Power Surge

The automotive industry is poised for major disruption—and growth. Are you ready?

PROTOLABS
Manufacturing. Accelerated.

Contents

The electric and autonomous vehicle (EV and AV) segment of the automotive industry is ready for massive growth. How massive? The EV market alone is expected to soar to $5 trillion by 2030, according to some estimates. EV investments will total $330 billion between 2021 and 2025. That includes the vehicles themselves, plus battery technology, charging stations, and other related products. This guide takes a closer look at this rapidly approaching electric future, and also explores how digital manufacturing is playing a key development role.

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Charging Toward an Electric Future

Automakers and tech firms drive acceleration of electric vehicle development while autonomous innovation has a longer journey.

We're in an electric vehicle arms race—that's what one industry insider is calling it.

Wedbush analyst Daniel Ives **said recently** General Motors (GM) and Ford are continually trying to outdo each other with announcements about investments in electric vehicles (EVs). "There is an EV arms race going on in Detroit with Ford and GM competing for market and mind share." And this arms race is also extending beyond our shores, with European OEM icons such as Volkswagen investing heavily in electric vehicles.

Even though EVs accounted for less than 2% of U.S. vehicle sales last year, automakers are wired for an electric future. Want some examples? **EV investments** rose by 41% just between 2020 and 2021, and will total $330 billion between 2021 and 2025. GM and Volkswagen will spend $35 billion and $42 billion respectively on electric and autonomous vehicles from 2020 to 2025. Jaguar plans to sell only electric cars by 2025, Volvo by 2030. Ford said its entire Lincoln luxury lineup would be electric or gas-electric hybrid by 2030, and the car company recently doubled its investment in EV to $22 billion by the end of 2025. GM hopes to be selling only electric passenger vehicles by 2035.

Online car-shopping site Edmunds reported that consumers will see a deluge of new models entering the market in the next year: 30 EVs from 21 brands, up from 17 models in 2020. Check out our infographic in the middle of the guide for more EV stats.

Beyond the large automakers, a plethora of startup, tech-forward companies are also key players in all segments of this market: EVs, AVs, battery technology, charging infrastructure, and more. Tesla, of course, is the pioneer of these modern automakers. But there's also Rivian, Lordstown Motors, and Nuro. And, beyond car makers automotive technology startups abound: GhostWave, which makes radar sensors used in AVs; Neteera, which is also developing sensors for AVs; EV Safe Charge; Mighty AI, which produces software for AVs; and hundreds more.

As several **industry sources** claim, we are in the middle of the biggest revolution in motoring since Henry Ford's first production line started back in 1913.

With the electric revolution in mind, we'll take a look at:

- The shift to EVs and why electric cars will take over sooner than we think
- The struggle this segment currently finds itself in as companies try to sustain major development work that's required without profitability in the short term
- Innovation emerging from tech and car companies collaborating with each other
- Battery technology and a needed, new EV infrastructure that will be pivotal to this segment's success
- How the EV trend is influencing industrial and commercial vehicles
- The various levels of autonomous vehicles and how AV innovation needs more R&D time

An EV Future: Investment, Development in High Gear

A striking factor in GM's major investment in an all-electric future isn't only the large dollar amount—it's the timing. GM's foot is firmly on the accelerator toward an EV future.

"We are making these investments so we can move faster and grow in ways that deliver value to our shareholders and our stakeholders," GM Chair and CEO Mary Barra **said recently**. "Our strategy to pursue an inclusive, all-electric future is the right thing to do, the necessary thing to do, and critical to the growth and long-term viability of our business as the world transforms."

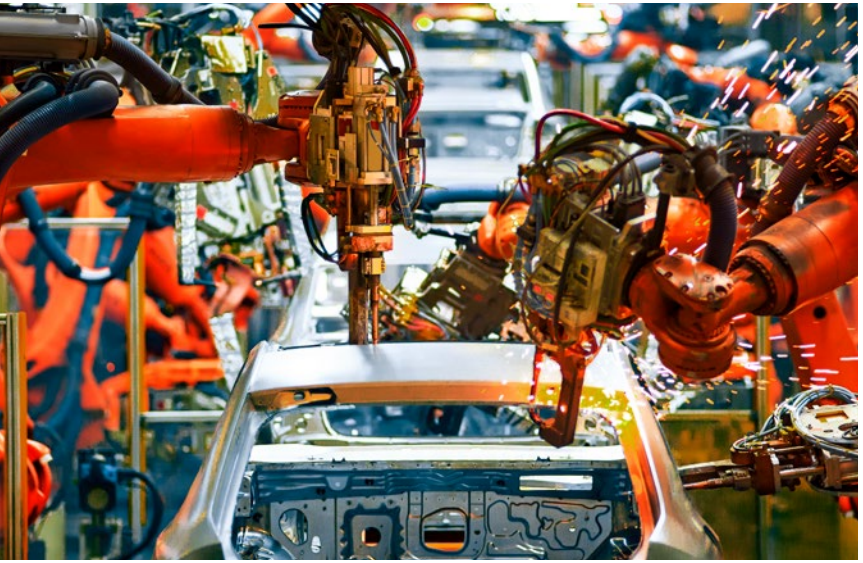
In fact, **global sales of EVs** raced ahead in 2020, rising by 43% to a total of 3.2 million, despite overall car sales slumping by a fifth during the pandemic. By 2025, 20% of all new cars sold globally will be electric, according to a forecast by the investment bank UBS. And by 2040, virtually every new car sold globally will be electric, UBS predicts. That's fast considering the EV market share in 2020 was just 2%.

Why this acceleration? Credit engineers' learning curve. BBC News: "The more we make something, the better we get at making it and the cheaper it gets to make." That's why computers, kitchen appliances, and oil- and gas-powered cars became so affordable.

> "The more we make something, the better we get at making it and the cheaper it gets to make."

GMC HUMMER EV PICKUP. Slated for 2021

A Speed Bump for EVs? Development Without Profit—For Now



EVs are bolting into the future, thanks in part to that learning curve, but that education requires research and development. A lot of it. Automakers **are investing in electric vehicles**, but at least for now, EVs won't generate the profits of conventional vehicles, according to a report by Alix Partners Consulting. "You have to invest now in a business that's less profitable than the one you're replacing."

This spending on development is also taking place as automakers struggle with higher raw material costs and a global semiconductor shortage.

Plus, the R&D phase may be taking longer because car makers are, in a sense, starting from scratch. With standard cars, most OEMs are operating from an existing line, so they already have a lot of the components in place. When developing a new model, for example, they are basically just evolving their design with a few new features. By contrast, electric vehicles are starting with a clean slate.

The R&D, innovation, and accelerated learning curve through rapid iterations that is needed in this stage can be streamlined through digital manufacturers such as Protolabs with quick-turn prototyping and low-volume production—benefits that are well-suited for R&D's iterative development process. Digital suppliers can help with a broad portfolio of components, from connectors, terminals, and charging inlets to sensors, wireless solutions, and power distribution units, to name a few applications.

Car and Tech Companies Connect

As automakers move to EVs and autonomous vehicles (AVs), tech companies are now playing larger roles in this segment. **Investors have long viewed electric-car pioneer Tesla as a technology** company, and its stock price has been supported by its continued superiority in battery costs, software, and the profitability of its electric cars.

