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AUTOMOTIVE

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The forthcoming Tesla Model S, shown in the Alpha development stage.

Source: Tesla





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The 'little guys' get their chance

Two of the first three issues of **SAE's Vehicle Electrification®** series have focused on major mainstream automakers and their electric vehicle (EV) offerings—**General Motors** with its extended-range Volt and **Nissan** with the all-electric Leaf. In this fourth edition of *Vehicle Electrification*, start-up EV makers—the “little guys,” if you will—have the spotlight shined on them.

Within the past decade, countless companies with dreams of making it big in the Wild West landscape of vehicle electrification have sprung up across the U.S., and the world.

Founded “way back” in 2003 by a group of Silicon Valley engineers, **Tesla** can be regarded as one of the grandfathers of EV start-ups. It is perhaps the most well-known automaker devoted exclusively to the production of EVs and is probably closest to turning into one of the “big guys” itself. Its latest project—the Model S sedan—embodies the company's aspirations of becoming a volume maker, with plans to produce 20,000 units in the first year.

Tesla believes steadfastly that it can play on par with the likes of **Audi**, **BMW**, and **Mercedes-Benz**, benchmarking models from each of these storied German stalwarts

in developing the Model S. (Read the whole development story on [page 8](#).)

Other much smaller and lesser-known companies also are covered in this issue. Along with Tesla, which calls The Golden State home, North Carolina-based **Li-ion Motors** and Maryland-based **Genovation** prove that you don't have to be anywhere near the tradition-laden Motor City to possess the desire and determination to become a stakeholder in the auto industry's future.

Tradition does, however, play a big part in the development of Li-ion Motors' all-electric supercar, the Inizio. (See [page 18](#).) The company draws not only inspiration—but also employees, technology, and its overall “git 'r done” mentality—from the motorsports-rich area surrounding Charlotte.

As Li-ion's Paul Daigrepoint puts it, “Some of the big manufacturers have one engineer who focuses on just one little latch for a month at a time; I need my engineer to make that during lunch. But that's what we have to work with...”

Motorsports also is providing an outlet to demonstrate the promise of “dynamic” wireless charging of electric vehicles. U.K.-based **HaloIPT**

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and fellow start-up **Drayson Racing Technologies** have teamed to outfit racecars and a racetrack with inductive power transfer (IPT) technology, with the ultimate goal of enabling smaller battery packs and, therefore, lighter EVs down the road. (Click to [page 26](#) for more details.)

Without huge or even modest budgets, many start-ups rely on infusions of funds from private investors and/or government grants and loans to keep their projects alive. And collaborations with other enterprises, both within the automotive space and outside of it, can supplement what is in many cases a pas-

sionate-but-scant engineering staff. For example, in addition to working with **Tata Technologies** on its upcoming G2 EV, Genovation employed the help of aerospace company **American Dynamics Flight Systems** for CFD analysis. (Read full story on [page 31](#).)

Despite substantial obstacles—and far from any guarantees of success—start-ups keep plugging along, laboring on their varied vehicle and technology development projects. Because in the still-burgeoning world of vehicle electrification, these little guys do have a chance to thrive—and maybe even make it big.



Ryan B. Gehm
SAE Assistant Editor

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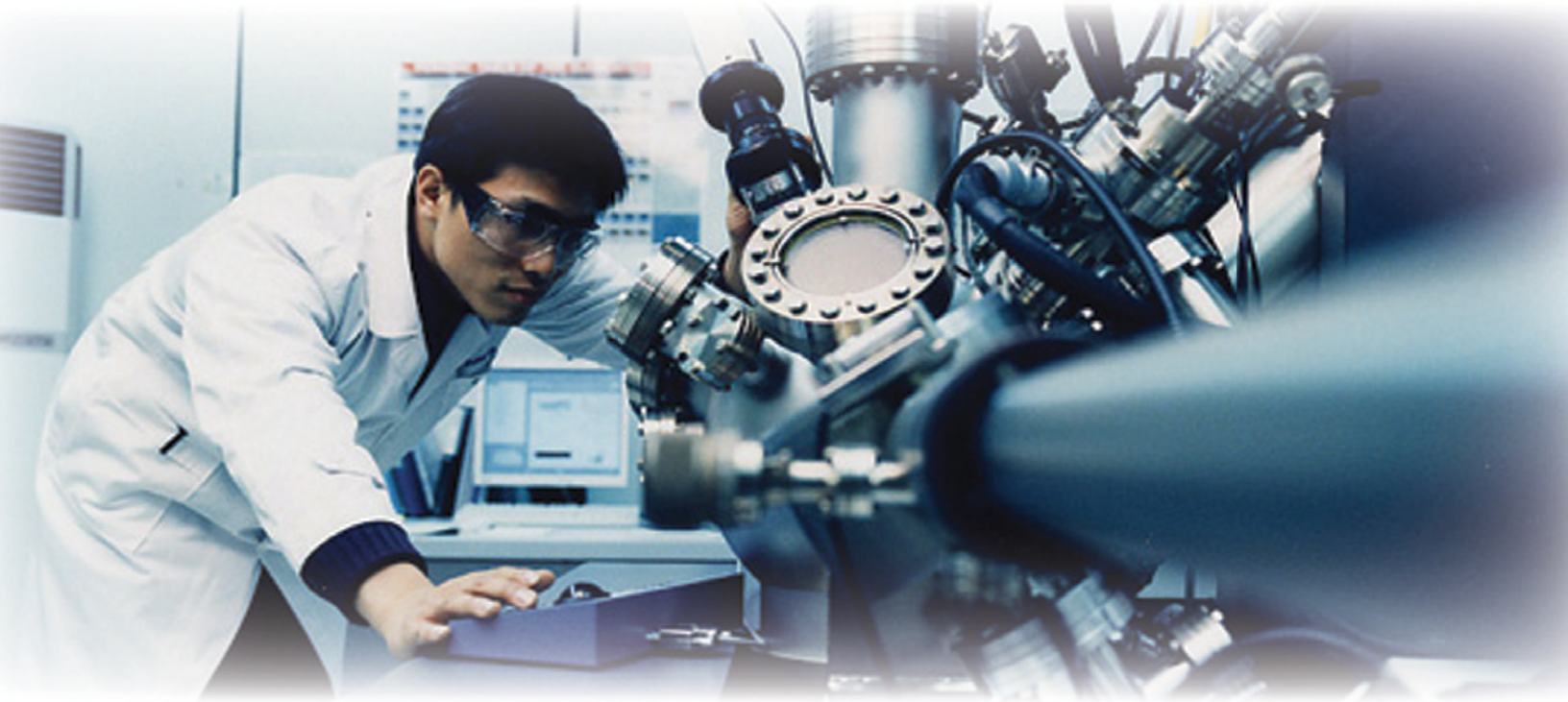
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Engineering Tesla's 2013 Model S

Tesla's Model S brings mighty high expectations when it debuts late next year as a 2013 model. The development team benchmarked the Audi A8, BMW 5 Series, Mercedes S550, and Porsche Panamera. Model S development is currently in the Beta-build phase.

The world's first near-luxury BEV abounds with innovation, promises serious performance—and makes the issue of range an option.

by Lindsay Brooke

For **Tesla Motors**, this is the big one. The Model S sedan, scheduled to enter production late next year in Fremont, CA, as a 2013 model, carries all the company's aspirations on its svelte, aluminum-intensive body. It's more than a single nameplate—Model S is the first use of a new Tesla vehicle architecture from which multiple vehicles will come, company executives say.

But just getting to its current Beta-build stage of development, let alone to the first-year volume projections of 20,000 units, has been a saga more akin to the old-school Detroit industry than the shining Silicon Valley model that was supposed to bury it.

Controversies, hype, lawsuits, and executive dismissals aside, however, this is a tenacious company. Tesla is well stocked with engineering talent, well capitalized through a 2009 initial public stock offering, fortified by product-development relationships with **Toyota**, **Daimler**, and **Panasonic**, and bolstered with a \$465 million loan from the **U.S. Department of Energy**. Competitors are advised not to dismiss company founder and CEO Elon Musk's promise to deliver the world's first premium sedan offering zero tailpipe emissions offering **BMW**-beating dynamic performance and a host of innovative technologies, at a relatively affordable base price (\$49,500 after the \$7500 federal tax rebate).

A clean-sheet, holistic, and collaborative approach to vehicle development enabled teams led by Chief Designer Franz von Holzenhausen and Vice President of Engineering Peter Rawlinson to create an electric sports sedan capable of carrying seven passengers—there are two cleverly packaged, side-facing rear child seats—in considerable comfort at speeds up to 130 mph (209 km/h). Zero to 60 mph (97 km/h) accelera-



Previous top engineering positions at Jaguar, Lotus, and GKN prepared Peter Rawlinson, Tesla's Vice President of Engineering, for the Model S program's challenges.
(Lindsay Brooke)

tion is in 5.6 s. The rear cargo trunk has front and rear sections totaling 30 ft³ (850 L) of capacity.

The cabin is remarkably roomy; Tesla's marketers claim Model S can accommodate a 50-in TV, a mountain bike, and a surfboard simultaneously. If true, such efficient packaging is enabled by the flat floorpan that incorporates one of Model S's major innovations—a 4-in-deep (102-mm) aluminum carrier spanning most of the car's underbody.

The torque-box-like structure houses between 6800 and 8000 lithium-ion batteries (depending on range configuration), serves as a coolant manifold for the liquid-cooled battery pack and ac induction traction motor, and plays a significant role in the body's structural rigidity and side-impact performance. Tesla engineers have not yet revealed details of the Model S's battery, but it

Engineering Tesla's 2013 Model S



Alpha prototype #2 was displayed at the 2011 Detroit Auto Show. The complete body-in-white including closures weighs 300 kg (661 lb). Tesla is evaluating future structures in high-strength steel, according to Rawlinson. (Lindsay Brooke)

is expected to feature commodity-type cylindrical cells that are chemically superior to the 18650-form laptop batteries used in the company's Roadster. Analysts familiar with Tesla's sourcing strategies expect Panasonic to supply the production cells.

Another unique design element on Model S is the choice of three range options, based on individual cell capacity and the number of cells. According to Assistant Chief Engineer Nick Sampson, who like Rawlinson came to Tesla from **Jaguar**, the propulsion system is designed to provide up to 90 kW·h total energy capacity—about three times that of the **Nissan Leaf**.

The base vehicle's 42-kW·h storage system is designed for up to 160 mi (257 km) per full 5-h charge, using the 6800-cell pack. Buyers can upgrade to the 90-kW·h system capable of 300 mi (483 km) per charge with an 8000-cell pack. That option raises the Model S's price to \$77,400. Between them there's a 70-kW·h (230-mi/370-km) option that costs \$67,500. Range is enhanced by excellent (.28 CdA) aerodynamics.

Depending on the charging source, the time needed to charge Model S's battery will run from 45 min (to an 80% state of charge using high voltage) to nearly 20 h using a 120-V household outlet.

Putting a V6 in the Model S

Most OEMs would love to build a product-development system from scratch, with their engineers unburdened by legacy CAD, CAE, and related processes. SAE *Vehicle Electrification*® spoke with **Tesla's** Engineering Tools Manager, Paul Lomangino, about building his company's virtual-engineering environment.

Q: You joined Tesla in 2006. What direction was the company's product development enterprise taking at that time?

Paul: We were using a variety of CAD systems—SolidWorks, ProEngineer, CATIA V4 and V5, and some NX. In an ideal world it would be great if everybody could use the tool they wanted. We had some serious fights in standardizing on a single tool. CAD is like religion. But after much discussion and the proper investments, our direction—**Dassault Systèmes'** CATIA V5 transitioning to the new V6—is working well for us.

Q: How is Tesla managing the single-platform strategy regarding your supply base?

