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The Road to Automobility

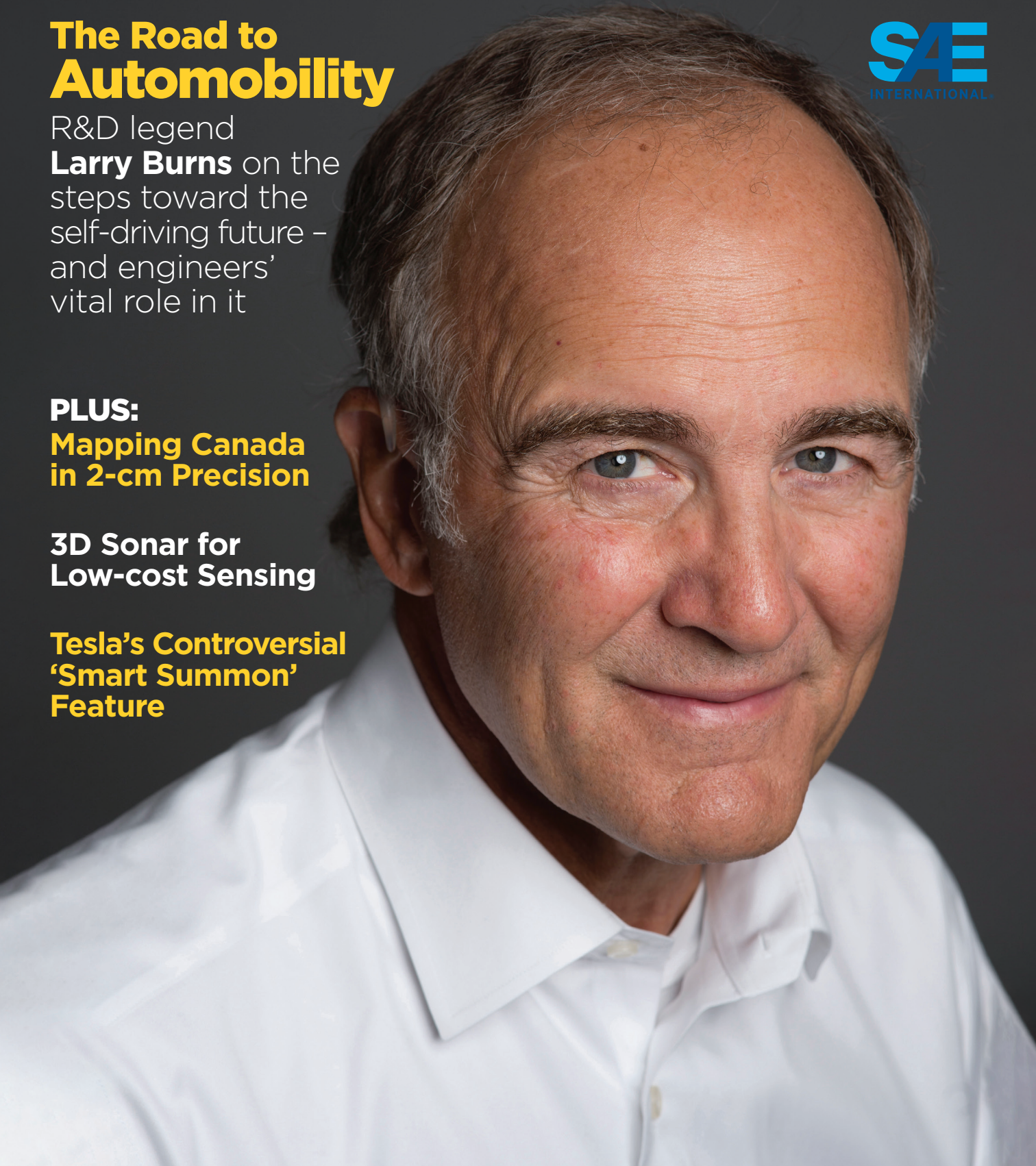
R&D legend
Larry Burns on the
steps toward the
self-driving future –
and engineers’
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The Road to Automobility

by Lawrence D. Burns

The era of electrified, self-driving vehicles is upon us. Engineers are key to the transformation – with much hard work still to be done.