Examples of big tech's presence in cars abound: voice-activated navigation, live-streaming media, heads-up displays, rear cameras, lane and parking assist, and other tech that makes our driving experience better and safer. Car makers are also teaming up with tech companies, in some cases taking on the role of contract manufacturer. In 2019, Fiat Chrysler partnered with Google spinoff Waymo to produce up to 62,000 self-driving, electric hybrid minivans. Waymo also partnered with Renault and Nissan for a fleet of robo-taxis in France and Japan. Software giant Autodesk has collaborated with GM on design innovations and works closely with other OEMs on design simulation, virtual and augmented reality tools, advanced software systems for vehicles, and more.

You see this trend everywhere—even car commercials. A recent spot for Nissan boasted that, "The most exciting tech you own is in your driveway." Even the big, showy, annual CES trade show in Las Vegas, which typically hosts the latest in new consumer electronics and technology, has been dominated in recent years by the automotive industry.

A prime example of what tech companies are bringing to the automotive sector is the concept of the connected car. This will likely prove to be a game-changing innovation. Recently, Tesla was having some issues with the brakes on one of its models. Accordingly, Tesla sent out a software upgrade—a software fix—to all of the affected cars, and the issue was fixed literally overnight. Compare that to the amount of time and money it would take for a recall of a standard, internal combustion engine car: email and regular-mail notifications to hundreds of thousands of car owners, vehicles brought back to dealerships worldwide, and on and on.

> "The most exciting tech you own is in your driveway."

This type of revolutionary technology, whether it's for EVs and AVs themselves, or related products such as batteries and charging stations, is accelerated to market with the help of digital manufacturing. Whether the companies are major automotive OEMs, tech-driven startups, or trusted Tier 1 automotive suppliers, they all find support from responsive, agile manufacturers that provide rapid iteration, quick-turn low-volume production, quality assurance systems, and more.

An Appetite for Infrastructure

Lost in all of the talk about EVs and the future of mobility, is a much needed discussion about **the infrastructure that's required** to make the widespread adoption of EVs a reality. Residential vehicle chargers are needed. A vast network of commercial charging stations, like gas stations, throughout the country are needed. This is not unlike how Ford Motor Company figured out in the early days of its vehicles that gas and service stations were needed to keep those early Model Ts rolling down the roads—such as they were at the time.

Again, digital manufacturers are poised to supply needed components for things like battery packs, energy storage/charging stations, and light detection/ranging (LIDAR) cameras for AVs as well as more traditional automotive parts like seals, gaskets, and sound dampening technology.

Just as the price of EVs is a concern with some consumers, batteries and the mileage range of a charge are also challenges.

"Cost is still a factor and range anxiety will be partly addressed by education," Stephanie Brinley, an industry expert at IHS Markit, **said recently**. "There's no reason a consumer can't adjust to an electric vehicle." True, but it would sure help if readily available charging stations were around, too.

As a result, this infrastructure need is spawning hundreds of startup companies that see opportunities in this segment. Additionally, the big OEMs themselves are getting into the act. **GM recently announced** two new Ultium Cells LLC battery plants in the U.S. (locations not disclosed) in addition to two plants already under construction in Ohio and Tennessee. Volkswagen is adding **six battery-making "gigafactories"** in Europe that will open by 2030.

In fact, the only true differentiators in this brave new EV marketplace may end up being batteries and software (see earlier Tesla example).

Tesla gigafactory construction in Austin, TX

Plugging Into Commercial, Industrial Vehicles

The commercial, industrial, and fleet segment of the auto industry is often overlooked, yet it's a sizable piece of vehicle sales for automakers and other OEMs. And, as with everything else automotive, EVs and AVs are being planned for this segment, too. In fact, heavy machinery companies such as Komatsu, Caterpillar, and Volvo Trucks are already **using autonomous heavy equipment vehicles** in mining and other operations around the world.

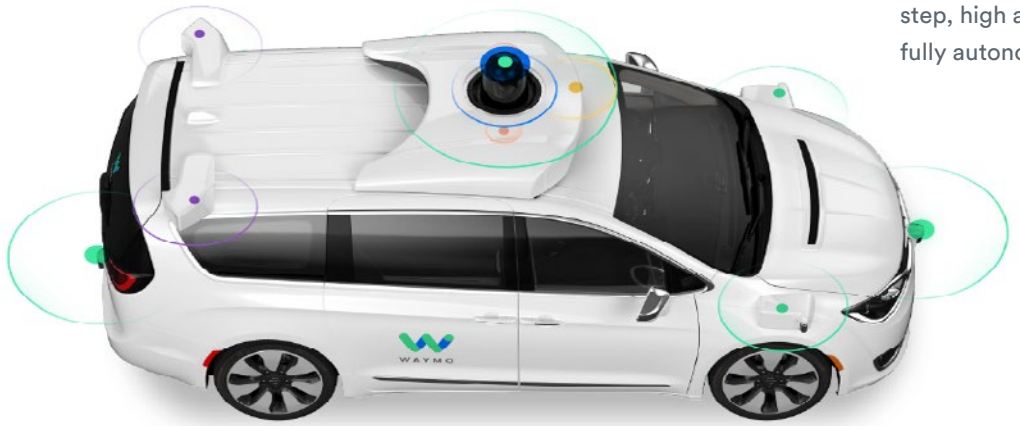
Additionally, technology developer **Waymo has teamed up with J.B. Hunt Transport Services** on an initiative focused on an intra-Texas test run shipment of freight for a J.B. Hunt shipping customer.

Oh, and two-thirds of Ford's commercial vehicle sales are expected to be all-electric or plug-in hybrids by 2030. So there's that.

Komatsu heavy equipment AV.

AVs Trail but are Picking Up the Pace

While the investment and development of EVs continues at an accelerated pace, most industry observers say that AV technology will take longer to develop and launch. That said, major strides have already been made in this sector. You don't have to look too far to see these advances—probably just out in your driveway. In other words, autonomous elements are already embedded in your car. Cruise control? Of course. Lane assist? Check. Facial recognition and mirror/seat adjustment based on identification? Sure. Well, you get the idea.



Waymo One™. Waymo's autonomous ride-hailing service

Several sources talk about AV development as being more of a **step-by-step or gradual journey**. When it comes to autonomous cars, the five steps toward full autonomy include:

Level 1: Feet off. Think cruise control. Already been around for decades.

Level 2: Hands off. The car automatically maintains a safe following distance or stays within lanes.

Level 3: Eyes off. This allows the driver to read or do other activities, but still intervene in an emergency.

Levels 4 and 5: Mind off, which translates with the fourth step, high automation, and finally, the fifth step, which is fully autonomous driving, with humans as passengers.

Did someone say mind off? Well, that's the piece that may take some getting used to. Probably fine for the aforementioned heavy machinery operating dump trucks and earth movers in remote, uninhabited mines, but on crowded urban streets or interstate highways? That's the question.