Paul: It's an evolutionary process. Going forward on Model S we're requiring that our suppliers use CATIA. However, we've had to work with many of our legacy suppliers, some of whom still use drawings and for whom working with 3-D models has been the next step in their progression.

Q: Tesla is migrating to DS's Enovia V6 as its PLM platform. How is that process coming?

Paul: We've uncovered a few snags, naturally. But a key attribute of V6 is it's been very quick to tailor to our needs. I won't call it customization, which is actually writing codes. The V6 is very flexible, which is great because we don't want to devote excess resources to process or tools. Our total PLM team including CAD support, which includes me, is just four people!

Q: Do the Model S guys like V6?

Paul: Yes. They were familiar with the incumbent tool, and obviously there are a lot of things we're still learning about V6. We're integrating CATIA V5 into V6 using a tool called Designer Central. We'd been using V5 with SmartTeam [a software integration tool]. It was a great tool for us out of the box, and we're managing expectations as we transition from SmartTeam to Enovia V6.



Engineering Tools Manager Paul Lomangino is a veteran of Silicon Valley's microelectronics industry and Ford's advanced CAD/CAE group.
(Lindsay Brooke)

Q: Where do you see Tesla headed regarding CAE?

Paul: We still have a fairly diverse CAE landscape, using tools many of our guys brought over from their prior experiences. We're looking at what will be available in the V6 platform for CAE for our future. Our adoption of a broad V6 solution will be more "vanilla, out-of-the-box" than a heavily customized environment.

Q: What about virtual manufacturing tools?

Paul: We've adopted DS's Delmia for body-in-white and assembly process planning. It's already delivered huge benefits. We'd been doing assembly simulations in CATIA, and we learned a lot from that. But there's so much more richness in the Delmia tool set, particularly in developing the manufacturing bill of material. But we're not there yet with it.

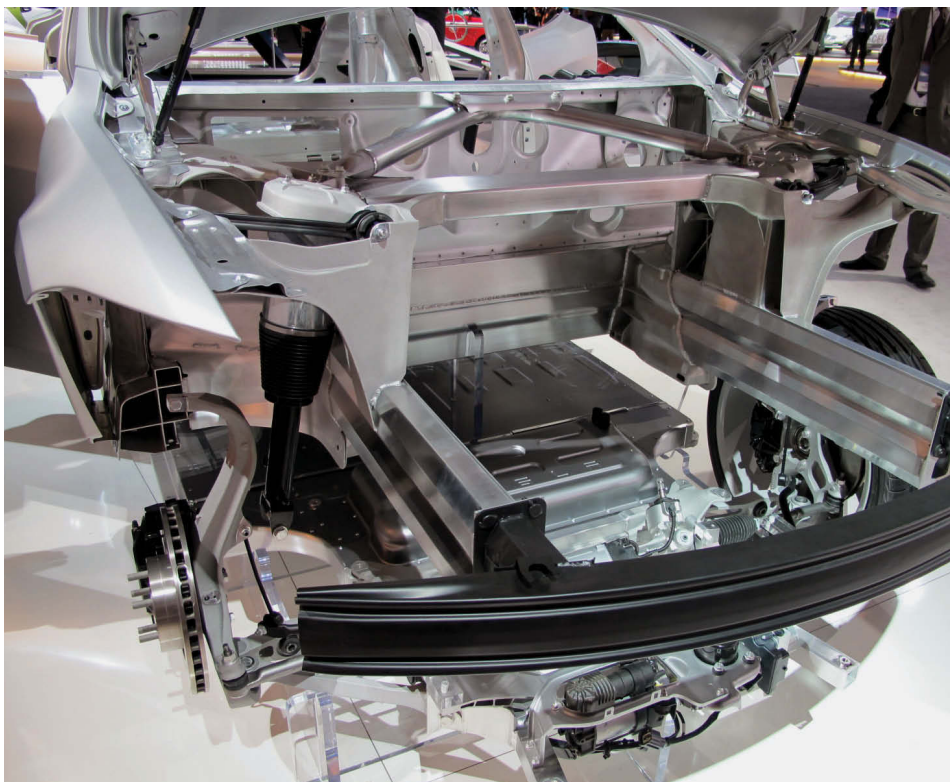
Q: As Tesla progresses in CAD and PLM, what is your team learning?

Paul: The traditional engineering practice that I and others were used to was very sequential. At Tesla we try to do as much as possible in parallel. It requires a huge amount of effort, but it's the only way to get things done very quickly.

We've learned that making scalable architectures, and the tools to go with them, really does pay off later on, in not having to repeat effort. As a start-up, we've realized that sometimes it's beneficial to have a little bit of ignorance. Learning some of the hard lessons on our own gives us an attitude to do it better.

And, a corporate lesson learned is that making cars is a damned hard thing to do!

Lindsay Brooke



The car's front structure is one of Rawlinson's proudest achievements at Tesla. Note combination of cast nodes, extrusions, and stampings. The semi-permanent-mold strut tower castings from Hydro Aluminum will change to high-pressure die castings in production.
(Lindsay Brooke)

What von Holzhausen calls “the centerpiece of the interior” is a 17-in touch-screen-based, fully configurable infotainment system that features a haptic interface and 4G wireless connectivity. The system serves as the central human-machine interface for all HVAC controls and internet browsing. While engineers report some development issues integrating the system, it is expected to be one of the Model S's main customer lures.

Approximate Model S dimensions are as follows:

- Overall length: 16 ft, 4 in (4978 mm)
- Overall height: 4 ft, 8 in (1422 mm)
- Overall width (with mirrors): 7 ft, 2 in (2184 mm)
- Ground clearance: 4.46 in (113 mm).

A simultaneous engineering crusade

Going from a 20-unit Alpha prototype fleet build to start of production in the 30 months promised by Musk has put Model S in the

crosshairs of skeptics. But Rawlinson is confident his team will execute to levels expected of the establishment, not a brash start-up.

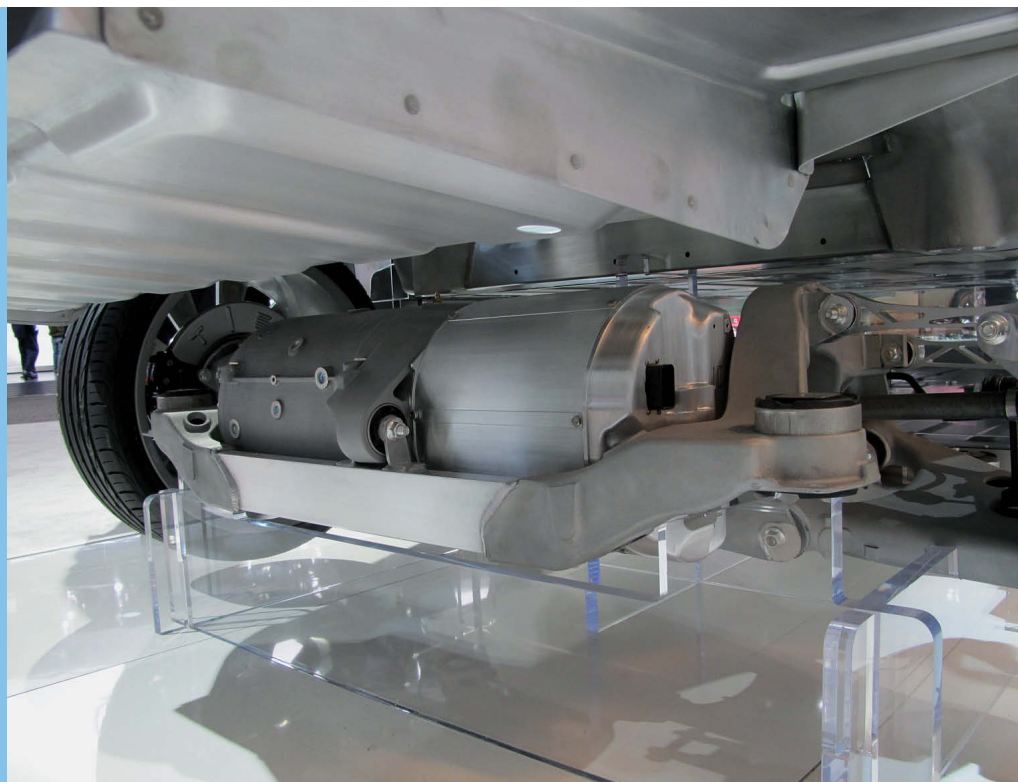
“This is the ‘big boy’ for me; everything else has been rehearsing,” he told SAE *Vehicle Electrification*®. “I’m the orchestra conductor, but I’ve got many great instrumentalists with me.”

Rawlinson's pre-Tesla experience includes Jaguar (where he was Principal Engineer), **Lotus** (Chief of Advanced Engineering), **GKN** (Manager of Advanced Drivetrain and Suspension Systems), and consultancy **Corus Automotive**, where he led development of **Think**'s EV platform executed with five engineers in six months.

He describes putting the Model S engineering team together as “a multidimensional challenge. We had to design an all-new electric vehicle platform and establish a clear methodology” for which he and Musk had a clear vision, but for which some of the team (a mix of auto-industry veterans, for-

Model S's rear subframe is comprised of large aluminum castings to support the liquid-cooled traction motor and incorporate suspension hard points.

(Lindsay Brooke)



mer Silicon Valley EEs, and various newcomers) had no experience. “We established a rather unorthodox methodology, a cornerstone of which is a completely free flow of information in a simultaneous engineering environment. It’s incredibly non-hierarchical,” he explained.

During Model S development Tesla also moved the majority of its vehicle engineering team from a shared San Carlos building, where engineers parked their bicycles along the office walls (many of them don’t commute in cars), to a dedicated facility in Palo Alto where much of the company’s product-development operations are now consolidated.

“Co-location comes to Tesla!” observed Engineering Tools Manager Paul Lomangino. The new complex includes battery and e-motor manufacturing—but bicycles aren’t permitted inside the offices. Another benefit is Tesla’s size. Being a small organization compared with even the smallest of the incumbent OEMs helps get the entire engi-

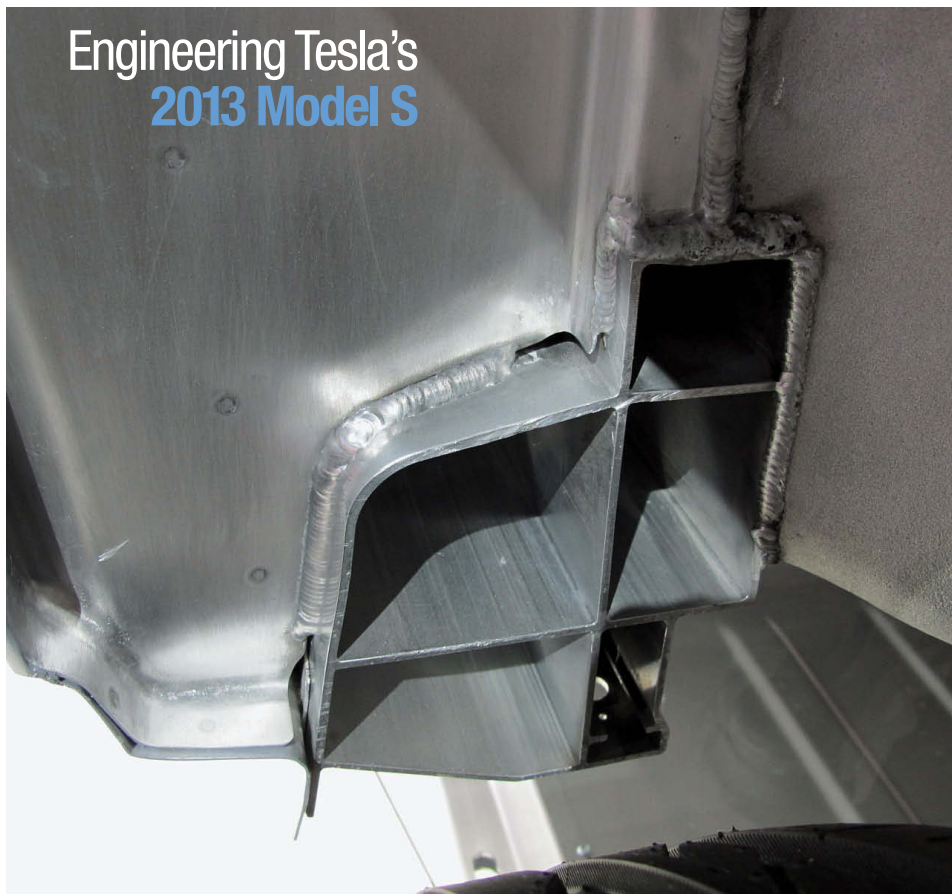
neering team focused keenly on the product.