In 1911, eight years after the Wright Brothers flew the first airplane, French general Ferdinand Foch dismissed the new technology. “Airplanes are interesting *scientific toys*,” he scoffed, “but they are of no military value.” World War I and the wave of aeronautical progress it triggered would prove Foch wrong. Today, *automobility* is the subject of a “hype or ripe” debate similar in spirit to what the airplane experienced in its nascent years.

Will automobility – transportation services based on autonomous electric vehicles – replace personal car ownership? Or is all the talk of this new era just so much hype? It’s a critical question for businesses that will be disrupted by driverless cars, and for investors.

While we have witnessed highly visible (and even deadly) pitfalls and outright mistakes, significant progress is being made toward this future. Many journalists and business analysts present this story as a *race*. I see it as a *quest*... a marathon, not a sprint. It is a long arduous journey like other transformational changes that have shaped our world.

Engineers and technologists who strive to make what’s possible real are best positioned to assess when autonomous-EV opportunities might reach market tipping points. While their timing assessments vary, nearly all conclude they are inevitable and will lead to widespread disruption of transportation. It is not a question of whether, but when. This article shares my perspective on the road to mature automobility.

The age of autonomous EVs for people and goods is destined to displace the age of automobiles based on human-driven combustion vehicles sold mostly to individuals. I believe this transportation future is fundamentally better than the past in terms of consumer value, user experience, vehicle design, business models and societal impacts. For people, it entails shared-use robotaxi services (Uber and Lyft without drivers) and exclusive use-subscription services—personal car usage without the hassles. For goods, it entails long-haul shipping (driverless Class-8 trucks) and local package delivery (mobile robots and drones).

Engineers are key to the transformation (Fig. 1). They innovate through product development and commercial learning cycles. I have observed this process with conventional and electrified powertrains, chassis-control systems, materials, robots, fuel cells, telematics and many more advances. And based on my experience, transformational change is never tidy. There are always false starts, setbacks, failures and players who can’t stay in the game. It’s like running a marathon in the fog with an unknown route and unknown terrain.

However, if a new product or service can deliver compelling benefits at a competitive price and profitable cost, then engineers and marketers find a path through the maze that leads to large-scale commercial success. Such quests are grounded in learning and require vision, purpose, courage, knowledge, patience, deep pockets



The transportation service market will have differentiated segments for people and goods – from value to premium experiences such as the Volvo concept shown. It encompasses urban to rural settings; short one-rider commutes to long family trips, and local deliveries to long-haul trucking.

and adaptability. There are rarely any short-cuts.

Automobility is on the verge of commercialization and is destined to grow to maturity through generational learning cycles. Big ideas have been conceived, fascinating concepts have been proven and prototype services have been demonstrated. There is much more hard work still to be done, but several companies are close to launching first-generation commercial automobility services in line with their driving systems' proven capabilities.

Where are we headed?

Today in the U.S., 80% of roadway vehicles are personally owned, 85% of personal travel is by automobile and 88% of households own a car. Automobiles dominate personal travel because they allow us to go almost everywhere, whenever the need arises and under a wide range of conditions. They supply a broad array of transportation *use cases*. This vast accessibility means you do not have to solve a transportation problem every time you want to go somewhere.

If you have your own car and it is parked nearby, you simply get in it and go. Accessibility explains why we buy automobiles and then park them over 90% of the time. For automobility to displace automobiles, transportation services using autonomous EVs must also serve a broad array of use cases under a wide range of conditions and do so better than automobiles. Automobility must

provide both compelling trips and vast accessibility.

This will not happen in one step. Instead, it will be accomplished through commercial learning cycles with improving autonomous driving systems, safely serving expanding sets of use cases each step of the way. This growth dynamic starts with first generation services and converges on mature automobility.