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An Emissions-Free Future, and New Automotive Landscape

Ultimately, this EV/AV trend means a greener future. As mentioned, GM's Barra referenced this in her recent LinkedIn article when she said an all-electric future is "the right thing to do, the necessary thing to do." Emissions-free vehicles mean a cleaner planet and a more sustainable energy source.

What will happen to the oil and gas industry? It remains to be seen. For now, traditional gas-powered cars still dominate. Remember, EVs only own 2% of the marketplace. Elon Musk, the well-known founder of Tesla, recognizes this situation: he is actually competing against the oil and gas industry, not against fellow EV manufacturers. That's part of the reason he has made his patents and other proprietary information available to EV startups. To move the needle on EV market share, he believes the industry needs to shift away from fossil fuel.

There are skeptics. As outlined in this report, a shift to an all-electric future is a giant disruption, complete with building a whole new infrastructure. Some experts have said better fuel economy and more advancements in electric hybrid technology are more realistic answers to the industry's future.

However, that thinking may be shortsighted. It conjures up comparisons to the famous quote, which was allegedly said by Henry Ford: "If I had asked people what they wanted, they would have said faster horses."

The Bold New World of Electric and Autonomous Vehicles

Take a glimpse into the innovative future of the growing EV/AV market and how digital manufacturing is helping drive speed and agility.

Leading the Charge

Electric vehicles (EV) and autonomous vehicles (AV) have been in the market for years, but recent developments in alternative energy and sustainability have supercharged development, creating a new ecosystem of next-gen automotive development. This ecosystem combines elements of existing internal combustion engine (ICE) vehicles with technology-driven companies powering change. Here's a look at the major players in the EV/AV industry.

Traditional OEMs

Ford

gm

VW

Battery Suppliers

TESLA

QuantumScape

Disrupter OEMs

TESLA

RIVIAN

LUCID

Charging Stations

chargepoint

blink

Tiered Suppliers

BRIDGESTONE

APTIV

Sika

LIDAR Technology

Velodyne

LUMINAR

Following the Numbers

2%

EV sales account for less than this percent of U.S. vehicle sales in 2020.
Associated Press

76 million

The number of vehicles that will be on the road with some level of autonomy by 2035.
IHS Markit research

6

The number of battery-making gigafactories in Europe that Volkswagen plans to open by 2030.
CNN

41%

EV investments rose by this amount just between 2020 and 2021. EV investments will total $330 billion between 2021 and 2025.
Alix Partners Consulting

$35 billion + $42 billion

The amounts that GM and Volkswagen, respectively, will spend on electric and autonomous vehicles from 2020 to 2025.
IHS Markit research

2035

The targeted year GM has set as a goal for selling only electric passenger vehicles.
Associated Press

33 million units

By 2040, this will be the number of annual sales of self-driving vehicles.
IHS Markit research

$5 trillion

EV industry expected to soar to this amount by 2030.
Wedbush Securities

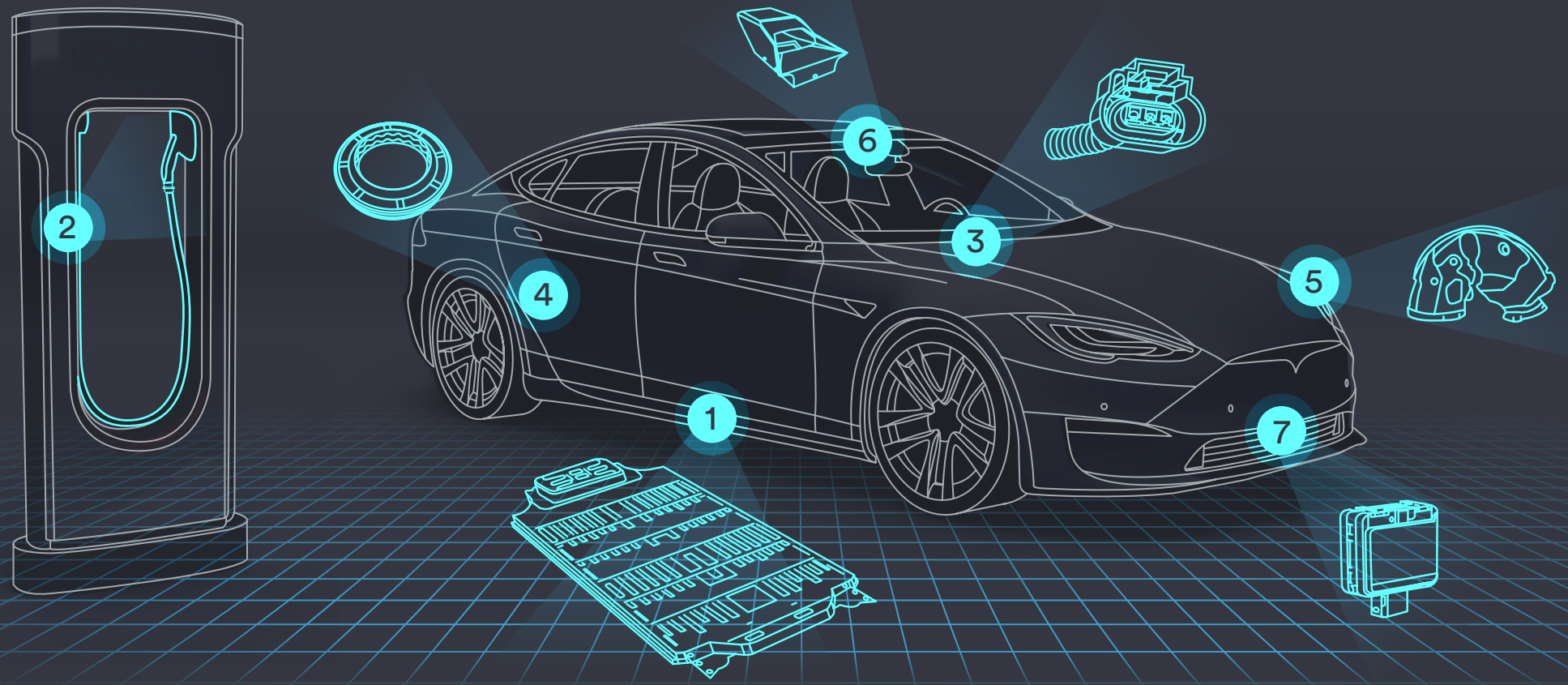
2040

By this year, virtually every new car sold globally will be electric.
UBS Investment Bank

EV Development x Digital Manufacturing

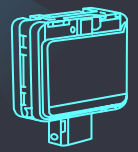
Electric Vehicle (EV) development has created new opportunities for innovative, tech-driven companies to enter the automotive ecosystem. Things that did not exist in ICE vehicle development (like charging stations and battery packs) are creating new product opportunities around the world and inspiring hundreds of new companies. Here's a look at some of the areas in which digital manufacturing is helping drive that innovation.