Rawlinson describes the early, pre-Alpha development as “a very rapid process of 3-D packaging, determining the big picture, and getting the fundamentals right. Not getting too detailed, just making sure everything’s right because package is king,” he recalled. “The fidelity of the CAD models and the CAE models is essential, and thus far are displaying close correlation to our testing. And this is where I think other car companies run into problems.” (See sidebar.)

Structure enhances electrification

Lightweight vehicle structures are a “gift” in the EV world, Rawlinson said. To develop the Model S’s unibody, Tesla purchased a formidable competitive fleet of the world’s best car bodies for benchmarking—**Audi A8**, **BMW 525**, **Mercedes S550**, and **Porsche Panamera**. Like the Audi, the Model S’s unibody is based primarily on aluminum stampings and extrusions joined with eight cast-

Engineering Tesla's 2013 Model S



Model S's side sills serve as torque boxes surrounding the passenger cell. The multiple-channel extrusions are from Hydro Aluminum.

(Lindsay Brooke)

aluminum connecting nodes using welds, rivets, and structural adhesive depending on the location. The body-in-white is in 6081- and 6082-series alloy; the exterior panels are 6000-series T4, which tempers to T6 during bake-hardening. According to Chief Body Engineer Rick Haas, Tesla is evaluating 5000-series material.

The husky castings are sourced from **Hydro Aluminum**. "They really stepped up to this project," said Haas, who spent 28 years in **Ford's** body engineering group. He said the semi-permanent mold castings used on the prototypes will change to high-pressure die castings for production. Hydro Aluminum also supplies the car's multichannel sill extrusions that surround the battery box and contribute to side-impact performance and the vehicle's low mass.

A cast-aluminum crossmember supports the front suspension. Another cast-aluminum

subframe that is rubber-mounted to the rear body structure at four locations carries another one of Model S's masterpieces: the traction motor, power inverter, and single-speed transaxle integrated into a single, cylindrically shaped module.

Switching the e-motor's polarity changes the forward gear to reverse gear. Initial production will be rear-drive, but engineers said an all-wheel-drive powertrain is being investigated.

Regarding suspension, the front uses lower control arms, while the multilink rear setup features air-assisted springs. Steering is by electrically assisted rack-and-pinion, which mounts rigidly to the body.

Model S's claimed curb weight is 3825 lb (1735 kg), which includes the 1200-lb (544-kg) battery pack. The complete BIW including closures weighs 661 lb (300 kg), according to Haas. Steel also plays a key role in the cross-



Chief Body Engineer Rick Haas decided to do the panoramic roof engineering and tooling for Model S in-house vs. outsourcing to a Tier 1. It saved 50% in variable cost and reduced the roof structure cross-section by 44 mm (1.7 in). (Lindsay Brooke)

car beam, as well as hot-stamped boron reinforcements in the B-pillars and bumpers.

Despite the major commitment to aluminum, the planners were conscious of cost in many areas. Aerospace composites were nixed almost from the start. Friction-stir welding was considered for the body pan/battery box but rejected as too costly. And Rawlinson revealed that Tesla is investigating an entire high-strength steel body-in-white. Critics, including engineers involved with **Chrysler's** Prowler program in the 1990s, note that Model S won't be inexpensive to insure, or repair.

Might Audi be the Model S's architectural and materials influence? "In terms of the technology, yes," Rawlinson said. "But in terms of the structural concept, the load paths are diametrically different. Because we've got a battery pack that fits under the floor that's a structural element and needs to crash, we couldn't have our load paths under the floor.

"One of the greatest engineering challenges for Model S was to ensure the edge of the safety cell is sufficiently strong and rigid to support the crumple zone," he noted. "So we came up with a series of architectural innovations which make the battery pack structural."

He said body structure and battery pack architecture were developed "interactively." Enabling the synergy was the geometric relationship between the battery cell arrangements within the pack. The 7000-odd cells are stacked in parallel to increase the current and stacked in series to increase the voltage in what Rawlinson calls "a natural geometry."

"One of the great breakthroughs with Model S was being able to reconcile and integrate the geometric constraints of those packs of cells, series and parallel, within the [vehicle] structural architecture," he explained.

When it came time to engineer and tool Model S's panoramic roof module, Haas ultimately decided to do it in-house, rather than outsource to a roof-systems Tier 1. The small team chose to relocate the actuator motors from their traditional space between the roof panels. This allowed them to reduce the roof cross-section by 44 mm (1.7 in) and slash variable cost by 50% compared with outsourcing.

Engineering Tesla's 2013 Model S



An Alpha-build Model S on test. The aluminum-intensive body's exterior panels are in 6000-series T4, which tempers to T6 during bake-hardening. The rest of the structure's stampings are 6081- and 6082-series material.

"Even areas where we have suppliers, we do the concept engineering ourselves," he said.

Haas said in the preliminary CAE the Model S's body structure displays 57 Hz in bending, 42 Hz in torsion, including the battery pack and fixed glazing. Overall body frequency is 58 Hz. Tesla will do most aluminum stamping in-house, having purchased and relocated an ex-**Tower Automotive** stamping plant from suburban Detroit to the ex-**NUMMI** plant in Fremont. Tesla will also do some injection molding in-house.

Toward homologation vehicles

The result of Tesla's effort won't be evident for another 12 months, and as *Vehicle Electrification* readers know the most innovative designs in the world's first premium battery-electric sedan are worth little if the final product isn't perfectly executed.

"We're getting exceptional feedback from our test drivers; most of what our analyses predicted is bearing out," Rawlinson reported. "Beyond the Alphas, our next step is the Beta program which will have even greater fidelity. Then when we have parts for production tooling we'll build our homologation fleet." **E**



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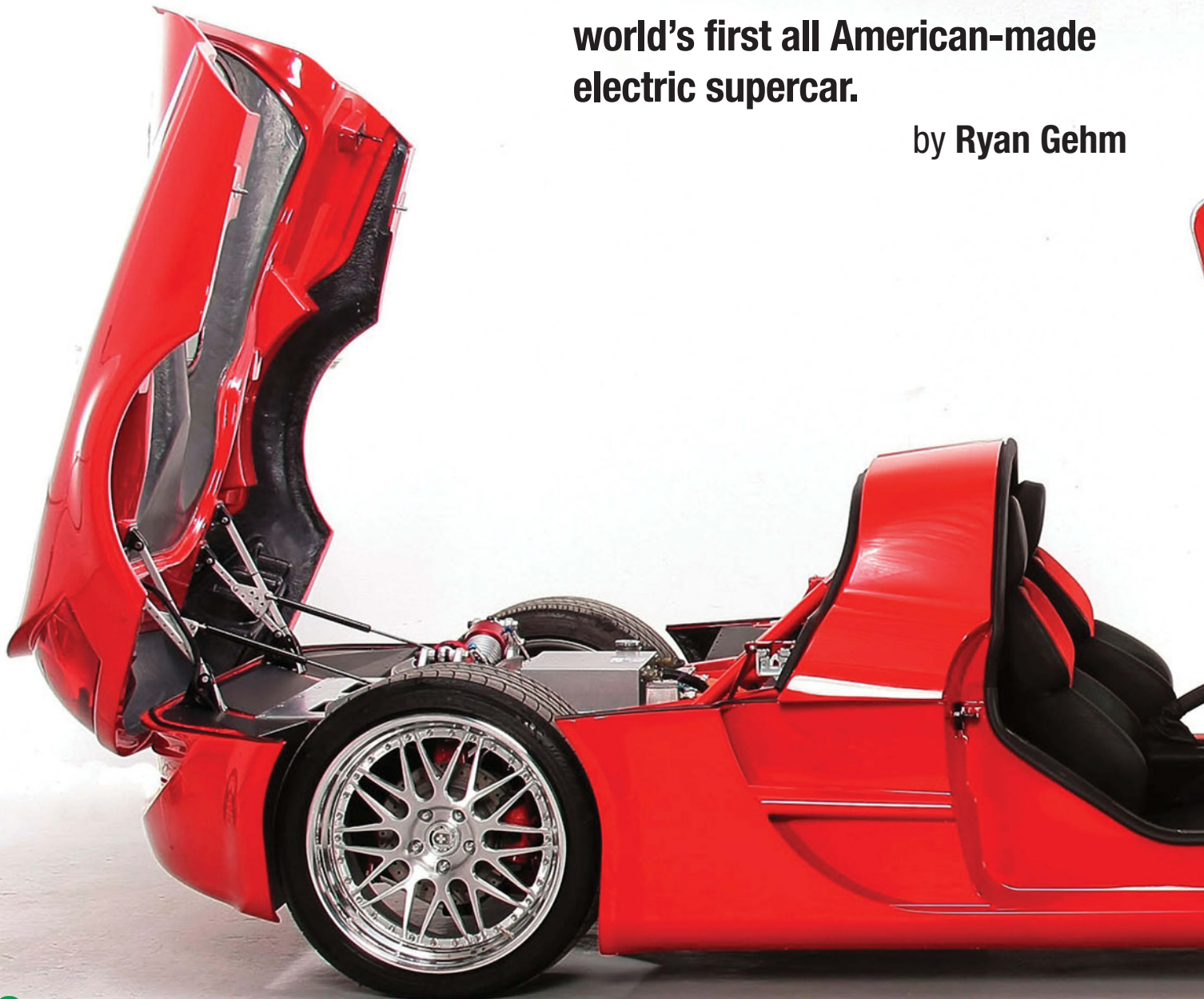


Valued Quality. Delivered.

One souped-up EV

North Carolina-based Li-ion Motors draws upon the region's motorsports heritage to engineer and build what it calls the world's first all American-made electric supercar.

by Ryan Gehm



North Carolina is **NASCAR** country—and, apparently, high-performance electric vehicle (EV) country, too.

In Mooresville, NC, a mere 30-min drive north from Charlotte on I-77, **Li-ion Motors'** scant but spirited team of designers and engineers has channeled the region's racing roots to create an all-electric, two-seater supercar that can accelerate from 0 to 60 mph (0 to 97 km/h) in 3.4 s and boasts a top speed of 170 mph (274 km/h).

"Absolutely," declared a company executive, commenting on whether there is a deep pool of talent in the area from which to draw, "as far as getting talent in here, and also just having a creative pool with dialogue that's ongoing because you have a mixture of people who build cars that go 200 mph for 4 hours [straight] on a regular basis.

"Charlotte to Mooresville is the center for stock car racing in the country, in the world. And we have the best fabricators, the best body builders anywhere," he asserted.

About two and a half years ago, Li-ion Motors hired one of those talented fabricators—and, suitably, racecar drivers—to oversee development of the Inizio electric supercar, which at the time was already "fairly well on the concept table," Paul Daigrepoint recalled.

"I've been pretty much in racing most of my life," Daigrepoint shared. "I owned a little company down in Louisiana until [hurricane] Katrina hit, building racecars, mostly drag racing." In 1999, he raced an **NMCA** (National Muscle Car Association) Pro Street Car and finished number two in the world championship.