SAE Level 4 High Automation Driving is an important enabler of automobility growth. Level 4 systems allow vehicles to operate without any human inputs for pre-specified use cases. "Geo-fencing" defines the use cases a Level 4 autonomous vehicle can serve – the vehicle's accessibility. It puts a virtual boundary around those places you can safely get to autonomously and the conditions (e.g., times, weather, traffic density) under which this can be done. It allows automobility learning to occur with expanding accessibility safely enabled by improving autonomous driving systems.

Companies are targeting Gen 1 commercialization in a variety of ways by focusing on different geo-fenced use cases. Zoox and GM/Cruise are in San Francisco with its fog and hills. Optimus Ride and Voyage are in gated communities deploying low speed solutions. EasyMile is pioneering low speed shuttles on campuses and Nuro is learning with low speed package delivery. Peloton Technology is positioning with Level 4 automated following for over-the-road trucks. Walmart has



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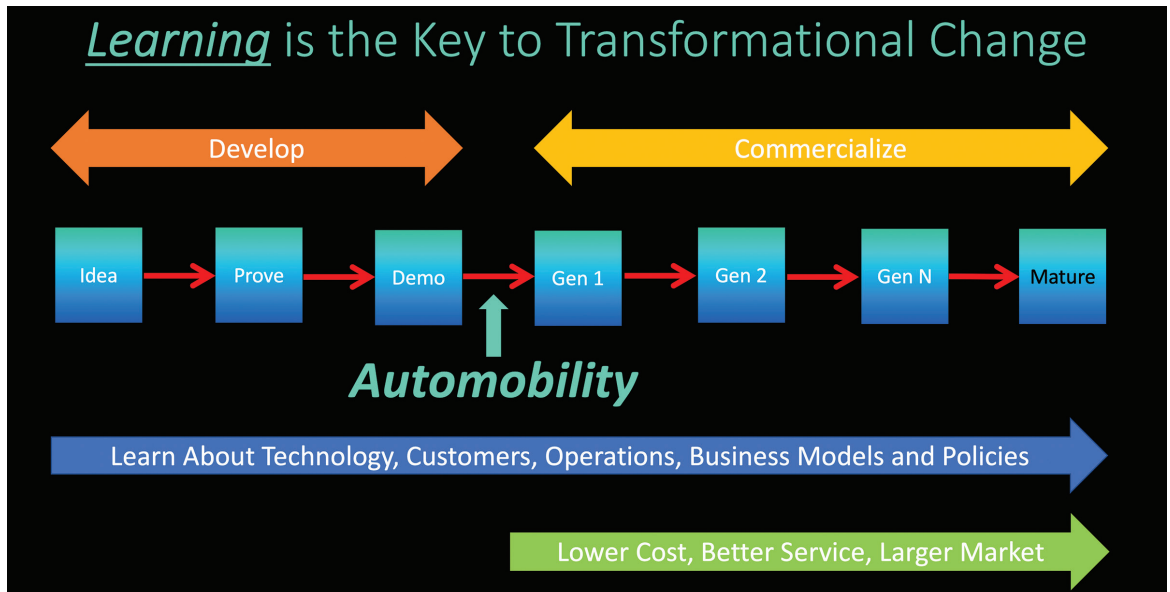


FIG. 1— Automobility is on the verge of commercialization and is destined to grow to maturity through generational learning cycles.

teamed with Gatik to automate “mid-mile” logistics. And, Waymo is learning to serve a portfolio of use cases in numerous U.S. cities under a wide range of traffic and weather conditions.

As shown in Figure 2, Gen 1 automobility will only cover a small set of use cases. This poor accessibility will limit automobility to supplying relatively few trips. Gen 1 service clearly will not motivate people to give-up their personal cars. But it will enable first-mover companies to learn how to improve their autonomous driving systems so they can safely serve a broader set of use cases, improve customer experiences and reduce cost in the next generation.

Gen 2 automobility offers more accessibility, captures more trips and begets Gen 3 systems. This dynamic will continue until autonomous EVs offer substantial accessibility and compete with personal automobile ownership. When this occurs, non-AV modes will be serving niche use cases.