1. Battery Packs
2. Charging Stations
3. Wiring Harnesses
4. Seals/Gaskets
5. Sound Dampening
6. Ranging (LIDAR)/Cameras
7. RADAR Systems



Navigating the EV Life Cycle

1 **Requirements**



2 **System Design & Simulation**

3DP Models for Customer Feedback

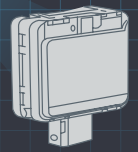
Confirm Requirements

3 **Component Design & Simulation**

Component Prototypes for CAE Validation

Confirm CAE is Representative

4 **Implementation**



5 **Component Test**

Prototype Components

Test Early

6 **System Test**

Prototype Components

Build System and Manufacturing Method Confidence

7 **Acceptance Test & Sign-Off**

Speed to market, recover from supply chain gaps, low TCO

Production Parts & Bridge Tooling

Final Product

Detail

Time

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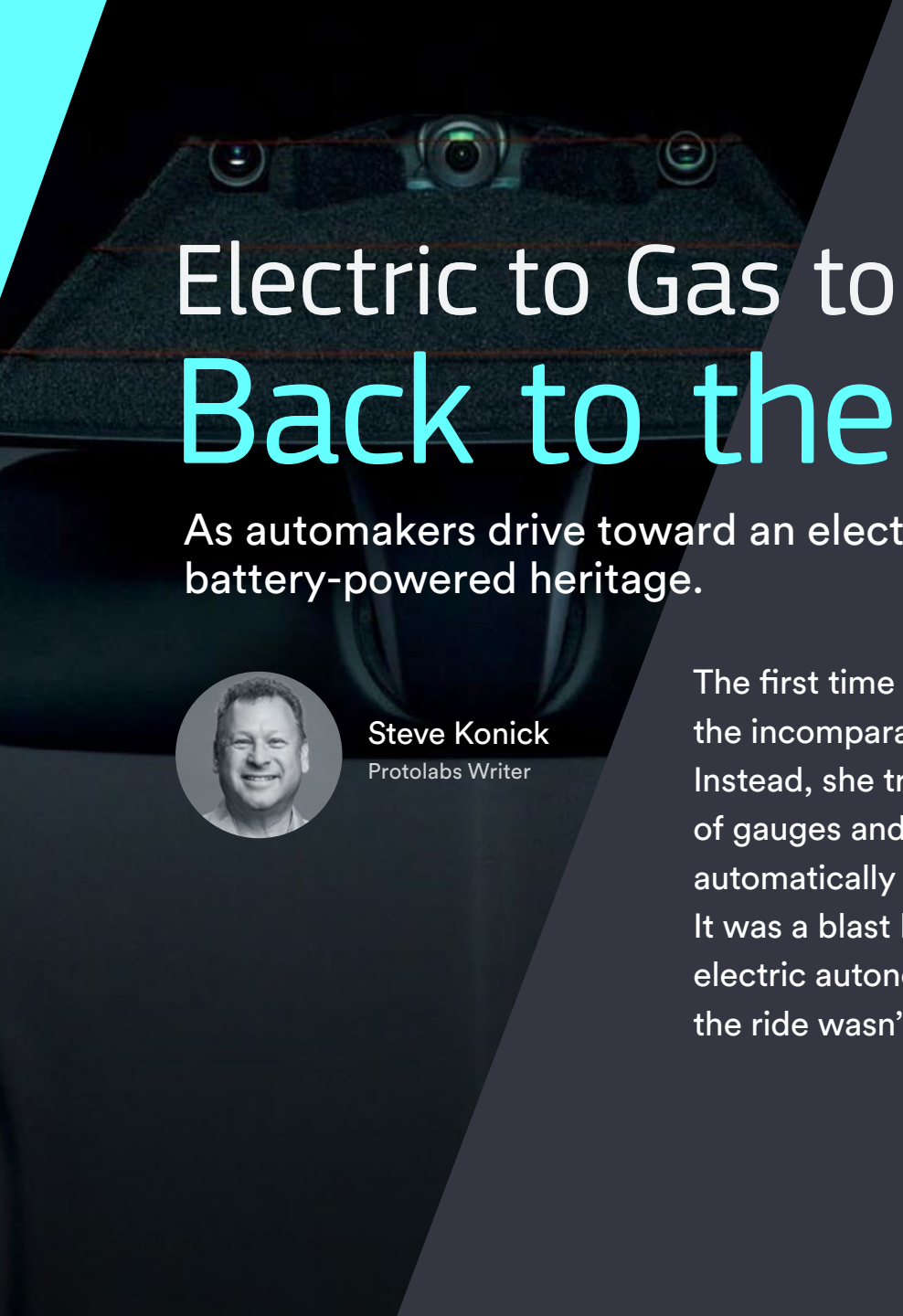

Electric to Gas to Electric:
Back to the Future

As automakers drive toward an electric future, a glimpse back reveals a surprising battery-powered heritage.

Steve Konick
Protolabs Writer

The first time my friend took me for a ride in her Tesla Model 3, I buckled in and anticipated the incomparable feeling of massive acceleration. It's true. My Prius wasn't up to the task. Instead, she treated me to a quiet, seemingly safe ride in a cabin devoid of the usual passel of gauges and knobs. Using autonomous driving on the highway, my friend changed lanes automatically with the touch of the turn-signal, effortlessly dodging cars in the adjacent lane. It was a blast being a passenger, and I quietly dreamed of someday driving my own totally electric autonomous vehicle (AV). Heading back, I thought we were done. As it turned out, the ride wasn't over…

Charging Forward: The History of the Battery

To understand how we got to this point, and because it's fun to geek out, we need to delve into the history of the battery a bit then exit onto the EV highway. An easy starting point is the Leyden jar, which is no more than a glass vessel filled with water and coated with foil, both inside and out, and a metal rod poking out the top. Come close to the rod and—ZAP. Benjamin Franklin—as part of his kite-flying-in-lightning experiment almost 300 years ago—called his version a battery, though we think of it today as a capacitor, and the modern version is ubiquitous in electronic devices.

In 1800, Alessandro Volta invented the voltaic pile. This was the first true battery because the combination of zinc and silver could hold a charge even when not in use.

Gaston Plante developed the first lead-acid rechargeable battery in 1859, and in 1880, Camille Alphonse Faure improved upon Plante's work, using lead sulfates to expand electrical storage capacity.

Two more important battery technologies followed. First, was the nickel-cadmium battery in 1899. The NiCad, as we call it today, was the first truly functional rechargeable battery. It was also the first alkaline battery, swapping out lead acids for an alkaline (basic, or high pH) electrolyte. Today's modern lithium-ion batteries first arrived in 1912. Li-ion has the advantage of holding more electricity while having low weight, compared to other battery products. In 1991, SONY released the first rechargeable Li-ion battery. More advanced versions of Li-ion batteries are the current international standard for EV and AV vehicles as they better tolerate discharge-charge cycles.

Early Volta Battery

The History of Electric Vehicles and Hybrids: Sparking the Future

Tech history dictates that you have to do something with your new device, so you know someone was going to plunk a battery (or a whole bunch of them) into a carriage. Scottish inventor Robert Anderson was that guy. In the 1830s, he developed the first electric vehicle. Batteries were obviously unsophisticated back then, severely limiting range. In the end, this was more of a proof-of-concept than a functional mode of transportation. But at this point, we're in first gear.

In 1887, William Morrison prototyped his first "electric carriage." A later version attached 24 heavy battery cells to the rear axle of a reconfigured horse-drawn carriage, probably leaving horses to snicker at its lack of speed and stamina.

