INVESTMENT STRATEGY UPDATE

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AUTONOMOUS VEHICLES

"I thought cars were the dominant lifeform. I was trying to introduce myself."
Douglas Adams, *The Hitchhiker's Guide to the Galaxy*

As investors in an age of technological wonders, there is no shortage of astounding products and services in which we could invest. Some are viable now, some may be in the future, and some never will be. On that scale, driverless cars or "autonomous vehicles" may at first seem like one of the more "out there" concepts. We all know they're being tested by a variety of automobile and technology companies, but how soon are they actually going to be on the roads with the rest of us? As of April 1 in California, and depending on where you live, some are already in action. In this *Investment Strategy Update*, we explore what is meant by an autonomous vehicle (AV), how far along the industry is toward achieving full autonomy, and as always, the investment implications presented by the trend towards AVs.

How Close Are We?

The goal of autonomous vehicles should be clear to anyone who's ever sat in traffic, gotten lost, or had an accident: taking imperfect humans out of the driving equation and allowing them to focus on something else in transit. The extent to which a car can drive itself is defined by the Society of Automotive Engineers International as consisting of 6 levels, with Level 0 being no automation. Level 1 is assisted driving, as represented by adaptive cruise control or lane-keeping assistance. Level 2 is partial automation, where more than one task can be automated, such as steering *and* controlling speed. At Level 3, while a human still needs to be ready to take control, the car itself can conduct all of the driving tasks, as well as monitor the environment in certain circumstances, such as in a traffic jam on the highway. Level 4 is where it gets real because there doesn't have to be a driver present, but this level is only applicable in defined scenarios, such as on a highway or in a strictly defined section of a city. Finally, at Level 5, the vehicle can navigate itself anywhere on-road.

While some people may have experience with Level 1 or Level 2 automation, such capabilities are hardly ubiquitous, and while there is a regular production car that claims Level 3 autonomy, there is some controversy as to whether it really achieves it. So, it may come as a surprise that cars with Level 4 capabilities not only exist as test vehicles but are also legal and gaining extensive real-world experience in Arizona. This is a function of that state's Governor and legislature, who have adopted an incredibly laissez-faire attitude toward AVs (to wit, the car needs to be insured and have a passenger with a driver's license). With California looking to join Arizona in April and thousands of Level 4-capable vehicles being delivered to Google's sister company Waymo, 2018 looks like it could be the year of commercial deployment of driverless cars.

So, it's happening. But how is it happening? What sorcery allows a soccer mom in Chandler to get her kids to practice without getting behind the wheel? The answer is practically every technology you've ever heard of, and maybe some you haven't. Obviously, the concept of cars with no drivers is to some degree terrifying, so the way to make them reliable enough to get political support for their deployment among the general populace is to take the old belt-and-suspenders approach. First, there are the sensors, all of which have drawbacks. Cameras see colors like a human but need good lighting. Radar can see behind or around objects or in bad weather but won't spot smaller objects. Lidar (LIght Detection And Ranging) can see the smaller objects and therefore provide a high-resolution map of the immediate surroundings but is limited in range and currently very expensive. Add on top of these, GPS, ultrasonic (for short-range applications like parking and lane changing), and infrared (to detect heat and motion in bad conditions). Second, detailed map data provide the vehicle with foresight as to what it can expect from the environment. Third, high-speed vehicle-to-vehicle (V2V) communications provide instantaneously updated insight about the real environment beyond the range of the sensor suite. Finally, artificial intelligence assimilates and processes all the data in order to give the vehicle instructions.

With All That Technology, What Could Possibly Go Wrong?

Data collected to date indicate that the vast majority of accidents involving AVs were caused by human, not computer, error. This is the promise of AVs: When the technology is truly ready and universally adopted, it will save many of the 1.3 million lives lost on global roadways each year, cut the total number of cars in the world, smooth out traffic, lower carbon emissions, eliminate many parking lots, and so on. Sadly, the first known death involving an AV occurred just last week in Tempe, Arizona. While it seems likely that a human driver would not have avoided the accident, it also appears that the Uber vehicle in question never "saw" the victim. We are very curious to see whether this accident was a failure of automation technology generally, or Uber's technology specifically.

Either way, this accident reminds us that we will not be moving overnight to a world of AVs, as a variety of issues still need to be resolved. Perhaps the biggest concern is who is liable when things do go wrong. It used to be that one could rely on the fact that a computer couldn't do anything it wasn't specifically programmed to do. Glitches were a function of coding mistakes by programmers, which, when identified, were relatively easily fixed. An AV, however, is not simply adding large numbers quickly or saving a document to a hard drive. It is attempting to mimic the judgment a human requires to drive a car safely. As such, the vehicle is controlled by a computer system that represents a highly complex form of artificial intelligence known as a deep neural network. Such systems are "optimizing algorithms" that learn on their own, without human intervention, based on exposure to new data and experiences. This functionality makes AVs scary in one particular way: If something goes wrong, it may not be so easy to figure out why. Hence, it may be impossible to assign blame.