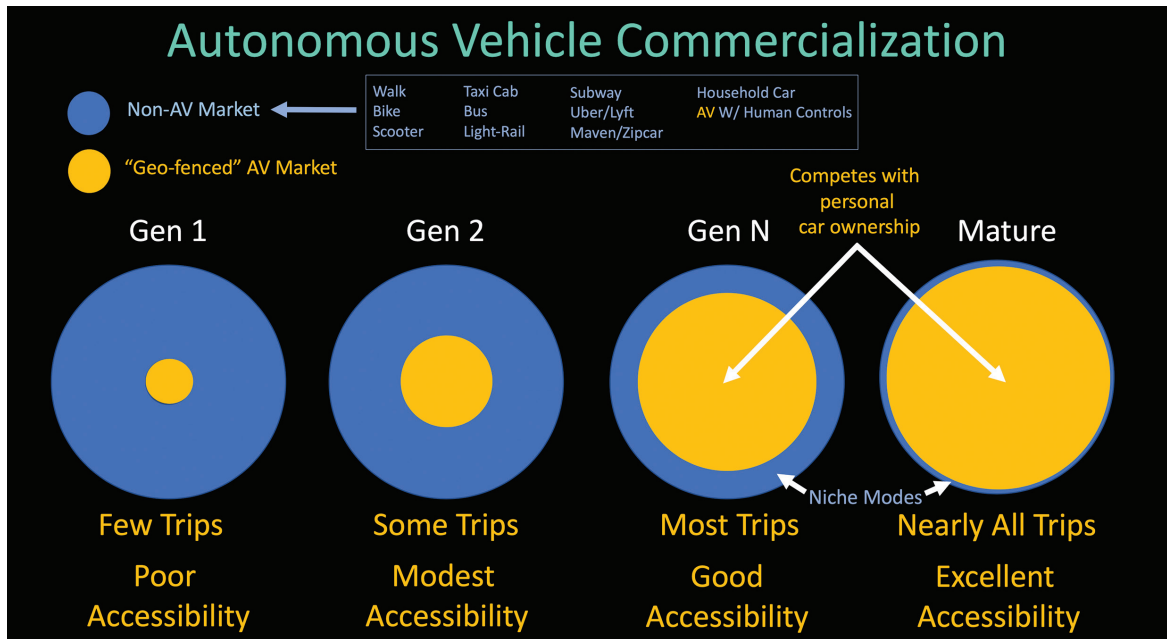
With each generation, Level 4 capability grows safely, the set of use cases served by AVs expands, cost per mile declines, service experiences improve, and commercial cash flow helps fund the next generation.

The non-AV modes remain essential for access outside the geo-fenced market. As such, AV and non-AV modes are interdependent, with the non-AV market share decreasing with each generation. Ultimately, automobility will eliminate the demand for personal car ownership and replace it with autonomous EV subscription services. These will offer exclusive vehicle use by trip, hour, day, week, month or year.

Implicit in the mature state of automobility is that SAE Level 5 Fully Autonomous Driving is not attained. Just like today’s aviation system does not allow all locations to be reached under all weather conditions, there will always be some use cases that AVs can’t handle; there will always be a “geo-fence.” This remaining niche market will be served by human-driven vehicles.

An important conclusion about the road to automobility is that the *safety leader* will be positioned to be the *market leader*. The safety leader will be able to:

- serve more use cases and learn faster than competitors
- make more confident, expedient and refined autonomous driving decisions resulting in better ride experiences
- realize a larger trip market share and better pricing



Burns

FIG. 2— The road to automobility. The outer circles represent all of the places one could go under all times and conditions with all ground transportation modes. The yellow circles represent the use cases that will be served by each automobility generation. The blue doughnuts represent the rest of the market being served by human controlled modes.

This means the quest for automobility leadership becomes the quest for safety leadership, which is exactly the way it should be: market forces driving safety and safety driving market performance.