It wasn't until 1894 that the first commercially viable EV—the Electrobat—was released. Sadly, for having such a great name, it was overly weighted-down by its batteries and rough-riding steel tires. After several iterations, it's now relegated to history, and might even be an answer on Jeopardy!

The first hybrid vehicle—made by Lohner-Porsche and called the Semper Vivus ("always alive")—came out at the turn of the 20th century. It followed in the steps of its older sibling the all-electric Egger-Lohner C.2 Phaeton. That's right! The first car with the Porsche name affixed to it was part electric!

You probably knew that somewhere along the way, the founder of General Electric, Thomas Edison, would drop into the history of electric cars. In the mid 1910s, the powerhouse duo of Henry Ford and Thomas Edison worked together to develop an affordable EV for the masses. The project never came to fruition, though, as the Edison batteries weighed far too much and couldn't properly power the car in many driving environments. That was the end of Ford's consideration of EVs as Ford moved exclusively to gasoline-powered autos, such as their already popular Model T. Other automakers followed suit. About a century later, Ford (the company) would revisit this decision.

Apollo 15 EV Moon Rover. Courtesy of NASA (top).
Late 1800s electric carriage *Electrobat* (bottom).

HOW DID WE GET HERE? Just take a trip through the electric vehicle timeline

1749
Benjamin Franklin improves on Leyden jar (electricity storage device). Calls it a *battery*.

1830s
Robert Anderson develops first electrically powered vehicle.

1859
First rechargeable battery invented by **Gaston Plante**.

1894
The **Electrobat** flies into history as first commercially viable EV.

1899
Rechargeable **nickel-cadmium** (Ni-Cad) battery invented. Still used today.

1899
Lohner-Porsche releases first hybrid vehicle.

1912
Lithium-ion (Li-ion) batteries developed. Holds more electricity, less weight.

1939
GM World's Fair exhibition, **"Futurama"** envisions a world of autonomous driving.

1969
GM's experimental **XP-883** is the first plug-in hybrid.

1971
EV goes to the moon via **Apollo 15's Lunar Roving Vehicle**.

1986
VaMoRs, a Daimler-Benz experimental autonomous vehicle debuts.

1991
First **rechargeable Li-ion battery**. Common in cars today.

1996
GM's **EV1 electric car** available for lease-only.

1999
First commercial hybrid, **Honda Insight**, goes on sale.

2000
Toyota releases the first ubiquitous **Prius**.

2012
Tesla Model S goes on sale.

2015
Tesla Autopilot available.

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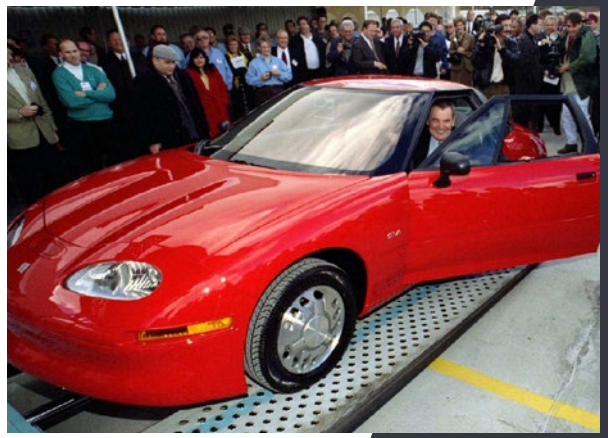
Mid-century EVs like the Henney Kilowatt and GM's Electrovair II never caught on with the public or stayed as concept cars. In 1969, GM decided to try something new with the experimental XP-883 plug-in hybrid. While plug-ins are on an ascension now, that one stayed on the drawing board, too. The next big news in EV was in 1971 when Boeing built the Lunar Roving Vehicle (LRV), essentially a golf cart that astronauts could use to take a drive in the country—on the moon. Apollo 15 astronauts were first, but Apollo 17's crew drove their LRV about five miles. To our knowledge, no one said "Are we there yet?" while riding in the LRV.

This discussion of EV and hybrid vehicles would be remiss if we didn't mention GM's EV1. Available primarily as a lease-only electric vehicle, it had lots of cool tech in the drivetrain. It never went beyond leasing. In 1997, Toyota released the all-electric RAV4 EV, which after 17 model years never sold well. But it's notable, in part, because Toyota worked on it with a little-known startup company called Tesla.

While the original hybrid vehicle concept parties like it's 1899, the Honda Insight went on sale in 1999. It was the first modern hybrid and is still available today. It was followed one year later by the car most people associate with hybrid technology, the Toyota Prius. The Prius lives on today with both hybrid and plug-in hybrid versions.

The luxury EV boom started in 2012 with the release of the Tesla Model S. Focusing on performance and range, though not on affordability, it quickly found an audience of enthusiasts and opened the door that other startup EV/AV manufacturers walked through, with traditional brands like GM, Volkswagen, Ford, Toyota, and others, following behind.



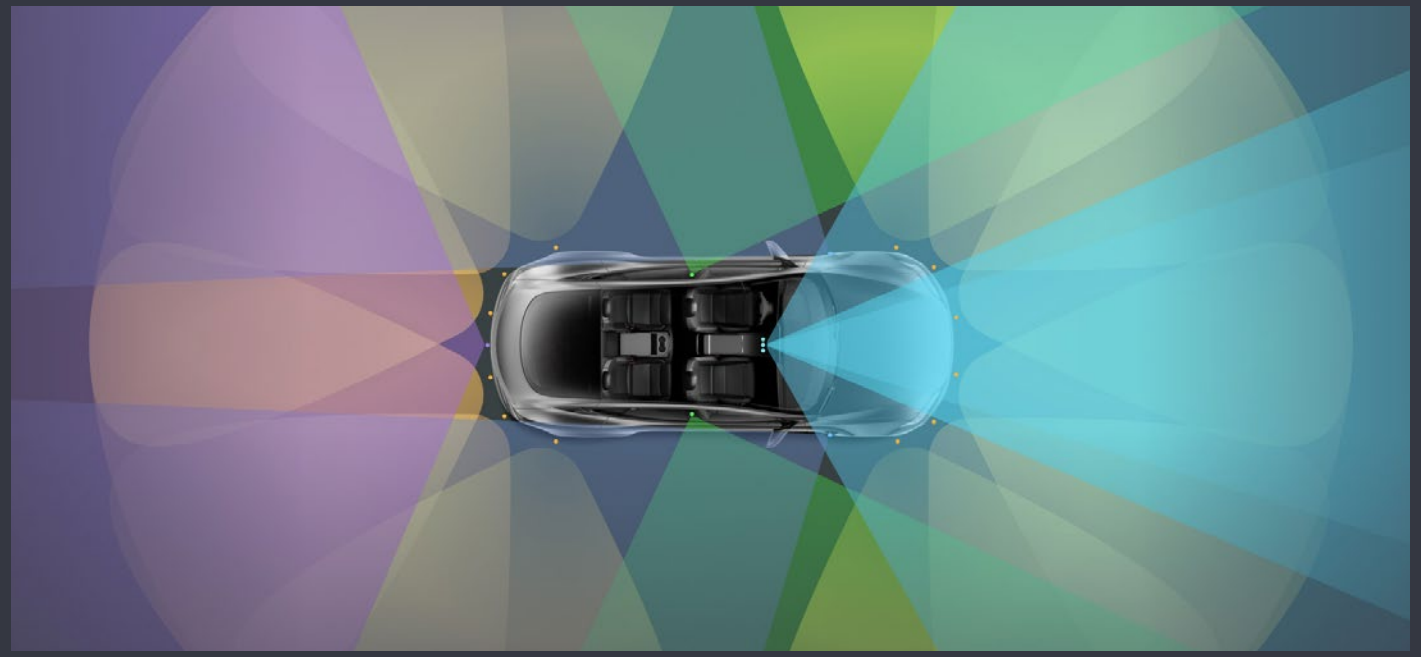
GM's EV1 Electric Car in 1996 (top).
First ubiquitous Toyota Prius in 2000 (bottom).