Later he built chassis and suspension components for a NASCAR team, before moving on to **Dale Earnhardt Inc.** (DEI) for a couple of years to run the chassis plate, building the so-called "Car of Tomorrow" chassis for drivers such as Dale Earnhardt Jr. and Paul Menard.

"Then I ran into these guys [at Li-ion Motors] and it was a whole different world. I kind of fell into this as a custom fabricator and have been moving up ever since. It's been a fun thing, and now



One souped-up EV

driving this,” Daigrepoint said, nodding to the candy-red supercar with its doors and hoods pointing skyward.

“It’s a 114-in wheelbase, 78-in wide footprint, which will tell you that inherently the car handles like a **Formula One**-type car. And the way our frames are built, you can see there’s a lot of race inspiration in it,” he continued. “If you open the back door of our facility, there’s **Jack Roush Racing**, and right next door is **Team Red Bull**. There’s a good bit of experience in that area, and a lot of suppliers for race-type parts, so that’s beneficial to what we do, too.”

The nuts and ‘volts’ of Inizio

The Inizio development project, from its onset, aimed to showcase the performance potential of EVs—to illustrate that they are “not necessarily little putt-putt-around golf carts,” as Joe Berardi, Engineering Manager for Inizio, plainly put it.

The first prototype was unveiled at the **SEMA** Show in November 2010, followed by a tour of other major auto shows, including Los Angeles, Detroit, and D.C., to gauge consumer interest.

“We’ve held true to our concept of building a high-performance road car that has European flair. That’s why when most people look at it they can’t believe it was built ground-up here in North Carolina,” Berardi said.

Many of Inizio’s components and most of its systems are proprietary to Li-ion Motors, from the battery management system (BMS) and transmission to the suspension and



body, including the molds—a remarkable feat, really, considering the size of the staff.

In all, Li-ion Motors employs 23 people, 19 of which are “techies”—engineers, designers, chemists, fabricators, and the such. They work not only on the Inizio but also its decidedly non-supercar, X Prize-winning sibling, the Wave II (see sidebar).

Power for Inizio is provided by Li-ion’s patent-pending lithium-ion polymer batteries and management system, which generate more than 40 kW (an upgrade to 97 kW is available), and its **UQM** electric motor that delivers 175 kW in the R and RT models. For the RTX (Rally Touring Extreme), two 290-kW UQM motors are standard, offering output nearly equivalent to that of a NASCAR Cup Car, appropriately enough.

“The advantage of electric motors is that they can be run very comfortably at high rpm,” Berardi explained. “Most electric vehicles run on a single-speed gearbox in order to run in the power band of the electric motor, so you end up sacrificing some pick up to get your top-end speed or vice versa. The Inizio compromises nothing in that area.

Li-ion Motors' Inizio may evoke European flair, but the all-electric supercar was built from the ground up in Mooresville, NC.

We have a four-speed manual gearbox, and we're working on that to go to a paddle shifter, which is unprecedented in an electric vehicle."

While the battery chemistry was concocted in-house, according to Daigrepont, the batteries themselves are manufactured in South Korea by **Kokam**.

Another innovation Li-ion Motors has developed is a quick-change battery system.

"Big manufacturers have one engineer who focuses on just one little latch for a month at a time; I need my engineer to make that during lunch."

—Paul Daigrepont, Project Manager for Inizio

When the car is taken to a service center, the batteries can be removed from underneath the car and a new stack installed "in a matter of minutes," Daigrepont claims.

For the BMS, a dash-mounted LCD touch-screen monitor displays remaining power and notifies the driver of nearby charging stations when necessary. It also monitors and displays battery temperature, power consumption, drive time, and distance driven.

A regenerative braking system is employed as well.

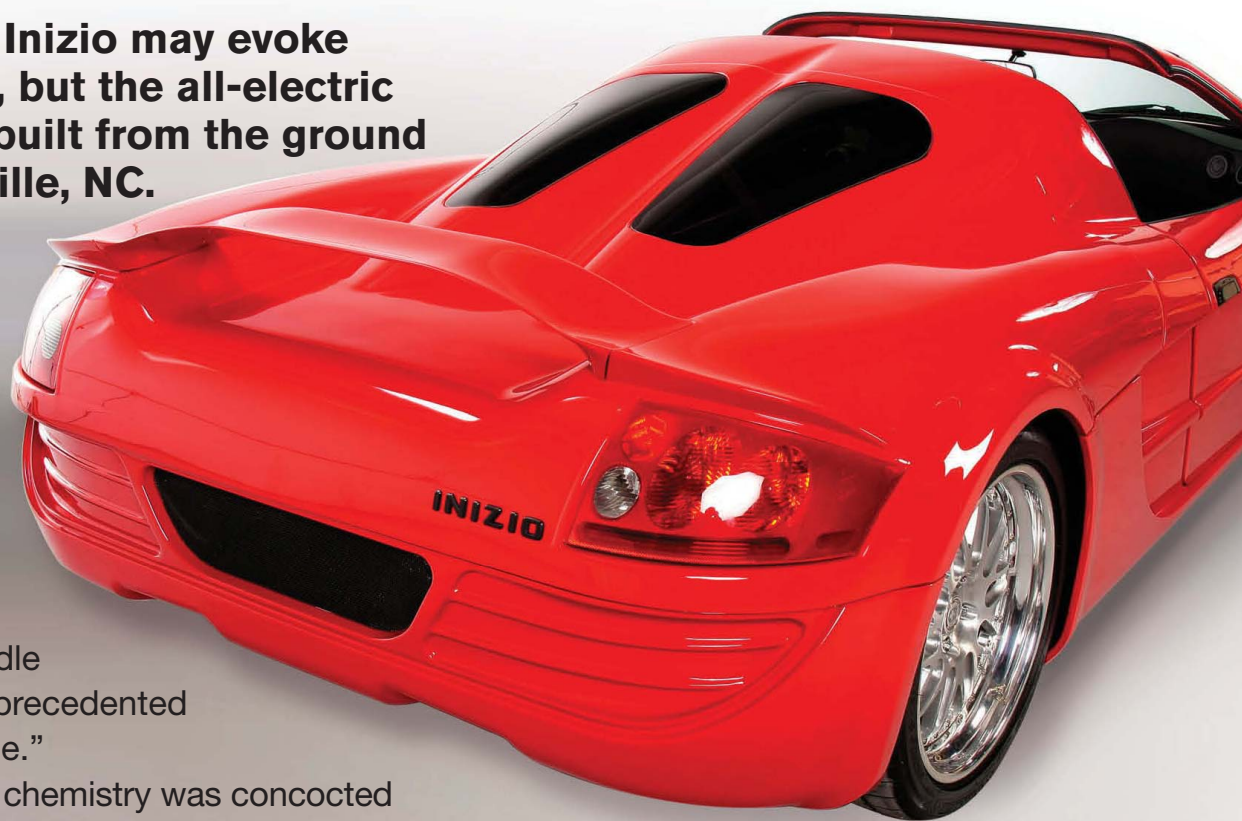
The engineering team spent considerable effort upgrading the chassis design to improve safety and manufacturability of the vehicle. Suspension is, no surprise, racing-inspired:

a fully independent Le Mans style setup. Standard brakes are four-piston caliper oversized four wheel disc; optional are six-piston caliper oversized brakes. Li-ion

plans to offer carbon ceramic matrix brakes in the future.

The car features a full steel frame with some honeycomb composite structure within the floor pan and A-posts, and the door beams are carbon with a polypropylene hybrid material to absorb side impacts. A fiberglass body is standard; a carbon-fiber body upgrade is available for about \$25,000.

To ease entry, rotational doors raise on a 90° angle and a custom hydraulic lift system raises the car 3 in (76 mm).



One souped-up EV

As Daigrepont points out, “Weight is king in an electric car, like with any car, really.” The R model tips the scales at 3100 lb (1406 kg). The RT and RTX, with their unique battery configurations, weigh more, accordingly (see table).

Inside the Inizio are full-power leather and suede **Recaro** seats with heating and cooling. A complete entertainment system includes a 5.0 digital surround sound system with 12-in subwoofer, GPS navigation, and video monitor with DVD, audio/video, and MP3 input.

Inizio’s ‘grocery-getter’ sibling

As is often the case with siblings, the very green (both in color and performance) Wave II battery-electric vehicle couldn’t be more different than the red-hot (again, in color and performance) Inizio supercar, especially in their outward appearance.

In September 2010, **Li-ion Motors** was awarded the Progressive Automotive X Prize—along with a \$2.5 million check—for winning the Side-by-Side Alternative Class with its two-seat Wave II, which boasts a coefficient-of-drag figure (0.157) more akin to a motorcycle than an automobile.

“The primary focus for Wave II development has been just the opposite [than with Inizio]; this is more of a grocery-getter—[about 28 ft³ of] storage in the rear, extremely aerodynamic, and it gets 202 mpg equivalent” according to tests conducted by the **U.S. Department of Energy’s Argonne National Laboratory**, said Li-ion Motors’ Paul Daigrepont.

The **X Prize Foundation**, an educational nonprofit prize organization, and **Progressive Insurance** awarded \$10 million to three teams—**Edison2** of Lynchburg, VA, and **X-Tracer** of Winterthur, Switzerland, in addition to Li-ion Motors—out of a field of 111 competing teams, representing 136 vehicle entries from around the world.

Developing an electric supercar— with limited resources

Hundreds of engineers labored for years to create the **Chevrolet Volt** extended-range EV and to bring it to market in late 2010. Daigrepont’s engineering team for the Inizio can be counted on two hands.

“Some of the big manufacturers have one engineer who focuses on just one little latch for a month at a time, where I need my engineer to make that during lunch,” the project manager quipped, in earnest. “But that’s what we have to work with.

“We can’t afford to compete with 100 engineers in an engineering farm; it’s just not doable. Hopefully through leases in technology and some investors, we’ll get there.”

The winners emerged from nearly 30 months of vehicle and business plan development, on-track testing at Michigan International Speedway, including dynamic safety testing by **Consumer Reports**, and laboratory verification at Argonne.

According to X Prize, the EV demonstrated “outstanding low mechanical and aerodynamic drag,” resulting in 187 mpg equivalent in combined on-track and laboratory efficiency testing, a 0-to-60 mph (0-to-97 km/h) acceleration time of 14.7 s, and over 100 mi (161 km) range during a real-world driving cycle.

The car tops out at 90 mph (145 km/h).

The Inizio and Wave II, despite their obvious differences, do share some technology. “Obviously, [Inizio] has a much higher kW motor in it than the Wave II for obvious reasons, but the batteries and battery management system—battery monitoring and cell balancing, the electrical compartmentry—are basically the same in both cars,” Daigrepont explained.

The basic vehicle structure is also the same—a full steel frame, honeycomb composite within the floor pan and A-posts, and door beams of a carbon/polypropylene hybrid material to absorb side impacts.

A 47-kW **Azure Dynamics** ac induction motor and

Source: Li-ion Motors

single-speed gearbox are employed in the Wave II, while the Inizio sports a 175-kW permanent magnet motor (R and RT models) and Li-ion's proprietary four-speed gearbox.

"This was a concept car originally and we played with it as far as the aerodynamics; we wanted to see if it would even work," said Daigrepont. "It almost seemed as if X Prize built their competition for us. We tailored it for the race, put racing seats in it, things like that. But now that we've proven the technology, we're going back and refining it into more of a passenger car—more comfortable seats, restyle the dash for more creature comforts, and use the same aero advantage and the same basic styling."

For the X Prize competition, the Wave II weighed in at 2176 lb (987 kg). The production model is about 2300 lb (1043 kg).

The Wave II is expected to hit market at \$39,900 retail—right around the cost of a new **Chevrolet Volt**

extended-range EV. As with the Inizio supercar, production of this all-electric "grocery-getter" has been pushed back (from its original December 2011 goal) due to government certification testing and a lack of funding.