Mature automobility – what’s at stake

My perspective on the mature age of automobility is conjecture based on my experiences in the auto and tech industries and what I have learned as a student of transportation and innovation. I know such speculation will likely prove to be wrong in some respects. Nevertheless, the six defining features of mature automobility shown in Figure 3 are what I see when I “connect the dots” for automobility. This is my best foresight at this time.

Automobility will be significantly safer than automobiles for all road users. Transportation service providers will be required to meet safety standards and regulations emerging as this new industry matures.

Nearly all trips will be supplied by transportation services using autonomous EVs. This will result because the value offered by these services will far exceed the value of owning and operating a car due to the compelling experiences and relatively low cost per mile of automobility. Riders will subscribe to a service and pay for shared and exclusive use of vehicles by trip, hour, day, week, month or year. You will not need to focus on driving, look for parking or stop to buy gas.

You will avoid the hassles of shopping for, insuring, financing and maintaining a car. You will be picked-up at your door at a moment’s notice and safely dropped off precisely at your destination. And, you will likely end your ride feeling better than when you started it.

The transportation service market will have differentiated segments for people and goods – from value to premium experiences; urban to rural settings; from short one-rider to long family trips, and from local delivery to long-haul trucks.

Vehicles will be owned and managed primarily as fleets with customer experience, service quality and cost per mile being the bases of competition. These companies will optimize lifetime fleet utilization and cost. They will use past and real-time data and advanced analytics to continuously improve operations, enhance customer experiences and optimize cost per mile.

A penny per mile will matter a lot, whether earned through higher pricing (from better experiences) or saved through lower cost (from better operations and vehicles). To illustrate, a penny per mile is \$3,000 for a 300,000-mile-life autonomous EV and \$30 billion a year for the 3 trillion miles Americans drive annually.

Operational excellence will be essential for automobility service providers to prosper. Managing transportation operations is challenging given the



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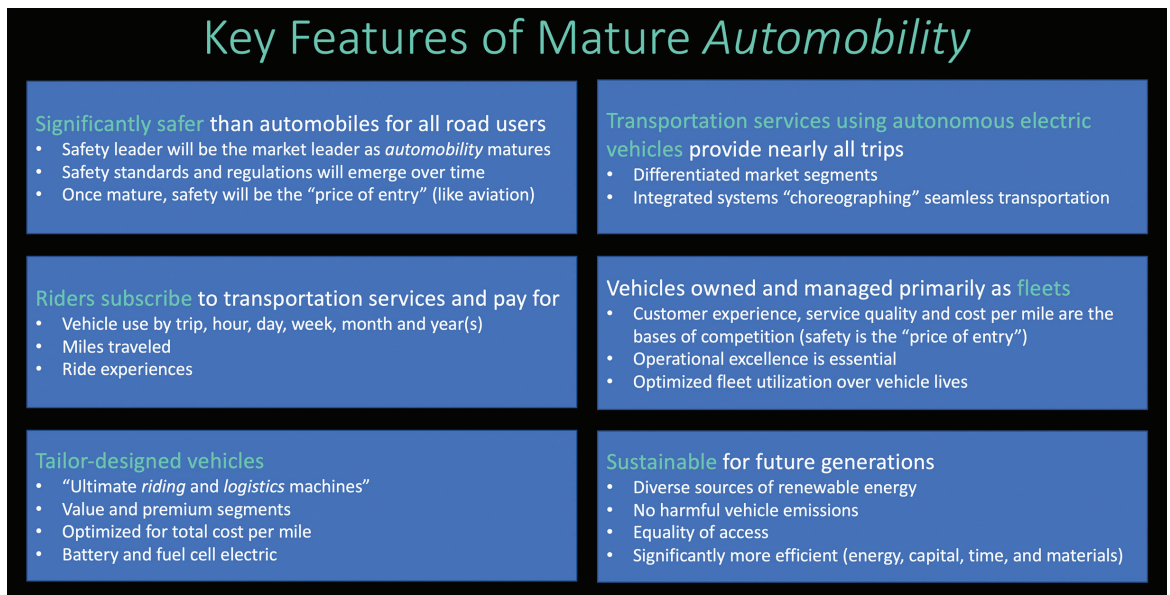


