in.

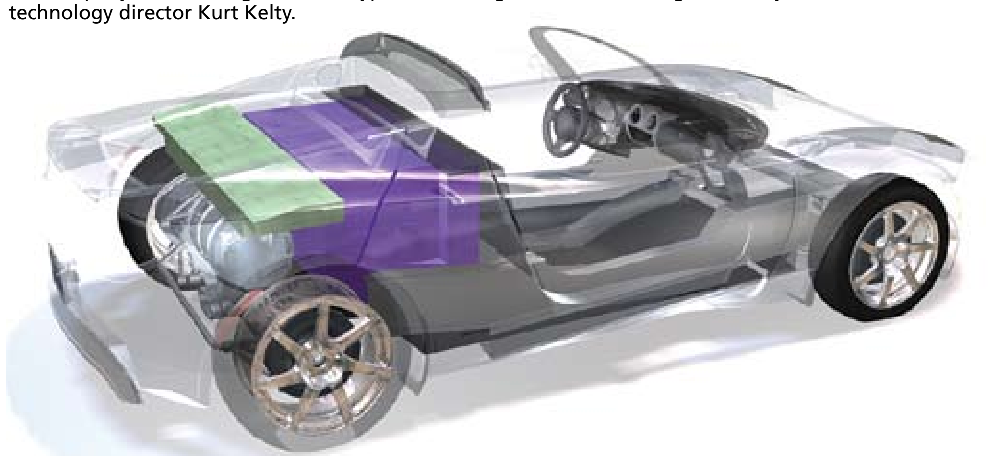
"It allowed me to take classes and invent this thing that I really loved," he recalled. The ESE major has since become one of Stanford's hottest undergrad programs. After graduating with a master's, Straubel joined **Rosen Motors** as a propulsion engineer developing a new hybrid-electric vehicle drivetrain based on a micro turbine and a high-speed flywheel. Later, he co-founded the aerospace firm **Volacom**, where he helped develop a high-altitude electric aircraft platform that was later licensed to **Boeing**.

He was also part of the early team at **Pentadyne**, where he designed and built a first-generation 150-kW power inverter, motor-generator controls, and magnetic bearing systems. Along the way, he converted a **Porsche** 944 to electric propulsion—the car set a world EV racing record. His other home-built designs include a custom electric bicycle and hybrid-electric trailer system.

Is Straubel's story a blueprint for future vehicle engineers? Judging from *AEI's* visit to Tesla's San Carlos, CA, engineering headquarters earlier this year, the answer would appear to be yes. The team arrayed throughout the large, open office space was by and large young, extremely bright, and probably had more electrons coursing through their veins than gasoline.

But interspersed among them are a number of traditional gearhead engineers and auto-industry veterans including Mike Donoughe (see sidebar), who are key to so much of Tesla's hardware development and vehicle integration activities. As one of them quipped, "You don't drive a dc inverter—you drive the vehicle."

By all independent road test accounts, the Roadster handles superbly despite its 35:65 front-rear weight bias due to the 950-lb (430-kg) battery pack's location. While the current production pack uses 6831 individual 18650-type lithium-ion battery cells, the company is evaluating other cell types and configurations, according to battery technology director Kurt Kelty.



Challenging the old school

Having built a multidisciplinary engineering team and successfully launched Tesla's first production vehicle, Straubel reflects on the many lessons he's learned thus far as CTO.

"The team that I run is more of the Silicon Valley culture—high energy and very creative," he said. "Sometimes we head down a lot of dead ends. It's not very process oriented. It's light on project management and heavy on creativity, and it has made me appreciate how different we are to the traditional automotive approach."

By comparison, Straubel considers traditional auto engineering groups to be heavy on project management—"they have high confidence that they can deliver on the schedule and dates. Everything is very deterministic on dollars and time," he said, adding that approach is much lighter on innovation. The leaps taken on each product cycle are often incremental.

"It's been fascinating to put those two cultures together," he noted. "Sometimes it's also frustrating as hell, but other times it's really invigorating blending the Silicon Valley culture I'm familiar with into the automotive culture of executing very large, complex projects—tons of vendors and moving parts, with requirements for high durability. We try to add a lot more innovation to that process without totally breaking it and making it impossible to control—not knowing when we'll be done and how much it will cost."