"We recently obtained funds to move through the certification process," a spokesman said. "We are a bit delayed but still on track."

Ryan Gehm

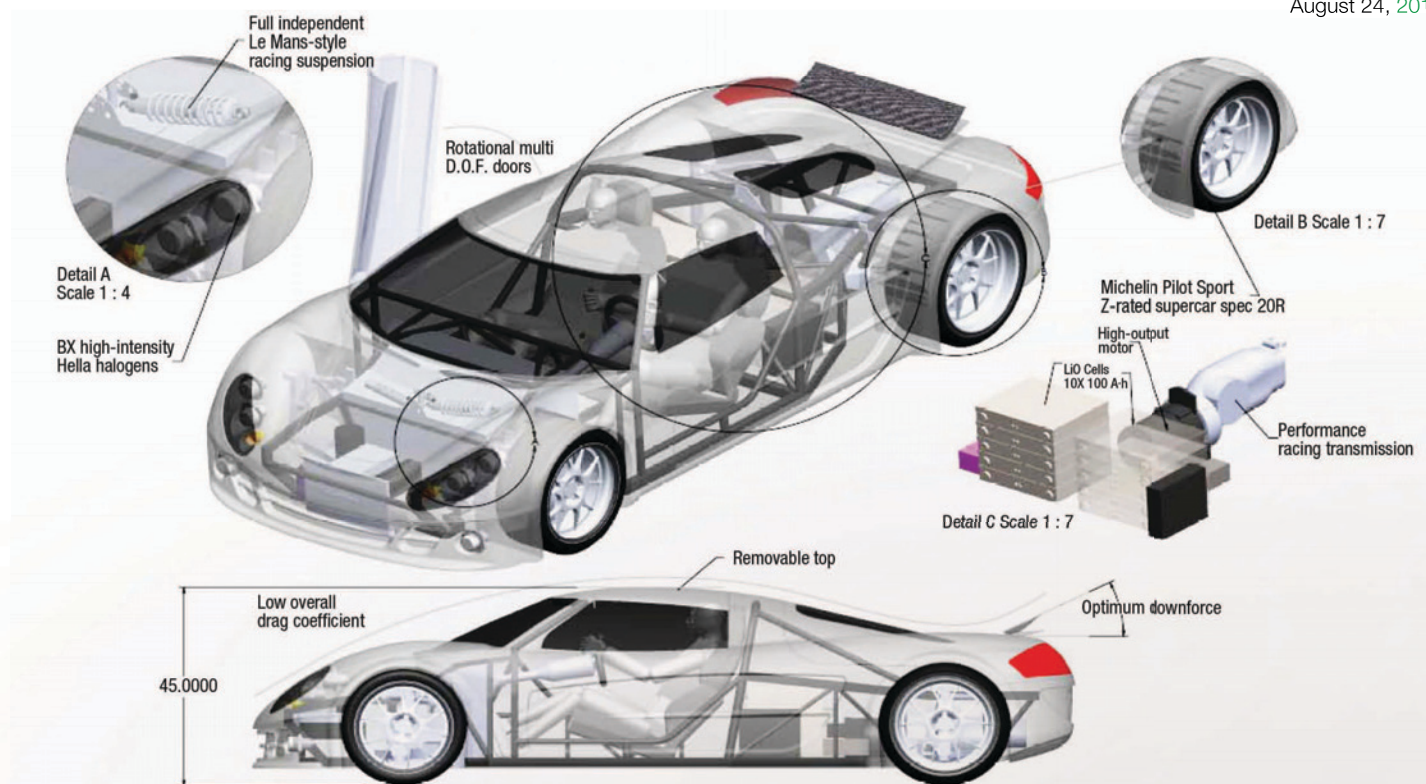
Inizio

by the Numbers

	R Model	RT Model	RTX Model
Motor	175-kW permanent magnet	175-kW permanent magnet	290-kW permanent magnet
No. of motors	1	1	2*
Battery	Li-ion polymer type	Li-ion polymer type	Li-ion polymer type
No. of batteries	12	12	24
Capacity, A-h	100	240	100
Peak energy, kW-h	40	97	80
Charge time**, h	8	10	10+
Charge time**, h (with additional charger option)	4	5	5+
Cycle life	Up to 2500 full charges	Up to 2500 full charges	Up to 2500 full charges
Estimated range, mi (km)	150 (241)	250 (402)	200 (322)
Top speed, mph (km/h)	130 (209)	132 (212)	170 (273)
Acceleration, 0-60 mph (0-97 km/h), s	5.9	7.1	3.4
Weight, lb (kg)	3100 (1406)	3600 (1633)	3900 (1769)
Length, in (mm)	175 (4445)	175 (4445)	175 (4445)
Height, in (mm)	46 (1168)	46 (1168)	46 (1168)
Width, in (mm)	78 (1981)	78 (1981)	78 (1981)
Ground clearance, in (mm)	4.5 (114)	4.5 (114)	4.5 (114)
Seating capacity	2	2	2

*RTX may be reconfigured with a single, much larger motor for production model

**Based on 220 V



Li-ion Motors has applied for—but has not received—federal funding to help with vehicle development and manufacture, according to a company spokesman. Thus far, private investors have backed the company's R&D activities. And the \$2.5 million X Prize winnings offered a financial boost as well.

Testing for government certification has proven to be another considerable challenge. Initially slated for a mid-2011 launch, the Inizio is currently in the process of **U.S. Department of Transportation** certification—"a time-consuming effort" that has caused a delay in the timeline, the spokesman said. Li-ion Motors now expects to begin production by year-end.

Looking far into the future is not necessarily prudent for an automaker that has yet to sell its first car (though the company began accumulating orders for both of its vehicles this past January). A take-things-as-they-come approach has been adopted at Li-ion.

"Ten years down the road? Geez, I'm looking at 10 months down the road," Daigrepoint admitted. "The whole industry is moving at a

really fast pace. We honestly don't have a lot of projections for the future; we're just kind of reacting to the moment. We'd like to be a shareholder in the marketplace, obviously."

For now, the 11-year-old EV maker is singularly focused on bringing its two existing cars to market.

So, what does an electrified high-performance vehicle cost these days? Pricing starts at \$139,000 for the base R model and extends to \$249,000 for the top-of-the-line RTX model. Inizio will be available to markets outside of North America.

Production will be limited and based on demand. "Obviously, we're not capable of manufacturing a thousand cars and have them sit there," Daigrepoint said. "We're planning to sell them from our facility—not that we're not looking to set up dealer networks. But we're that small company just trying to start and move forward."

Calling motorsports country home, Li-ion Motors is perfectly located to not just move forward—but fast. **E**



Inductive charging gets **GREEN FLAG**

U.K.-based start-up HalolPT partners with Drayson Racing to bring ‘dynamic’ wireless charging to electric racecars.

by **Ryan Gehm**

No pit stopping to refuel is an ideal scenario for motorsports teams, even if that “fuel” happens to be electricity. With “dynamic” (*i.e.*, in-motion) charging technology, the prospect of electric racecars—as well as electric road-going vehicles—being charged on the go, without ever having to be plugged in, could become reality.

Photo source: Drayson
Racing Technologies

HalolIPT, a U.K.-based start-up that develops inductive power transfer (IPT) systems for wirelessly charging electric vehicles (EVs), recently formed a strategic partnership with **Drayson Racing Technologies** to test the technology on the track. They will also collaborate on the development of electric drive-train packages to replace the racecar's internal-combustion engine.

HalolIPT was founded in 2010 by the New Zealand-based R&D commercialization company **UniServices**, **Trans Tasman Commercialization Fund**, and design consultancy **Arup**.

"Dynamic wireless charging will be a real game-changer, enabling zero-emission electric vehicles to race over long periods without the need for heavy batteries," said Lord Paul Drayson, former UK Minister for Science and Innovation, and co-founder of the green R&D racing organization in 2007. "This is a milestone innovation that will have a dramatic effect not just on racing but on the mainstream auto industry. We're looking forward to putting this technology through its paces as it charges electric racecars at speeds of up to 200 mph."

The track an ideal testbed

The basic idea is that racecars, fitted with a receiver pad and controller, will continuously draw power from transmitters buried under the surface of the racetrack (or road in the case of passenger and commercial vehicles). The controller converts the magnetic energy to dc power to charge the battery.

"The power supply takes electrical power from the mains supply and energizes a lumped coil, with a current typically in the range 5-125 A," Dr. Anthony Thomson, Chief



Inductive power transfer (IPT) can be used to power any type of electric vehicle regardless of size and weight, according to HalolIPT's Chief Executive, Dr. Anthony Thomson.

Executive at HalolIPT, explained in more detail. "Power is transferred by tuning the pick-up coil to the operating frequency of the primary coil with a series or parallel capacitor. The power transfer is controllable with a switch-mode controller. In an electric vehicle, IPT wireless charging uses strongly coupled magnetic resonance to transfer power from a transmitting pad on the ground to a receiving pad on the car."

An obstacle for mainstream dynamic inductive charging is the costly and time-consuming effort of installing the charging circuits beneath millions of miles of established roadways. So the comparatively short, confined surfaces at racetracks present an ideal testbed for the technology.

Initially, the companies plan to establish trackside charging systems, a setup similar to how racecars currently refuel by pulling off. HalolIPT static charging systems are expected to be installed in the pit lane by Q3 2012.

Development of the dynamic charging system with Drayson will continue throughout 2013 and 2014, Thomson said. If all goes according to plan, by Q3 2015 the dynamic

Inductive charging gets **GREEN FLAG**



IPT wireless charging uses strongly coupled magnetic resonance to transfer power from a transmitting pad on the ground (or underground, for dynamic charging) to a receiving pad on the electric vehicle.

charging system will be installed in the main track and demonstrated in races.

To maintain a continuous charge, “we would place the pads at 1 per lineal meter with a gap of 250 mm between each pad. So there would be 100 pads/100 m,” he shared.

Which racetrack will be outfitted with this infrastructure has not yet been revealed.

A ‘vehicle agnostic’ technology

Inductive charging itself is a proven technology. Some common home applications include toothbrush chargers, induction cooktops, and more recently chargers for electronic devices such as cell phones. Even theme park rides have exploited the technology.

“Wireless charging has been used worldwide for close to two decades, in materials handling, auto assembly, factory automation and clean-room robotics,” Thomson explained. “However, the systems developed for materials handling all rely on computer- or track-controlled guidance systems to ensure the vehicle’s follow a tightly defined route.

HalolPT’s new dynamic charging technology...is tolerant to large misalignment [with the transmitter pads] to allow cars, trucks, and buses to travel freely and still pick up high efficient charge.”

The IPT system automatically adjusts for changing vertical gap; the gap between a vehicle and a pad can be up to 400 mm (15.7 in). The lateral alignment between vehicle and pad can be ± 250 mm (9.8 in) with “minimal loss of efficiency,” according to HalolPT.

The pads themselves measure 600 x 400 x 30 mm (23.6 x 15.7 x 1.2 in) for a 3.3-kW, “small-car” system. The company claims very low magnetic field emission from the system, conforming to **ICNIRP** (International Commission on Non-Ionizing Radiation Protection) guidelines, and no electromagnetic interference into the vehicle.

Multiple IPT systems have been (or are being) developed to suit different applications. The one for small cars was demonstrated in London late last year in a **Citroën C1** converted by **Electric Car Corp.**; a 7-kW system

for larger cars is featured on the **Rolls-Royce** 102EX, an experimental electric Phantom launched at the Geneva Motor Show in March; and a new 18-kW product suitable for EV fleets (*i.e.*, taxis, delivery vans, and trucks) is under development and expected to deploy in 2012. Trials with fleet owners in the U.K. and European Union, as well as in North America, are in the planning stages.

Commercial systems from HalolPT's co-founder UniServices, with power levels up to 60 kW, have been successfully operating in two fleets of buses (approximately 40 buses in total) for 10 years in Turin and Genoa, Italy.