FIG.3 – When automobility reaches a mature level, vehicles will be tailor-designed for duty cycle, safety and cost-per-mile.

stochastic nature of everyday travel. Stuff happens randomly. Roads ice-over. Traffic peaks. Equipment fails. Vehicles get dirty. Customers will *always* expect their ride to show up as promised, their vehicle to be clean and refined, their route to be intuitive, and their arrival to be on time. They will not tolerate excuses and they will look elsewhere for services if brand promises are not met. Operators must be adept at meeting these lofty expectations while realizing high fleet utilization and uptime, and long vehicle life.

Vehicles will be tailor-designed for the types of trips they serve. They will be ultimate riding machines rather than ultimate driving machines, be optimized for safety, ride comfort and total cost per mile and be electric (both battery and fuel cell). Designers will be freed from the packaging constraints defined by current safety regulations, human factors for drivers and combustion powertrains. And they'll have the opportunity to create compelling transportation experiences, not just compelling cars.

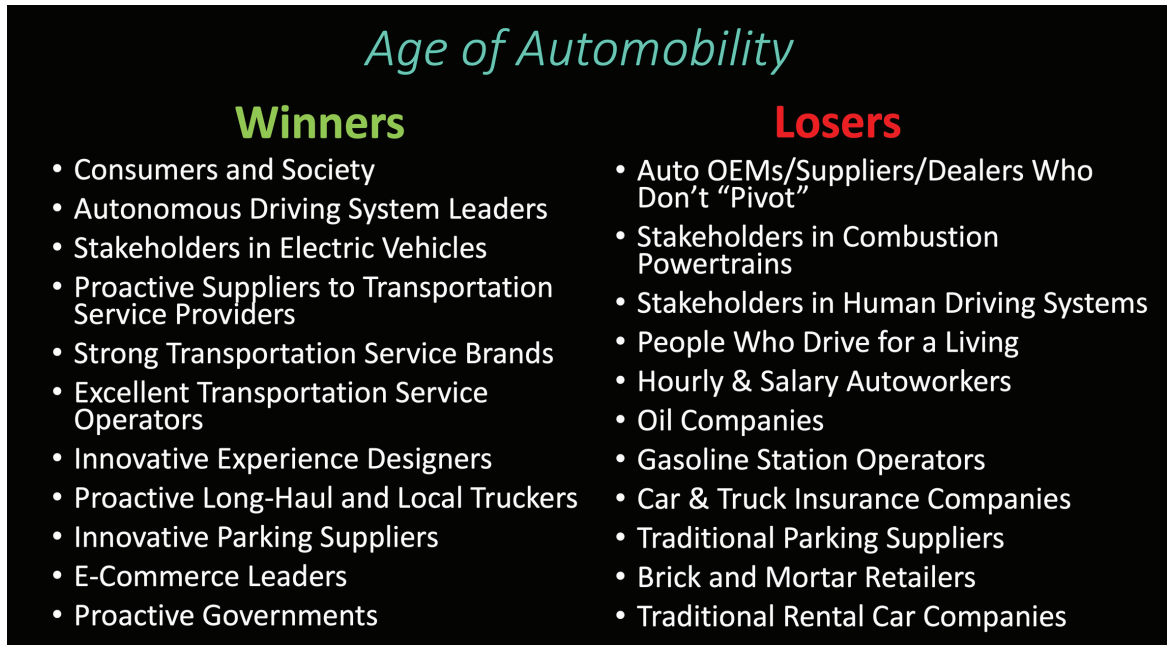
Trading human drivers for autonomous systems reduces operating costs and vehicle costs. Similarly, electric vehicles are less costly to operate and maintain than their gas-powered counterparts. And because

80% of the car trips Americans make have only one or two occupants, autonomous EVs can be tailored to be smaller and lighter. Combined, these factors mean that transportation service vehicles will have far *fewer* parts. They'll be much simpler to develop and build—and consequently, manufacturers will require far fewer salaried and hourly workers.