Joining the AV Club

EV and AV vehicles are often spoken about in the same breath, as if they exist in the same ecosystem. AV really refers to automated safety and driving features that use sensors to interact with the environment. To that extent, basic AV has been around a long time: in traction control, cruise control, and the like. But modern AV technology employs even more specialized sensors, including laser-based LIDAR. Sensors explore the environment and react to stimuli, such as adjusting your car to the speed of surrounding traffic (adaptive cruise control), pedestrian detection, blind spot monitoring, and collision avoidance. These features involve high-requirement parts and assemblies to ensure that the sensors provide accurate data to the central computer system.

Ah, but the Holy Grail is hands-free driving.

What makes AVs so special is the promise that they will bring us 100% safe driving and effortless travel across long distances. Certainly, that was the dream presented in GM's 1939 World's Fair exhibition, Futurama. Admittedly, some of an AV's best features are not 100% ready for prime time (BZZZZ: Put your hands back on the steering wheel!), but as with all technology these days, software updates are bringing us closer to a safer driving world requiring less input from the driver. Time will tell if drivers—many of whom love the feeling of driving their cars—will be willing to cede control of their cars to an onboard computer.



An illustration of Tesla Autopilot sensors and cameras. Courtesy Tesla

Whether EV or AV, Digital Manufacturing Helps Drive Development

As well-known OEMs and tech-forward startups move aggressively to the game-changing future of EVs and AVs, digital manufacturing is there, supporting this shift. In many ways, it's a match made in heaven. Automakers are testing and experimenting with EV, AV, and related battery technology as they go, requiring multiple—and rapid—iterations. This type of R&D activity is well-suited for agile digital manufacturers that can provide multiple iterations, low-volume production, quality assurance systems, single sourcing, and more. Oh, and provide all of it fast, accelerating R&D and enabling companies to get to market faster with whatever products they are creating—EVs, AVs, batteries, charging stations, or the next breakthrough transportation technology.

A Sweet Ride

As for that first Tesla ride, 15 minutes after I got into the car, and figuring my friend was done with showing off her cool ride, she drove us to a quiet, uninhabited side road and slammed her foot on the accelerator. I flew back into my seat while she laughed maniacally. The power from the dual electric motors blew me away. I screamed like a little kid at a theme park. Unfortunately, like all of the best rides, it was over too soon. I spent the next two hours overusing the word "cool" and the next two weeks researching EV and AV cars. If only they can get the price down.

A side view and blind spot camera. Courtesy Tesla

An Eye on EV Innovation

Clean—not dirty—dozen shows range of electric vehicles hitting the market.

More automakers than ever are plugging into the electric vehicle (EV) market. By year's end, analysts say there could be 30 EVs from 21 different brands available—less than20 models from 12 brands were available in 2020.

As giant OEMs and innovative startups race to develop vehicles rapidly, tech-driven digital manufacturing is helping to accelerate that development and speed these modern EVs to market.

Accordingly, with all of the emerging EV choices, here's a snapshot of a dozen emissions-free, electric vehicles that represent the growing variety of innovation emerging in the automotive sector.

Electric SUVs

Cadillac LYRIQ

A luxury SUV, actual production models will probably be available in 2022, sources report. Bold styling, a striking front grill, massive wheels, two electric motors—one for each axle, one pedal driving, on-demand regenerative braking technology, and battery power that promises 300 miles on a single charge.

Est. price: $59,000.

Ford Mustang Mach-E

This compact SUV adds to the icon's long legacy. Will it be a positive or negative addition? That remains to be seen, but given Ford's history with the Mustang, here's hoping for the best. Raise your hand if you remember the Mustang II. Of course Ford did redeem itself with the cool Mustang Bullitt edition.

Est. price: $43,000.

Kia Niro EV SUV

An affordable, accessible hybrid option, plus, with this 2021 model, you get Kia reliability and a pretty generous range of around 240 miles before you need to recharge.

Est. price: $25,000.

Jaguar I-Pace

This 2022 model is a compact SUV that has all-wheel drive and starship-like, in-car technology.

Est. price: $70,000.

Electric Cars

Porsche Taycan

Just the fact that a luxury brand like Porsche is investing in this segment shows a commitment to EVs by the industry. Plus, Porsche is known for having its luxury innovations eventually trickle down to more affordable car choices.

Est. price: $80,000.

McLaren Artura EV

Super cool and super lightweight, the 2022 model is available for order now. And, though not fully electric, it may help get us over the hump from fossil fuels. But of course, you better bring a heap of cash.

Est. price: $225,000.

Upload a 3D CAD model today for an interactive quote with manufacturing analysis—within hours.

Tesla Model S and Model 3

We're cheating here by listing two Tesla sedans, but the company has been such a pioneer in this sector, it deserves a little extra credit. The designs are distinct, you immediately recognize these on the streets, and automotive reviews of both models have been mostly stellar. These cars also have the longest range and likely the quickest acceleration of any electric vehicle on the market. Range estimates approach 400 miles per charge.

Est. prices: S: $80,000; 3: $39,000.

Audi A6 e-tron

Sleek and elegant, this sedan is actually powered by two electric motors with one driving each axle, which endows it with all-wheel drive. This model should go on sale by early 2023.

Car and Driver estimates the price will be $80,000.

Honda Clarity

This sedan, which has been around since 2019, is offered either as a plug-in hybrid or a hydrogen fuel cell. As Car and Driver reported, despite its advanced methods of propulsion, the Clarity still functions quite nicely as a midsize family sedan.

Est. price: $34,500.

Electric Trucks

Rivian R1T

This all-electric pickup truck from the new EV startup, is expected to be available this fall after delays. Off-road capabilities have been impressive, according to reviews, and it has an estimated 300-mile driving range. A larger battery pack with a claimed 400 miles of range is coming later and will cost $10,000 more.

Est. price: $73,000.

Lordstown Endurance

Another EV pickup, another startup, another delay. Lordstown Motors, a startup company that took over an old GM plant in Lordstown, Ohio, has had leadership issues (including resignations at the top), but promises the truck will start production this fall. The Endurance offers a distinct look and overall design that, according to the company's website, is geared to be smarter, safer, and more productive for work (with a towing capacity of 6,000 pounds). The truck will feature four in-hub motors that will power the truck. Hub motor systems are regular features in electric concept cars, but none of those systems has yet made it to market, according to Car and Driver.