Another set of pitfalls of AVs is their focus on safety. They are bound to the law and rules of the road. They will respect the speed limit. They *should* defer to pedestrians, or to

human-driven cars that are rolling through stop signs or otherwise violating rules. The initial experience of an AV passenger and the drivers around them may therefore be frustrating. Also, despite the focus on safety, an extensive self-driving car environment connected by high-speed wireless networks could be a target of cyberattacks. Taking control of an individual vehicle has already been demonstrated, but another risk is that the overall environment could be compromised, perhaps through feeding bad data into the network or defacing road signs so that they fool the artificial intelligence systems.

Of course, positive government intervention, as opposed to a hands-off approach, is one way to speed up AV development, but such steps could lead to restrictions on personal freedom (e.g. the right to drive oneself). While that approach might work in some places, many of our citizens are likely to view this as very un-American. As a result, there are two on-ramps by which AVs are likely to merge with our driving culture. One is commercial trucking, which can be made much more efficient with today's technologies. A logistics company executive has noted that airplanes already essentially fly themselves, with the pilots present to handle takeoffs, landings, and emergencies. Long-haul trucks are similar, in that their driving scenarios are often simpler than driving around a city or its suburbs. A truck that could drive itself long distances and then call on a driver to handle local roads, parking, and cargo would improve the lives of such drivers, of whom there is a significant shortage. Using V2V communications to allow one driver to control a group of vehicles through "platooning" is another advantage.

The other "on-ramp" is transportation as a service. Residents of the Phoenix metro area will soon be able to hail a ride in a Level 4 Chrysler minivan. While there are 3.8 million Americans who drive for a living, there are millions more Americans who drive to, or as an incidental part of, their work. Letting them focus on work-related or other tasks while in transit will either make them more productive or just happier.

Investment Implications

There are a number of industries that would be impacted by the advent of AVs but, first and foremost, automakers will have to reconsider their business models. Singapore estimates it can provide mobility on demand with only one-third as many cars. While that example is probably the extreme of a densely populated and well-managed city, it seems clear that urban and suburban dwellers everywhere might reconsider how many vehicles (which sit idle 95% of the time) they actually need to own. Rather than selling cars, automakers could provide autonomous transportation as a subscription or a-la-carte service, with different pricing depending on what model is requested. In doing so, they will be competing with "new economy" companies that rely on extensive expertise in software, data analysis (an AV will generate an estimated 4 terabytes of data per day), and artificial intelligence. In fact, the vast majority of truly autonomous miles driven to date have been by Waymo and Uber. Both companies also happen to have deep pockets.

Semiconductor and sensor manufacturers also present a way to invest in the trend toward more intelligent vehicles in the nearer term. Such companies have for years been increasing the value of their in-vehicle componentry, and that course should only continue.

Deutsche Bank estimates current semiconductor content of a typical light vehicle at $350. Level 2 autonomous capability adds $100 to that, Level 3 adds another $400, and Level 4 yet another $200. For large trucks, semiconductor content is more on the order of $2,000 currently. Adding autonomous capability would expand that significantly more than for light vehicles because the sensor suite would need to envelop not just the truck but the trailer, too. Meanwhile, logistics companies could benefit the most in the near-to-intermediate term from AV technology as they face a driver shortage that is likely to get worse.

Communications infrastructure is another back door into the development of AVs and other Internet of Things applications. Over time, fifth generation (5G) wireless technology will provide the high bandwidth and low latency required by a variety of applications, including V2V communications. Denser networks to provide the necessary coverage will necessitate the build out of cellular base stations.

A discussion of AVs is not complete without a mention of electric vehicles, which some analysts believe will develop hand-in-hand with AVs. We're not sure that will be the case. Electric cars existed well over a century ago, but battery technology has developed much more slowly than computing technology. Perhaps the net added cost of a battery pack will eventually be more than made up for in fuel and maintenance savings. A breakthrough in solid-state batteries at vehicle scale would be most noteworthy. For now, we suspect the cost of the sensors, computing power, and artificial intelligence required to convert a normal car into an AV is, or will soon be, less than the ongoing cost of paying a driver.

Market Outlook

The return of volatility is the story of the stock market for the first quarter of 2018. After a strong rise in both stocks and interest rates in January, we have since experienced the first stock market correction in approximately two years. However, we view this corrective period as perfectly normal and healthy. Any type of news may trigger a downward move, and in this case, the rhetoric about global tariffs has understandably been a source of concern. That doesn't mean a new long-term trend has begun. We continue to believe the U.S. economy is in strong shape, and likely getting stronger in the short term due to the new tax law. Along with that strength, though, will eventually come higher inflation. Hence the rise in long-term interest rates. The Federal Reserve Board confirmed this trend in its most recent meeting, where it raised short-term rates a quarter of a percent. While we expect 2018 to be a decent year for stocks, we do know that this economic expansion and bull market will not go on forever. We are, therefore, keeping our eyes on the economic data and company-specific earnings.