The auto jobs impact of automobility is further compounded by the fact that transportation-service vehicles will likely last twice as long (in miles) as today's vehicles, likely reducing the number required to serve American's travel needs.

Finally, mature automobility will be sustainable for future generations. It will rely on diverse sources of renewable energy and produce no harmful vehicle emissions. It will be significantly more efficient in the use of energy, capital, materials and time. And, accessibility will be more equitable for old, young, poor and disabled people.

The stakes in the quest to build the driverless car are high indeed. Based on my research at Columbia University, \$4 trillion per year of the U.S. economy could be redistributed among consumers, companies, workers and investors once automobility matures.



Burns

FIG. 4— Investing in new capabilities and shedding obsolete resources will be a tall order for many incumbents.

Incumbents in the many industries that automobility will disrupt must be prepared for how autonomous EVs used in transportation services will impact their customers, revenue, profit and valuations. They also must position for opportunities that align with their core capabilities, invest in new capabilities and shed obsolete resources to remain relevant. This is a tall order, especially for players like auto OEMs who must continue to invest and operate legacy businesses that likely will shrink over time.

Navigating the road ahead

Auto companies and technology investors are making a wager when considering automobility: the potential gains if you commit to this future, versus potential losses, if you cling to the past. My conclusion is that players with a stake in automobility should behave as if it is inevitable. If you want to be one of the winners and avoid being one of the losers, you need to join the quest and be proficient at navigating the road ahead.

It matters little whether initial commercialization occurs in 2020, 2022 or even 2025. Gen 1 commercialization will eventually happen and beget Gen 2, which will beget Gen 3 and so on, until eventually automobiles as we have known them go the way of the horse and buggy.

Importantly, at this stage in the journey, you don't need to bet the farm. But you do need a seat at the table,

some strong cards to play and the insight to know, as singer Kenny Rogers famously put it, "when to hold 'em and know when to fold 'em."

Whether you are a large incumbent with a long history or a small start-up with Series-A funding, to navigate the road to automobility you must learn about technologies, customers, business models, operations and policies. You must learn fast, efficiently and systematically with real commercial applications in real markets. This will position you to ultimately scale smart which is when the big money comes in play.

The capabilities required to excel in the age of automobility as a totally vertically integrated service provider are so vast that it is hard for me to imagine such monolithic players emerging. A co-dependent ecosystem, similar to what arose as the internet matured, is more likely (Figure 5). Players in the upper tiers of this system who are close to automobility consumers will learn market requirements. They'll rely on players in the lower tiers to meet sub-system and component specifications. All players must be open to collaboration and adept at building win/win business relationships.

If you intend to be an automobility service provider, you need to craft commercial learning opportunities in line with the use cases your autonomous driving system can safely serve. If instead you intend to supply a facet of the ecosystem, you need a seat at the table with the players

commercializing services to learn the requirements you must meet. Don't, for example, try to specify the requirements for a future generation sensor in isolation. The requirements of future lidars will depend on what future radars, cameras, digital maps, onboard processors and autonomous driving software can do in the context of what is required for safety and to succeed in the market.

Business and government leaders must deeply understand what is possible with evolving technology (especially digital) and innovative business models.

Only those working on the cutting edge of knowledge and know-how comprehend what must be true to expand use cases and how these requirements might be met. Only those profound experts who have learned how to safely handle the first 99% of the challenges of real-world driving can assess what is required to handle the remaining 1%. This is why learning and talent are fundamental to automobility leadership.

You should not get distracted by or make decisions based on forecasts of mid-to-long term market penetration. Such forecasts are fiction because they are based on many variables beyond anyone's control. Instead, you should focus on what must be true to reach a market tipping point and the potential timing of these conditions.