Est. price: $225,000.

Ford F-150 Lightning

This EV entry from the truck experts, the Lightning promises powerful towing and swaps the regular F-150's gas-powered V-6 and V-8 options for a pair of electric motors and one of two different battery packs, **Car and Driver reports**. The Standard-Range battery delivers up to 230 miles per charge and the Extended-Range version aims for 300 miles. The Lightning comes to market in 2022.

Est. price: $42,000.

As you can see, the future of the automotive industry is arriving now and into the near future with the growing variety of innovative EVs. And, unlike the auto industry's previous, traditional playbook for internal combustion engine (ICE) cars, which focused more on incremental model year updates than disruptive innovation, for EVs, automakers are testing and learning as they go. As a result, these companies are seeking help from agile digital manufacturers that provide rapid iteration, low-volume production, single sourcing, and quality assurance systems.

Vehicle Photos Courtesy of Manufacturer's Websites.

Steering Through Supply Shortages

How to navigate supply challenges as electronic and autonomous vehicle development ramps up.

Bernie Henderson
Director of Global Procurement
Protolabs

Anyone who's been out shopping for a new car or truck recently might be disappointed. Inventories are low, so that Iconic Silver F-150 XLT you were hoping for might end being an Oxford White Lariat instead. That, and there's little room for negotiating, even on used cars. This is especially true in the electronic and autonomous vehicle (EV/AV) market, where buyers can expect to wait months, drive hundreds of miles, or pay top dollar—and sometimes all three—for any car, truck, or SUV with an EV in its name.

A semiconductor chip shortage is making things especially challenging for the automotive industry in general. This chip shortage is expected to cost the global automotive industry **$110 billion in revenue in 2021**.

These challenges are especially concerning for those automotive companies in the middle of **unprecedented investment efforts** in the EV sector. EV investments will total $330 billion between 2021 and 2025. General Motors, for instance, plans to spend $35 billion on electric and autonomous vehicles between now and 2025. So now is not a good time to run into the headwinds of supply chain issues.

What's causing these vehicular hardships? Some might blame the tariffs. Others say it's all due to the pandemic. Still others suggest that a skilled labor shortage is the cause. They're all right, but so are the people who blame hurricanes in the Gulf of Mexico, frozen power grids in Texas, and a fire at a semiconductor chip plant near Tokyo, never mind a massive container ship blocking the Suez Canal. All have had a negative effect on the global supply chain over the past year or so, slamming carmakers as well as any other manufacturer that depends on raw materials and purchased components—which is basically all of them.

Supply Challenges Met with Procurement Flexibility

Speaking for Protolabs, staying ahead of resin shortages has been a challenge. The same is true for metals, machine tools, and laptop computers. Lead times are increasing and inflation has become noticeable. As the **New York Times** recently reported, in the automotive industry, the "cure for high prices is high prices."

As a global manufacturer, however, we have a fair amount of flexibility as to how we procure materials, and have been, in the past at least, mostly successful in making sure that we have enough to meet our customer demands. That said, we're not immune to shortages and recently have encountered issues just like everyone else. Accordingly, we're trying to focus on alternatives and consultation to solve problems, which is a little easier in a digital environment than a traditional one.

Of course, supply chain disruptions are nothing new. Shortages of everything from fasteners and paint to grapes and Sony PlayStations have occurred over the past couple of decades, yet most manufacturers would agree that these are unprecedented times.

> "The one thing that'll get everyone through the current situation is when customers work directly with their suppliers, no matter what type or tier of supplier they are."

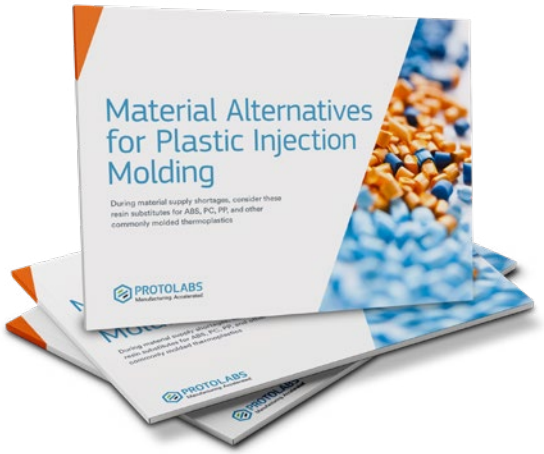
Source Regionally, Build Relationships

The most relevant question is what to do about these supply challenges. As the director of global procurement, I tell my team to source regionally as much as possible. Spot buy as needed. Don't be afraid to carry more inventory than we might like, and don't ever try to strong-arm suppliers. The market is simply too tough right now.

This last point is critical. It speaks to the importance of relationships and collaboration. The one thing that'll get everyone through the current situation is when customers work directly with their suppliers, no matter what type or tier of supplier they are. Because the more that we can work collaboratively together, the more that we can improve response times and meet one another's needs.

Alternative Materials, Agility, and Speed

That brings us back to digital manufacturing. When a customer uploads a CAD model into our system, we can not only help them make iterations or design changes based on product quality and cost-effectiveness, but also make adjustments based on the available materials. Carrying a wide variety of raw materials—and **alternative materials** during shortages—issues just like everyone else.



For production-based parts, the solution is a little different. In a world where lead times are unacceptably long because the customer's current supplier is overseas, we're usually able to fill the gap with different soft or hard tooling options, or help them redesign the part to make manufacturing faster. Recently, we have helped general automotive and EV-battery part suppliers inject more agility into their manufacturing process by helping them purchase components from us using our **on-demand production** option.

A close cousin to agility is speed, of course, which is a prime specialty of ours as a quick-turn manufacturer. How fast are we? Recently, one of our customers, told us he especially appreciated how fast we were, commenting that competitors of ours require one-and-a-half to two times the lead time that we do.

We look at manufacturing and supply challenges from the standpoint of speed. Whether it's the United States, Europe, or Asia, we're regionally based, so our manufacturing facilities are near our customers and suppliers alike. That makes us fast and flexible.

Despite all these current challenges, I think the manufacturing industry is through the worst of its supply chain struggles. It was a long time getting to where we're at today, and what we call normalcy remains a bit distant, but we're definitely marching toward a full recovery. In the meantime—and beyond—we just need to keep working together, solving problems, and meeting demands. That's what we're good at in manufacturing.

5 Ways Electric Vehicle Innovation is Being Driven by Digital Manufacturing

Rob Young
Product Manager, Injection Molding
Protolabs

Uh-oh, the cat's out of the bag. Electric vehicles (EVs) and the companies that make them are no longer hidden under a veil of secrecy, conducting business in non-descript warehouses up and down the coasts. We're now in a full-on race to develop the best technology possible, put it into electric vehicles, and ultimately deliver it to the masses—for drivers, for shareholders, and for the betterment of society.

But the game looks a little different in 2021. Automobile manufacturers used to have a strategic playbook for development, and it started with incremental model year innovation on a thoroughly vetted, proven, and predictable machine. That meant minimal iteration, predictable demand, high volumes, and so much red tape to cut through that thoughts about doing anything differently were quickly banished to the scary closet in your mind with Stephen King's IT and any movie in the last 20 years with a doll that talks (or is that just me?).