"IPT is a vehicle agnostic technology and can therefore be used to power any type of electric vehicle regardless of size and weight," Thomson said. "HalolPT's system allows cars, vans, buses, and trucks to

travel along the same stretch of IPT highway, with each vehicle harvesting the appropriate amount of energy, controlled from within the vehicle."

The time it takes to recharge an EV with the static system depends on the model and battery size. "However, HalolPT's systems are comparable to a plug-in system, so it will take the same length of time," he claimed. "If you take a 20-kW·h system that would have a usable 15 kW·h, this would take five hours to charge with a 3-kW IPT system."

Infrastructure deployment

To expedite the process of bringing inductive charging—and by extension, plug-less EVs—to the mainstream, HalolPT has been working with a number of public sector bodies including **Transport for London** (the local govern-

Source: HalolPT

Drayson Racing collaborates with Lola on electric racecar

Serving as a “laboratory” to develop green technologies in motorsport, **Drayson Racing Technologies** has fielded racecars fueled by second-generation biofuels but more recently has turned its attention to electric racing.

In addition to the dynamic inductive charging project with **HaloIPT**, Drayson Racing recently announced a new partnership with **Lola Cars International Ltd.** to initially deliver an all-electric prototype racecar, the Lola-Drayson B12/69EV. Lola Cars will develop the racing car chassis; Drayson Racing will have responsibility for the electric drivetrain.

The project aims to accelerate the development of not only the all-electric drivetrain but also sustainably sourced composite parts for the B12/69EV. The companies expect these technologies to eventually benefit industries beyond motorsports, such as aerospace, automotive, and defense.

Plans call for the Lola-Drayson racecar to be revealed to the public in the last quarter of this year; more details on the specific innovations will be released in September. The ultimate goal of the Lola-Drayson partnership is to deliver an all-electric racecar for the planned 2013 **FIA** electric car championship.

“This project aims to tap into the huge demand from high-tech industry for innovative new technologies that improve vehicle performance and sustainability,” said Lord Paul Drayson, Managing Partner of Drayson Racing Technologies. “The Lola-Drayson B12/69EV will act as a racing laboratory, catalyzing technology innovation and driving commercial application in the automotive and related industries.”

The green R&D racing company, based in the U.K. at Kidlington, near Oxford, is also working on several other programs with technical partners, including the development of a high-voltage electric motor controller for motorsport, a programmable fuel pump, and a “bio-safe” fuel system adhesive.

Ryan Gehm

Inductive charging gets **GREEN FLAG**

ment body responsible for most aspects of the transport system in Greater London), **TSB CABLED** (the U.K.’s largest trial of EVs), and **Oxford Brookes University**. It has partnered with several private companies as well.

One recent agreement, between HaloIPT and **Evida Power Ltd.**, a manufacturer of lithium-ion battery packs for EVs, will jointly explore the feasibility of the manufacture of 40,000 IPT systems over a five-year period. The goal is to develop a long-term venture for deployment of the system, which is intended as a specification option on a forthcoming EV (the make and model could not yet be revealed), with sales estimated to reach 70,000 units by 2015.

The start-up also recently formed a strategic partnership with **Chargemaster PLC** to manage the low-volume build, manufacturing, and infrastructure planning for its IPT systems in the U.K. and Europe. By Q2 2012, the two companies expect to have plans in place for Chargemaster to oversee the delivery of fully assembled and tested production IPT systems, including primary and secondary pads, power supplies, and associated controllers, ready for deployment.

“We are now working tirelessly with numerous government bodies and private companies to define infrastructure deployment projects, which represent the key next stage of development for charging network implementation,” Thomson said. “There is a need for governments and private-public partnerships to deploy the infrastructure to encourage the production of EVs with smaller battery packs.” **E**

Product Development

Tata Technologies helps Genovation get G2 up to speed



One of the first companies to enlist the services of Tata Technologies' Vehicle Product Development (VPD) group was Maryland-based Genovation Inc., which used the group for the design of its G2 electric vehicle, shown in concept form at the Tata Technologies offices.

One of the first companies to work with **Tata Technologies'** Vehicle Programs & Development (VPD) group, launched in April 2011, was Maryland-based **Genovation** Inc. The three-year-old start-up company, which began by building conversion vehicles including a **Ford** Focus modified to run on batteries called the G1, selected Tata Technologies to help design and build a prototype of a two-door, four-seat hatchback EV called the G2.

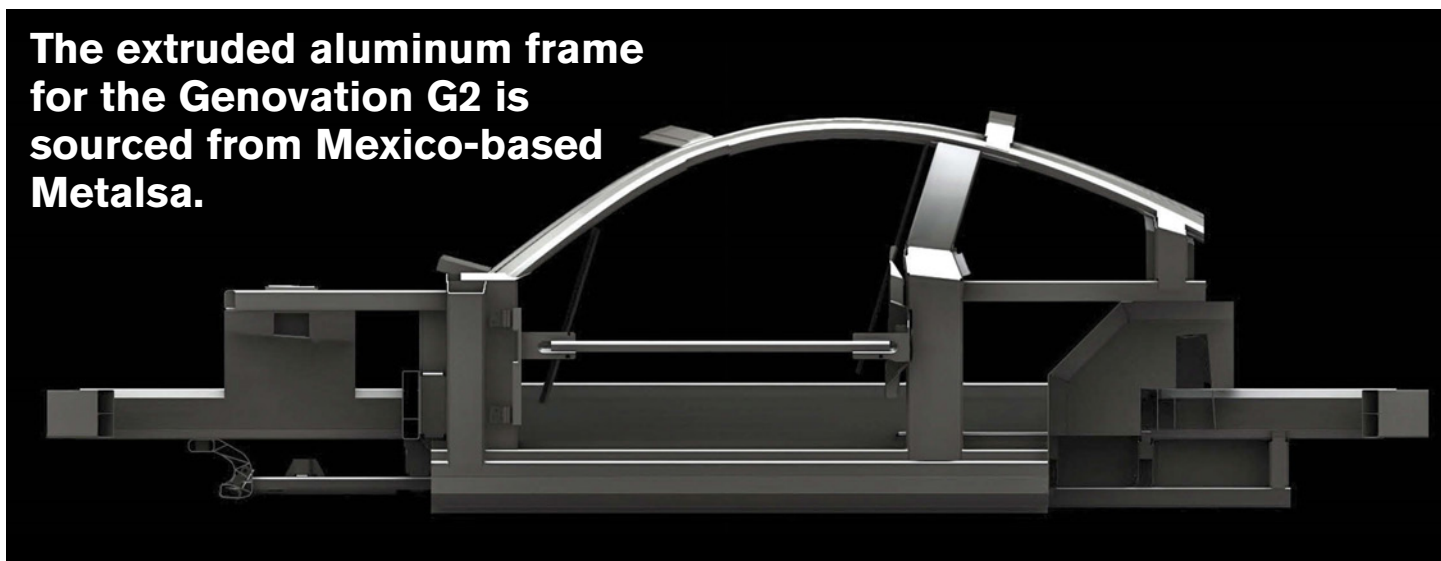
The first G2 produced will be a series plug-in hybrid electric vehicle (PHEV), with a 22-kW·h battery pack and three-cylinder gaso-

line engine for an electric-only range of about 50 mi (80 km) and a 300-mi (483-km) range with a full tank of gas. A battery-electric version with a 38-kW·h battery pack will provide an electric-only range of 100 mi (161 km) under worst-case conditions with everything turned on.

Genovation began its relationship with Tata Technologies through the **Dana** Corp.

"Dana sort of took us under their wing a couple of years ago and helped us put together a request for a proposal that went out to three different companies, one of which

The extruded aluminum frame for the Genovation G2 is sourced from Mexico-based Metalsa.



was Tata Technologies and the other two were their competitors; and we were much more familiar with their two competitors,” said Andrew Saul, Founder and CEO, Genovation. “The response we received from Tata was by far the most detailed and also provided the most value; at least 30 to 40% more value than what we would have received from their competitors.”

Thus began a successful business relationship, with Tata Technologies helping to find subcontractors for the extruded aluminum frame (**Metalsa**), thermal management system (Dana Corp.), battery (**K2 Energy**), and CFD analysis (**American Dynamics Flight Systems**).

Genovation recently received a product-development grant worth \$135,110 from The Maryland Industrial Partnerships Program to fund validation of the car’s CFD models at the Glenn L. Martin Wind Tunnel at the **University of Maryland**, College Park.

Some of the initial design work was conducted by Tata in India during off-business hours, with impressive results, according to Saul.

“One of the things that impressed me was the amount of work that would get done in one overnight,” he said. “I think that really

helped to bring the design to its conclusion much more quickly and in a much more detailed fashion.”

Tata Technologies operates the largest and most experienced automotive engineering staff in India and recently opened a new Global Engineering Center in Bengaluru, Karnataka.

The relationship with Tata also proved to be beneficial in Genovation’s quest to make the vehicle as green as possible, identifying areas where sustainable materials can be easily implemented. Some of the G2’s exterior body panels will be made of green composite materials using soy-based resins and natural fibers such as burlap, jute, and basalt. Tires will be made from a natural rubber infused with oil from orange peels, a byproduct of the beverage industry, and carpeting and floor mats will be made by a company that uses recycled plastic bottles.

“We’re really trying to take it to the next level in terms of sustainability and design a vehicle that won’t compromise people’s driving habits and that won’t compromise safety and yet be very stylish and desirable—a fun car to own and drive,” Saul said.

Genovation and Tata completed phase one of the G2 project in November 2010, and

Powertrain

ALTe focuses on fleets for range-extended electric powertrain

Passenger vehicles most often come to mind when the EV topic arises, but all-electric light- and medium-duty fleet vehicles such as delivery trucks, vans, and shuttle buses may present the ideal outlet for the technology in the near to mid-term. These vehicles run mostly fixed routes that maximize vehicle utilization rates and can recharge at central facilities at off-peak times. (Click [“Commercial fleets key to heavy BEV adoption”](#) to read more.)

ALTe Powertrain Technologies has developed a modular range-extended electric powertrain (REEP) system that specifically targets those markets for retrofit application—and eventually maybe as an original-equipment option. The company projects an 80 to 200% improvement in fuel economy with a REEP installation, with no loss in cargo capacity, increased torque, and power and towing capability comparable to a factory V8 engine.

Founded in 2008, the Auburn Hills, MI-based start-up has developed the technology over the past few years, and will be ready to begin fleet conversions in 2012. ALTe currently employs about 40 people, of which 80% are engineers. It plans to reach 70 employees by the end of the year and over 180 employees by next summer, as conversions ramp up.