Markets tip when customer value exceeds market price (so people want to buy it) and market price exceeds supplier cost (so companies want to supply it). This is the magic moment when it is clear value exists and money can be made in the market. It is the moment when new innovations take off and demand begins to accelerate rapidly. It is the moment when investors start flowing boatloads of capital to fund the growth of what is now perceived as a lower risk opportunity with more certain upside. And, it is the moment when Wall Street is brutal to those clinging to the past.

For the automobility market to tip, Level 4 autonomous driving systems must safely enable commercially meaningful transportation use cases. Customers must embrace automobility for these use cases based on the value they provide. Regulators must allow automobility services to be commercialized based on their assessment of societal risk. And society must not allow progress to be impeded by players with strong vested interests in the age of automobiles.

My sense is that these tipping point conditions could be attained within five years with Gen 2 or Gen 3 commercial automobility services. Whether they are met depends on what remains to be learned, how fast this knowledge and know-how is gained, and random events (e.g., wars, recessions, politics) that are tough to control.

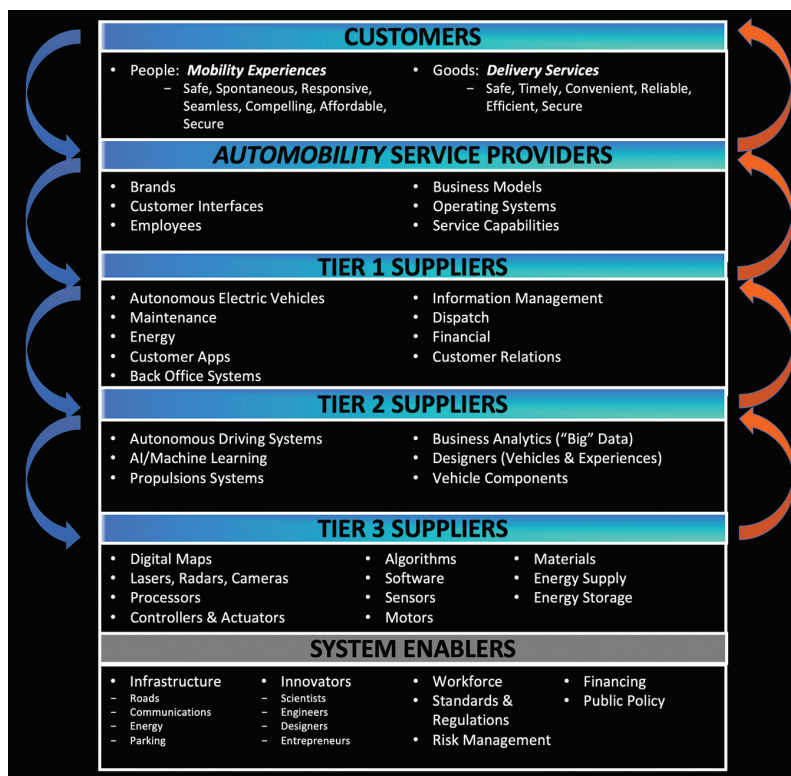


FIG. 5— The co-dependent automobility ecosystem.

Finally, as you learn your way to the market tipping point, focus on making value using:

- design and technology innovation to ensure and enhance compelling customer experiences
- operational excellence to deliver consistently positive customer experiences

While substantial progress has been made, we are still on the first leg of the road to automobility. The innovation is in its infancy; there are plenty of opportunities for new ideas and breakthroughs.

I believe the biggest risk is not realizing automobility's profound and compelling societal opportunities as soon as we safely can. ■

Lawrence D. Burns, Ph.D, advises organizations on the future of mobility, logistics, manufacturing, energy and innovation. His current clients include Waymo, Peloton Technology, and Kitson & Partners. Larry served as General Motors corporate VP of R&D and Planning from 1998-2009. Between 2010 and 2016, he was professor of engineering practice at the University of Michigan, director of the Program for Sustainable Mobility at Columbia University, and an advisor to several major companies. Larry's latest book (with Christopher Shulgan) is *Autonomy: The Quest To Build The Driverless Car—And How It Will Reshape Our World* (Ecco / HarperCollins, 2018).