Well, even though clowns remain terrifying, the times have changed.

A lot of people doubted Elon Musk when he began with Tesla, and it wasn't just because he was an eccentric billionaire; it was because he was attempting to change the mindset of an auto industry that had been cemented into the collective vehicular brain in Detroit since the start of the 20th century. Internal combustion engine (ICE) vehicles were meant to be long range, and the new kids on the block cared more about sustainability. That one idea has spurred perhaps the largest sea change in automotive manufacturing since Henry Ford gave the ole' assembly line a chance.

And as a result of this paradigm shift, automakers and companies supporting those vehicles—think charging stations and LIDAR tech—are in a race to develop vehicles fast and get to market with new and innovative ideas before their competitors. But how can they do that? What will give them that advantage? Digital manufacturing is one big way—and here are five reasons why.

01

Modern Mindset

The ICE auto market has been around for a long time, and has had more than a century to perfect vehicle production. However, EVs have ushered in a massive shift in traditional thinking. Companies are testing and learning as they go, and they need manufacturers that enable quick iteration and agility. Enter digital manufacturing.

02

Digitalization x Quality

So what exactly does digital manufacturing even mean? It's essentially a tech-driven subset of the manufacturing industry that uses software automation and a network of connected machines to manufacture components, often at speeds that are unheard of in traditional manufacturing. Aside from speed, this digitalization brings some pretty important additional benefits to auto manufacturers—particularly quality. Virtually all of the manufacturing steps from part analysis to shipping are recorded, timestamped, verified, and stored indefinitely, meaning robust quality systems that happen fast and transparency from start to finish.

03

Low-volume Production

Perhaps the biggest shift in thinking, and one of the largest challenges that manufacturers face, is the low-volume nature of electric vehicles compared to their ICE counterparts. Product developers often face challenges like higher production costs for low volumes, if they're even able to get a manufacturer to take the contract. Traditional manufacturing business models really require volume to make the processes cost effective; at low volumes, you either pay a significant premium, or you don't get a quote at all. Digital manufacturing effectively eliminates the manual cost drivers that you find in traditional manufacturing, meaning quick turnaround and low volume production isn't just okay, it's truly what we were built for.

04

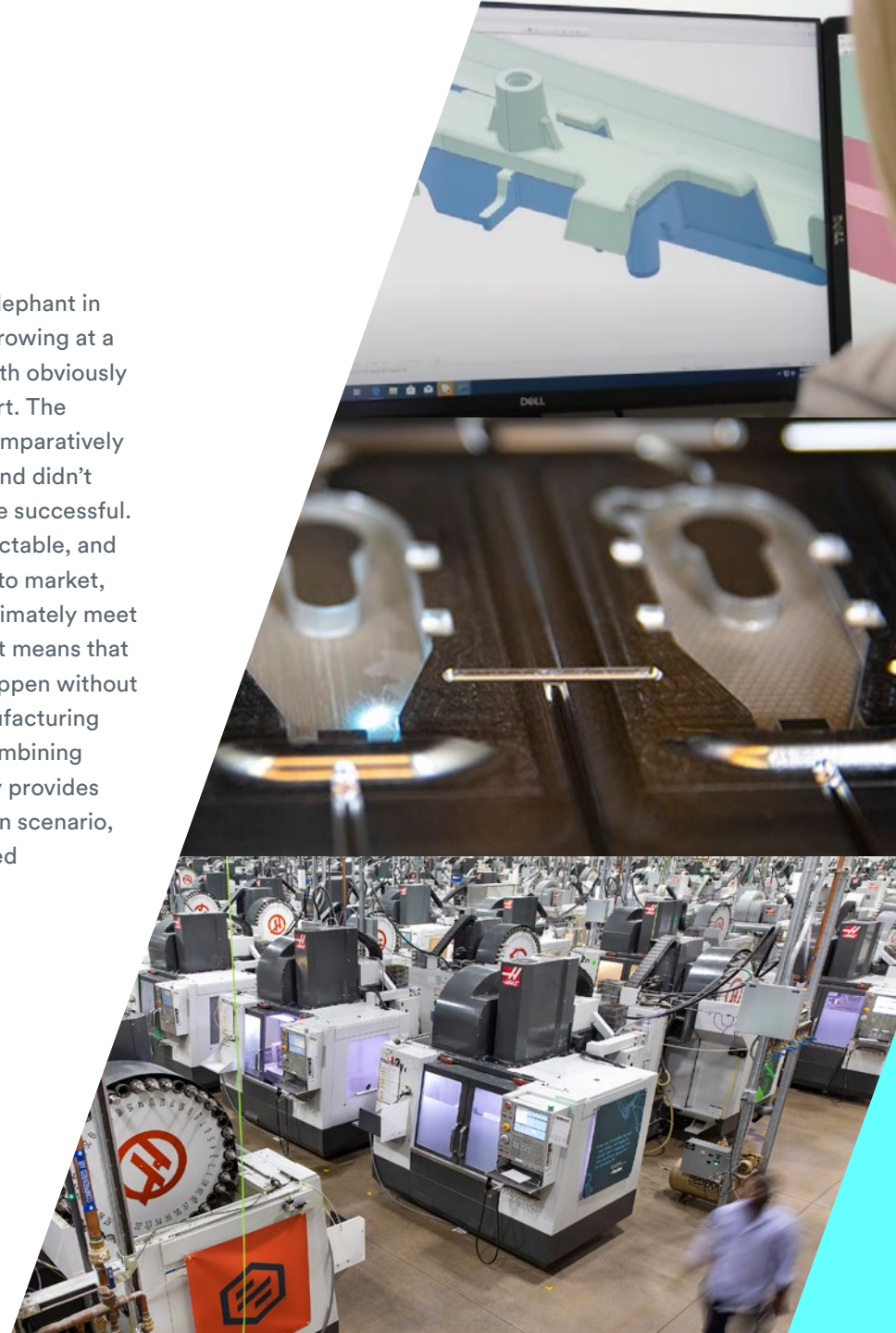
Single Supplier

When you need to move quickly, the last thing you want to do is switch suppliers. However, it's rarely as easy as just sticking with one supplier for the life of a component. Different suppliers have different specialties—some focus on speed, some focus on quality, some are low cost, and you can generally choose from only a few of those attributes. The nature of the digital manufacturing process gives it innate value in speed and quality. In fact, the speed at which digital manufacturers can move is what makes them so valuable for low-volume production, an area where they produce at significantly lower costs than traditional manufacturing. In the end, it lets you streamline your product life cycle from development to production.

05

Speed

Finally, we get to the 800 lb. elephant in the room. The EV industry is growing at a ridiculous pace, and that growth obviously requires manufacturing support. The traditional ICE mindset was comparatively easy to predict and forecast, and didn't necessarily require speed to be successful. EV however is much less predictable, and requires agility in order to get to market, meet launch initiatives, and ultimately meet shareholder expectations. That means that the entire process needs to happen without sacrificing speed. Digital manufacturing was built for this purpose—combining automation with robust quality provides an ideal low-volume production scenario, without having to remove speed from the equation.



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