“We’re in a sense inspired by the **Chevy** Volt powertrain solution, and also locomotive engines from back in the day when they had basically a big engine turning an electric generator that produced the electricity to drive the wheels,” John Thomas, CEO and co-



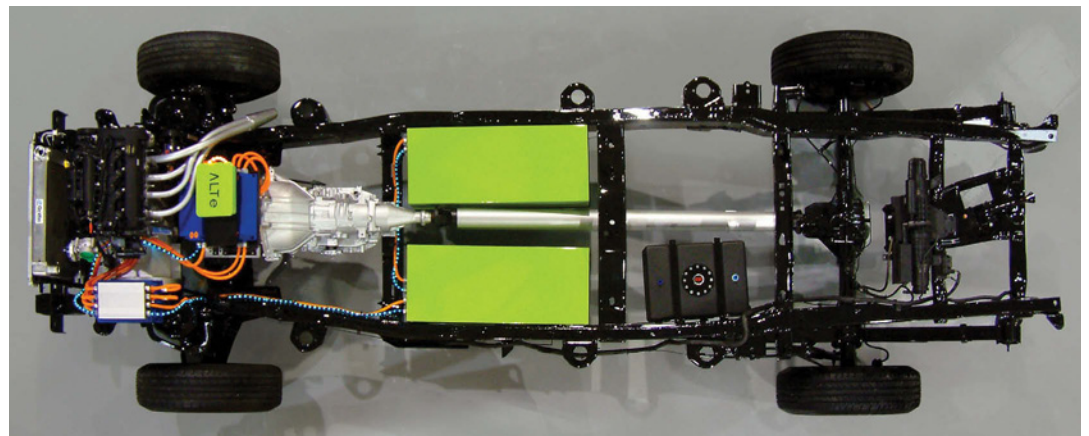
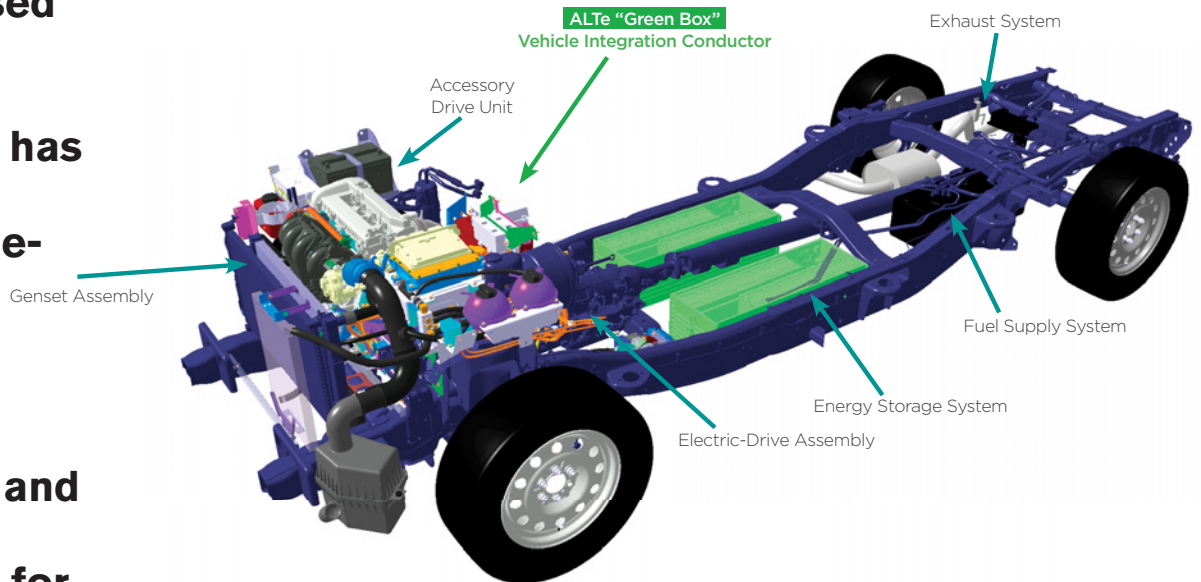
Tata Technologies’ VPD group operates from four automotive engineering centers of excellence worldwide, including Novi, MI (shown); Coventry, U.K., Pune, India; and Stuttgart, Germany.

phase two is under way with prototypes scheduled for 2013 and vehicle deliveries commencing in 2014.

“We took all the information that we learned from this phase-one process and used it to improve our business plan and really give it a lot more depth,” Saul said. “Now we have a bill of materials; we have timelines and headcounts that Tata helped us put together as well as simulated crash tests, two quarter-scale models, and the aerodynamic analysis. I think [Tata] really helped us bring it to the next level.”

Matthew Monaghan

Michigan-based start-up ALTe Powertrain Technologies has developed a modular range-extended electric powertrain (REEP) that targets light- and medium-duty fleet vehicles for retrofit application. The company projects an 80 to 200% improvement in fuel economy with a REEP installation.



founder of ALTe, explained to *Vehicle Electrification*®. “So really the technology has been out there 100 years, but it’s been waiting for the convergence of all the right elements to come together—mainly affordable, reliable, high-voltage power electronics.”

The other key element to making this system possible was the advancement of lithium-ion batteries. “We had to wait for enough power density so that you could put enough batteries on board without penalizing the weight of the vehicle so much that you took away all payload carrying capacity,” he said.

According to Thomas, only about 13% of the potential energy in a gallon of gasoline makes it to drive the tires with an average internal-combustion engine; electric propulsion

systems are on the order of 94% efficient. “The efficiency losses through a normal engine, transmission, and driveline are surprisingly high,” he said.

ALTe replaces a vehicle’s factory engine with one that has been optimized, with new camshafts, pistons, piston rings, and emission management system. These changes alone can increase an engine’s efficiency to about 25%, Thomas said: “We go to a 2.0-L optimized engine that is made for our genset; that’s all we need. And we’re finding that we can even go to less than 1.0-L engines in some fleet applications.”

Two electric motors, which are supplied by **Remy**, are mounted to the front of the existing factory transmission. “A lot of people in



“Electric miles purchased in the form of batteries is the most expensive way to get electric miles,” said ALTe CEO and cofounder John Thomas. Hydraulic hybrid systems make more sense for heavy-duty vehicles, he added.

the EV and hybrid space throw out the old transmission and come up with a new one-gear or two-speed transmission,” Thomas shared. “We do make modifications to it; we have an external pump and we use two to three of the gears within the normal transmission to drive the tires...There is a point when you want a different gear, and we maintain that capability.”

It takes around 14 man-hours to complete a conversion. The system is projected to provide an initial 30 mi (48 km) of all-electric driving, followed by an estimated 275 mi (443 km) in a charge-sustained mode, before needing to be recharged or refueled.

For a shuttle bus application, ALTe almost doubled the fuel economy of the stock 5.4-L V8, increasing it to 11.7 mpg.

The start-up is focusing on light- to medium-duty fleet vehicles for a reason: heavier vehicles require more batteries and a larger engine to create the electricity. “Electric miles purchased in the form of batteries is the most expensive way to get electric miles,” Thomas said. “There is a point when it doesn’t make economic sense.” Hydraulic hybrid systems make more sense for heavy vehicles, he added.

A conversion system for a light-duty truck costs under \$30,000 installed. “We take out the entire old powertrain and replace everything: fuel tank, battery, engine, exhaust. It extends the useful life of the vehicle several years, so now instead of a fleet buyer having to purchase a brand new vehicle with a green powertrain, we’re able to keep them in their old vehicle a few more years for a fraction of the cost,” he said.

The conversion comes with a five-year, 75,000-mi (120,700-km) warranty.

The payback time depends on each individual customer’s case, with the primary variables being the cost of gasoline and the number of miles driven annually. Some customers will realize a payback in less than one year, but most will average between 2-3 years at \$3.75/gal gasoline, according to Thomas.

Multiple distribution channels will be offered for the REEP system, because as the company discovered, “it’s a very fragmented market,” Thomas said. ALTe has partnered with **Manheim** to do conversions at any of their 75 facilities around the U.S., or it can sell the kits to larger fleet owners that have their own garages and prefer to install the system themselves (once they have been approved, trained, and certified by ALTe).

Other markets could include custom car builders for limousines or other stretch vehicles, as well as military and government de-



ALTe has retrofit several prototype vehicles for commercial customers. It plans to begin production conversions in August 2012.

pots. For those organizations wanting to perform the retrofit at their own facility, such as military outlets that must ensure a secure environment, ALTe provides training to their employees through its ALTe University.

In addition to retrofits, the company is talking to several OEM partners about the possibility of employing the technology as original equipment. According to Thomas, ALTe received a “boost to our credibility” when former **Chrysler** executives Tom LaSorda and Steven Landry became board members in December 2009.

The company has formed a Customer Advisory Board that includes about 15 of the largest fleets in North America, including **Frito Lay, PG&E, Cox Communication, DirecTV, Service Master, Waste Management, Duke Energy**, and **Club Assist** among other companies. ALTe also has initiated pilot projects with several large fleets where one of their vehicles will be retrofit with the REEP system and the fleet will provide an evaluation and feedback to ALTe.

The company has signed long-term supply agreements with several major suppliers (e.g.,

Remy for electric motors) with an announcement expected by mid-September on a battery supplier.

Purchase orders will begin to be accepted at the end of 2011, with production launch targeted for August 2012.

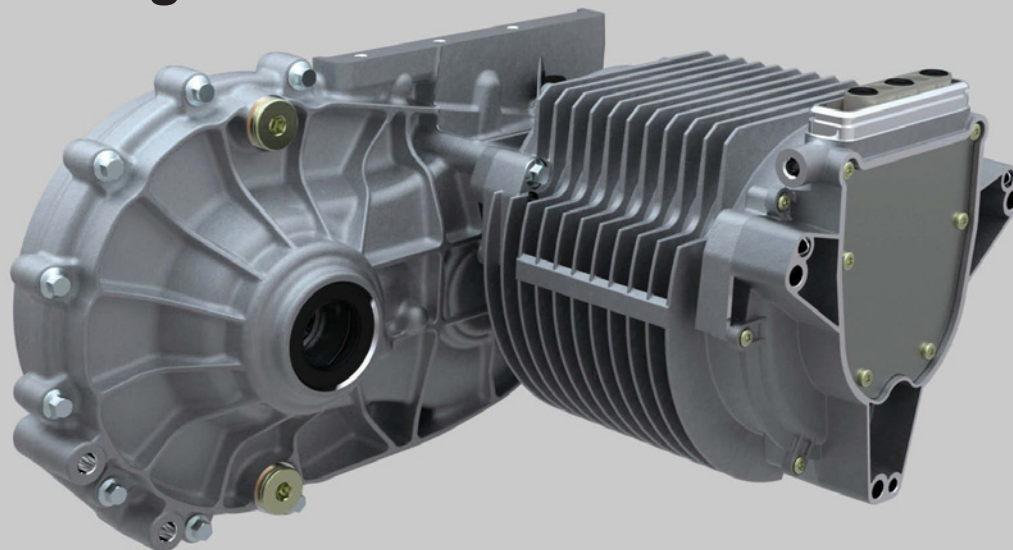
“We’re probably going to have about 20 strategic relationships set up with companies who can really produce and deliver for the quantities we need” when production starts next year, Thomas said. The company plans to retrofit several hundred fleet vehicles in the first year. It expects this number to increase to almost 50,000 units by 2015, reflecting the strong interest being expressed by major fleets and the overall size of its target market (over 10 million pickup trucks, vans, and SUVs registered to corporate and government fleets in the U.S., according to ALTe).

While ALTe is focusing on on-road vehicles to begin with, it has not ruled out application of its REEP system in agricultural or other off-highway equipment, according to Thomas. “Our powertrain can be applied to any and all wheeled vehicles, and we’re looking at it.”

Ryan Gehm

Powertrain|Vehicle

Low-mass ZYTEK powertrain key to Murray's new 700-kg EV



The heart of the T.27's powertrain is its air-cooled ZYTEK traction motor and Vocis single-speed transmission.

The electric **Gordon Murray Design** T.27 city car was recently unveiled in near-production-ready form. Based closely on the company's T.25 design, which Murray claims could establish a new "world car class" for efficient vehicles, the T.27 emphasizes light weight and what the company regards as a "unique, holistic" design manufacturing process (its patented iStream).

The T.27 has a claimed curb weight of less than 700 kg (1543 lb). Its electric powertrain was designed and built by **ZYTEK Automotive**, a key member of the consortium established to develop the project. Powered by a 25-kW electric motor via a 12.1-kW·h lithium-ion battery, the EV has performance targets that include a top speed of 105 km/h (65 mph) and 0-100 km/h (0-62 mph) acceleration in less than 15 s.

Claimed range between charges on the New European Drive Cycle (NEDC) is 100 mi

(161 km). The claimed ECE 15 (European Drive Cycle) range is 130 mi (209 km).