Straubel said Tesla has become much better at learning

From ‘old school’ Midwest to ‘new wave’ Left Coast

Q&A with Mike Donoughe,
Tesla’s Executive Vice President
of Manufacturing
and Engineering

In July 2008, Mike Donoughe said goodbye to 24 years at ***Chrysler*** *and joined* ***Tesla Motors****, where he is in charge of vehicle engineering, manufacturing operations, quality, and supply chain functions. He was previously head of Chrysler’s ‘Project D’ midsize vehicle program and earlier directed development of* ***Mercedes-Benz****’s M- and R-Class vehicles. When AEI caught up with him on the Tesla stand at the Detroit auto show last January, Donoughe pointed to his open shirt collar—“Look, I’ve forgotten how to tie a necktie!” he chuckled. “Evidence that I work in California.”*

Q: Are you enjoying the engineering experience at a much smaller OEM?

It’s fun. I have a wide range of responsibilities. JB [Straubel] and I complement each other well, as he’s fundamentally responsible for our powertrain technology, where a lot of our core IP resides, and activities associated with that. The atmosphere in our team is what I’d call a laid-back intensity.

Q: Tell us about Tesla’s ‘engineering culture.’

We’re relatively small so we have what I’ll call a loosely organized structure that morphs itself around what our high-priority needs are at any given time. We’re very flexible and adaptable to those changes. We’re very focused on speed, efficiency, and excellence—getting there fast but right. It’s very invigorating. And it’s a culture that encourages innovation.

Q: What’s the powertrain plan for the Model S?

The battery pack is different than the Roadster’s. It will be more of a ‘skateboard’ shape, underneath the length of the floor to just underneath the dash panel. It won’t be a structural element of the car because to tie it in would drive a whole lot more structure than we need. Underneath the rear seat will have a couple layers of battery and in front of the dash panel they’ll be a couple layers. The majority of the pack will run down the centerline, about 100 mm deep. A lot of Tesla’s existing motor, gearbox, and power electronics transfer quite nicely, but the Model S motor will be liquid cooled rather than air cooled. For the power electronics, we continue to evaluate opportunities to ride that technology curve down.

Q: Can we expect to see process innovation in the Model S’ manufacturing plant?

The short answer is, we’ll see. We’re not far enough along in the development yet. We’ll be relatively low volume, which gives us some flexibility. We’re modeling some manufacturing processes, constantly iterating them. We did some studies last summer on the body shop, paint shop, and final assembly layouts. We’re developing our processes using people from the auto industry and from diverse backgrounds, within what I call ‘the Silicon Valley perspective’ on how to do things. We’re creating a Kevlar-like ‘weave’ in our manufacturing culture.

Tesla will supply lithium-ion battery packs to Daimler for use in its next-generation Smart EV. The initial contract for 1000 packs could be expanded if demand warrants.

from the incumbent OEMs on how to execute a vehicle program overall. He also acknowledges that his company shed some of its early smugness when Tesla’s prototype two-speed gearbox for the Roadster failed constantly under test. The company sucked in its pride and reached out to **BorgWarner**, one of the industry’s oldest transmission vendors. The production single-speed BorgWarner gearbox has proved to be bulletproof.

The Tesla engineering model is still in its formative years, and without a century-old legacy creating institutional inertia there is still much to learn and change. Straubel is determined, however, that many aspects of the automotive engineering culture can and will be challenged by his team.

“There is room for innovation and doing things differently without actually breaking the requirements of having a durable product,” he asserted. “Those things tend not to get challenged as much as we do, and certainly not as much as I think they could be challenged inside of the existing companies.”

He claims that a number of the engineers he’s hired from the auto companies left their former employers in “huge frustration” because they worked within “firewalled little pockets of their organizations. They desperately wanted to do great work and apply it,” he said, “but there wasn’t a mechanism for them. Tesla’s been a unique haven for people who are interested in getting closer to the R&D and pushing the technology further and faster.”

And in terms of speed, few engineers at Tesla are running as fast as Straubel while managing so many responsibilities—he oversees all propulsion system design, engineering, and testing; evaluates new powertrain and vehicle technologies, and handles the technical interface with key vendors. He admits he could use a clone to help shorten his crushingly long work days. But he is there because he thoroughly enjoys the team.

“They’re the kind of people I’d enjoy working with no matter what the field,” he said. “I love the feeling that we’re pioneering an industry and being a thought leader. That was one of Tesla’s goals—to be a thought leader in electric transportation, influence public perception, and show what’s possible. And our product is something that makes me feel good about spending my time at this company.” ***aei***