ZYTEK developed the car's powertrain to be the most compact, power-dense system available for use in lightweight EVs. With £1.5 million in funding from the U.K. Technology Strategy Board (the U.K. government-backed board has pumped £4.5 million into the whole T.27 program), ZYTEK was responsible for all aspects of the design and manufacture of the complete drive system, including motor, inverter, and battery. It also worked closely with gearbox supplier **Vocis** on the car's lightweight single-speed drive unit.

Air-cooled battery for low mass

Creating a lightweight structure for the T.27 allowed the electric motor to be small and light, too, although it needed to have a high maximum operating speed. ZYTEK settled on



Gordon Murrery Design's distinctively styled T.27 electric city car closely resembles its sibling T.25.

14,500 rpm, which gave required torque of 64 N·m (47 lb·ft). This met the requirement for the vehicle to be sufficiently lively and responsive. The 25-kW peak power output is available for 30 s.

Although Zytec has 15 years' experience in designing electric powertrains, the company opted to create the T.27's propulsion system from a "clean sheet of paper," said CEO Neil Heslington.

"A working prototype was completed within six months for dyno-based work and led to a second stage design for installation in the car," he explained.

Exceptionally high powertrain efficiency with light weight were design priorities from the start of the program. So an air-cooled configuration for motor, inverter, and battery was applied. Combined weight of the motor, gearbox, and three-phase inverter is less than 50 kg (110 lb). The inverter combines battery-charging and high-voltage-switching functions; this helps reduce copper cabling, thus saving weight while avoiding any reliability issues regarding high-voltage connectors.

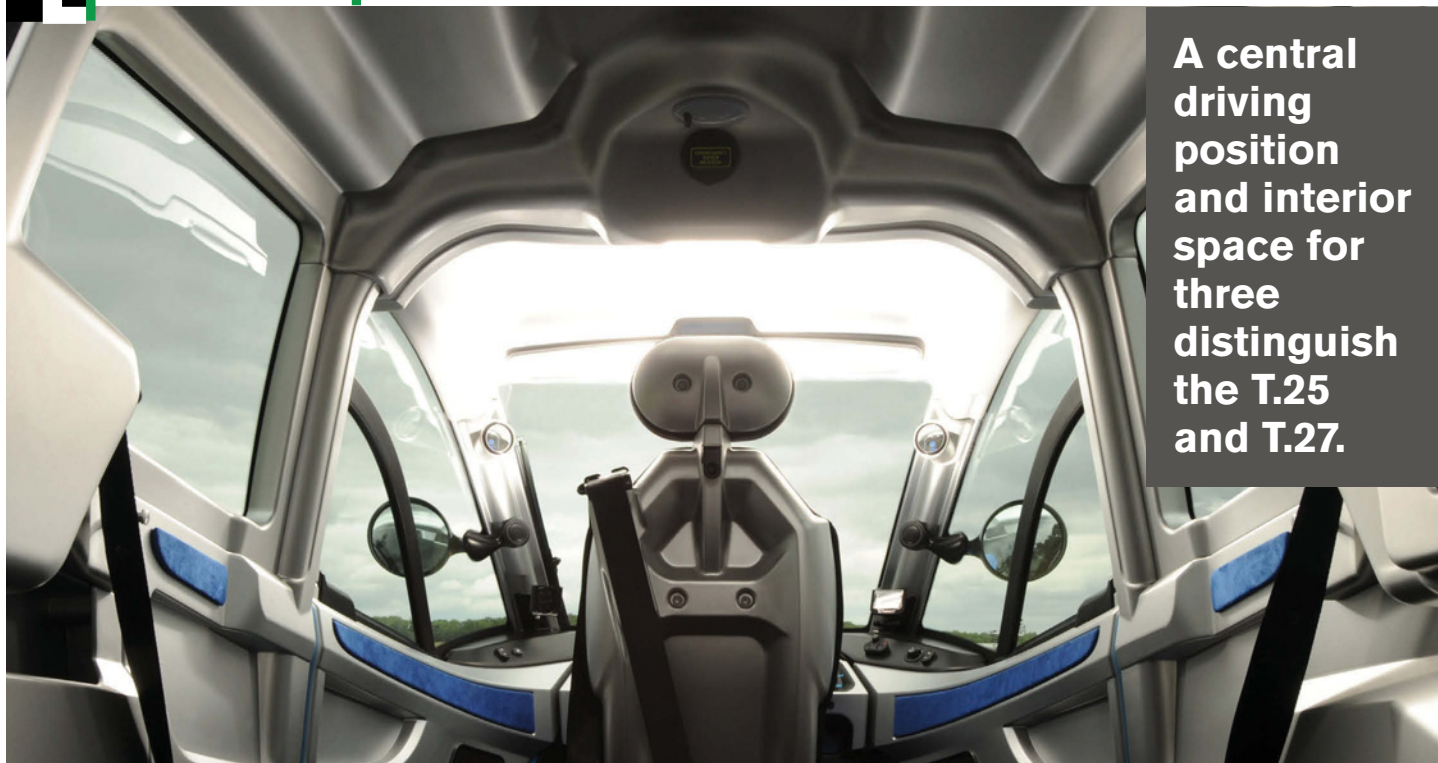
Powertrain mass is approximately 45% that of a comparable production liquid-cooled electric drivetrain with its associated radiator, coolant, pumps, etc., Heslington noted.

The compact Zytec unit allows both luggage space enhancement and also a reduction in carbon footprint during component manufacture. The relationship with Vocis facilitated more effective communication between the two companies, resulting in significant systems optimization.

New battery pack design

Choices regarding lithium-ion battery design, package size, and weight were crucial aspects of this optimization. It took a year of CFD analyses of various cooling system possibilities to achieve a satisfactory design of a new pouch-cell frame incorporating cooling channels and a dedicated battery management system.

Heslington stated that the battery has been safety-tested in prototype form to assess thermal characteristics, together with cell performance under extremes of electrical and mechanical abuse. Battery-pack weight is



A central driving position and interior space for three distinguish the T.25 and T.27.



T.27 undergoing tests at the MIRA test facility in the U.K. Gordon Murray regards its side-impact performance as a milestone in vehicle safety development.

129 kg (284 lb). Heslington described the design as being a single structure instead of a traditional “box within a box” configuration. The battery is designated ZyteK 25kW E-Drive.

Said former **Brabham** and **McLaren** Formula 1 designer Murray of the T.27: “Light weight is the most powerful tool we have in our armory in the fight against emissions and fuel consumption. A lightweight car

means a lightweight battery, increasing the levels of safety and reducing the retail price dramatically.”

He claims the T.27 sets new standards in weight, footprint, small car dynamics, safety, packaging, and efficiency and addresses full life-cycle CO₂ emissions, congestion, parking, and low-cost motoring issues.

Stuart Birch

ELECTRIFICATION

SAE Vehicle Electrification
Digital Magazine Schedule
for 2011

February 23

May 25

August 24

November 30

In the past decade, “vehicle electrification” has rapidly evolved from a mere buzzword to a key element in every global OEM’s product-development plans.

For the engineers charged with developing the technology solutions that will drive electrification, **SAE International** has created an exclusive new source of information. It’s a new Vehicle Electrification Web portal at evsae.com created to be the “go-to” source for engineering professionals looking for the latest technical information on technology advances, product solutions, supplier news, and vehicle-development trends from the most plugged-in experts in the electrified-

vehicle field. You’ll also be able to find information on the latest SAE books, events, technical papers, standards, and training—as well as content from an increasing number of SAE partners. The site is being updated and upgraded continually, so check it out and come back often.

In addition, this *SAE Vehicle Electrification*® digital magazine is part of a series devoted to the most significant hybrid and electric vehicles and the current and future technologies being developed for them and other vehicles.

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What’s on evsae.com



SAE's J1772 'combo connector' advances with IEEE's help

A strategic partnership in vehicular technology related to the smart grid between the **IEEE Standards Association** (IEEE-SA) and **SAE International** is less than half a year old. But its value in influencing the speed and quality of global standards rollout is already in evidence. SAE’s work on a prototype charging coupler that leverages technology standardized by IEEE is one prime example. In the first quarter of next year, SAE plans to establish a standard, integrated coupler that would allow electric vehicles and plug-in hybrid electric vehicles to be charged from either a conventional 15-A ac wall outlet or a dc connector of up to 90 kW.

Vehicle Battery Summit to be held in Shanghai

A surge of recent research on Li-ion battery development, along with the

growing international commitment to the market penetration of battery-powered vehicles, has prompted development of the **SAE International** 2011 Vehicle Battery Summit, Nov. 14-15, 2011, in Shanghai. Designed to integrate the most recent battery innovations with lessons learned in recent electric vehicle and plug-in hybrid electric vehicle commercialization efforts, this year’s summit will build significantly on the knowledge presented at last year’s highly successful event. The Summit will be chaired by Dr. Menahem Anderman, President of **Advanced Automotive Batteries** and founder of **Total Battery Consulting**, Inc.

Electromechanical drivetrain for tractors trialed

With the goal of improving fuel efficiency, increasing implement productivity, and enhancing other aspects of a 300-hp- (224-kW)-class agricultural wheeled tractor, a group of researchers in Russia decided to design and test an electromechanical drivetrain. In their work, the researchers from **Production Association Minsk Tractor Works** and **Ruselprom-ElectricDrive Ltd.** found that the use of electric

drivetrains is especially beneficial for powerful tractors. This article is based on a technical paper jointly published by **SAE International** (2011-01-2296) and **AVL List GmbH** (ICPC 2011 – 3.3).



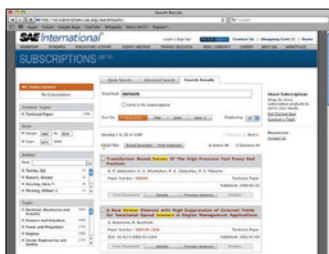
Hybrids and Plug-In Vehicles Report

The global market for hybrid-electric vehicles (HEVs) is now well-established with considerable numbers being sold over the past three years. *The Hybrid and Plug-In Vehicles Report* looks at current market drivers and includes detailed sections on incentives, hybrid technology, grid technology and charging infrastructures, key OEM strategies, and battery technology and energy storage. The report also includes detailed profiles of 26 of the leading battery and motor suppliers.



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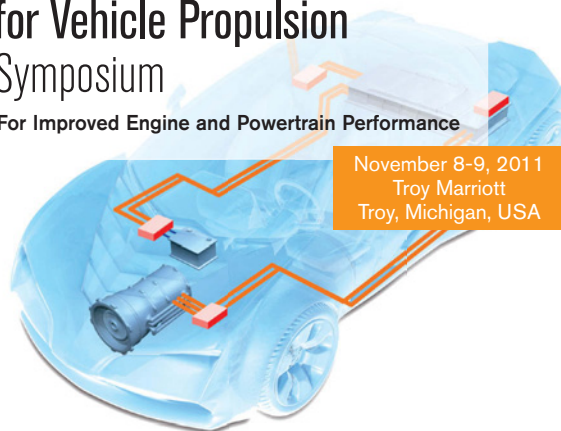
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Read THE inside story about the engineering of the Volt

Edited by Lindsay Brooke

This compendium presents the most complete design and engineering story available anywhere about this groundbreaking new vehicle. It also introduces you to the engineering team and how they made the world's first production extended-range electric vehicle a reality.

You will learn:

- Details about the Volt's systems, components, and model-based design
- Exclusive "behind-the-wheel" information about the Volt prototype
- How the Volt's engineering team used OnStar to collect test drive data from preproduction Volt vehicles

Combining articles from SAE International's *Vehicle Electrification* and *Automotive Engineering International* magazines, new SAE technical papers, and all-new content, this full-color book is the only one of its kind that lifts the veil on how the GM team and key supplier partners met the difficult engineering challenges faced in developing the Volt. There is also an interview with GM's Micky Bly in which the executive explains how the Volt program enabled GM to take new approaches to vehicle electrical architectures.

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Edited by
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