We are in midst of a major Technological Revolution

One of the most dramatic developments is self-driving cars

Source: USDOT

Street scene, San Francisco, 1906

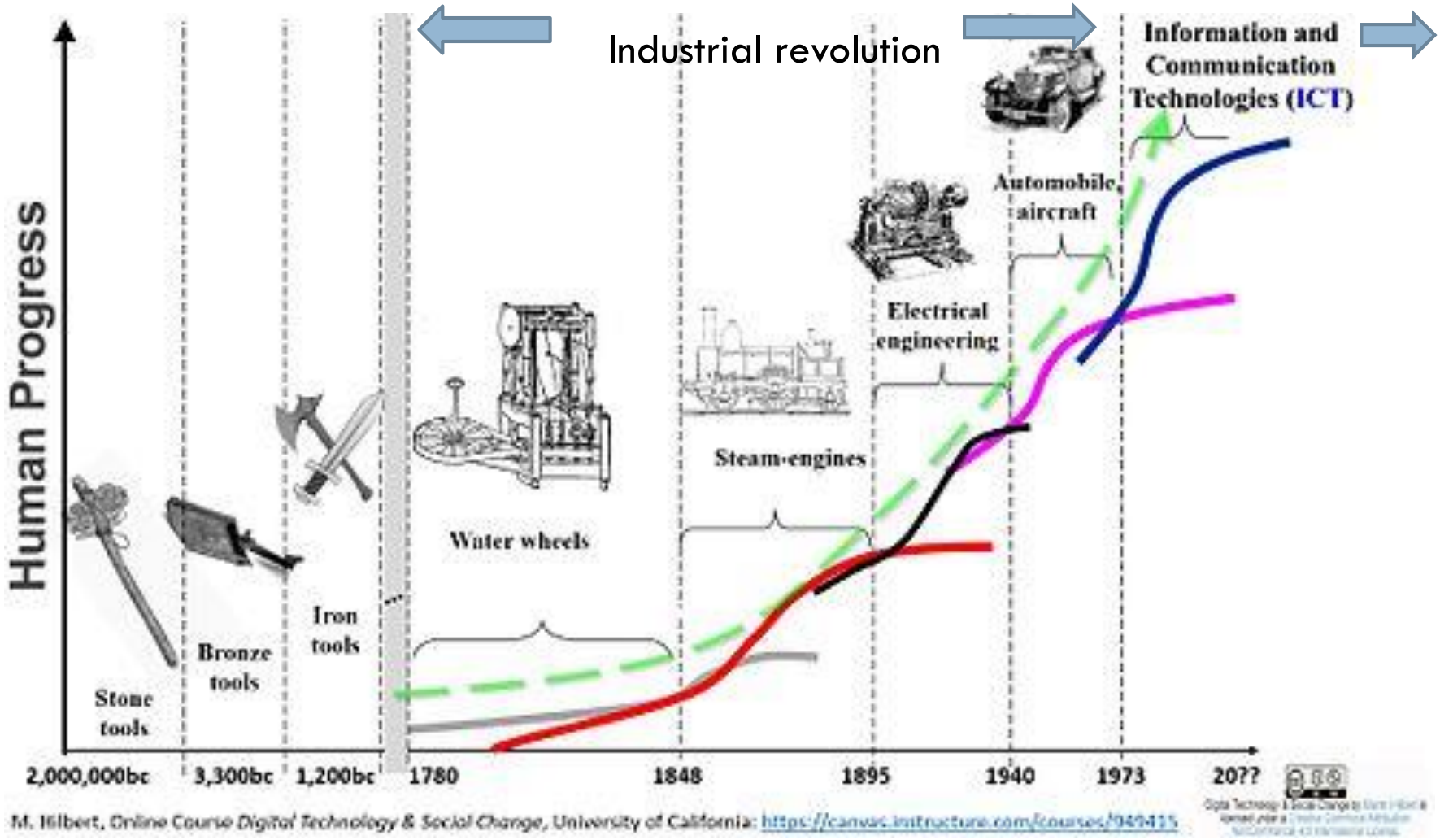
Objectives for Session

1. Technological Revolution (emphasis on transportation and logistics)
2. Self-Driving Technology Experience to Date
3. Likely Next Steps and Societal Implications?

The Technological Revolution

- We are in a second big economic revolution; this time its technological/digital (Second Machine Age, MIT Press)
- Many benefits to society of technology like global connectivity, mobility, productivity, knowledge dispersal, medical advancements…….
- But--Jobs are being 'destroyed' and new ones are slow to emerge for many. Oxford Univ. study says nearly half of all jobs are susceptible to at least partial automation.
- Causing economic inequality as well as social and political upheaval and likely to go on for decades.

Technological revolution timeline?



How technology has linked us in the early years of the 21st Century

- The Internet linked:
  - 1 billion people by 2005
  - 2 billion people by 2010
  - 3 billion people by 2015
  - Nearing 4 billion now
- Wireless Technology
  - Smartphones--nearly 2.5 billion users
- What is in store for the remainder of the 21st Century?

Robotics reducing need for labor

Robotics in automobile assembly line

Artificial Intelligence(AI): AI with super computers beating human minds

Google's Go Computer beats top ranked human in 2016

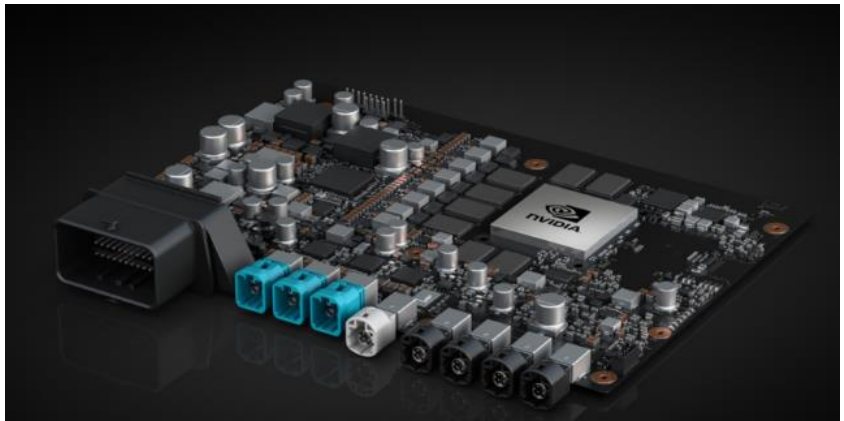
Go player Ke Jie competes against Google's artificial intelligence program AlphaGo during their second match at the Future of Go Summit in China.

Super Computers and Artificial Intelligence

- **IBM Watson in medicine:**

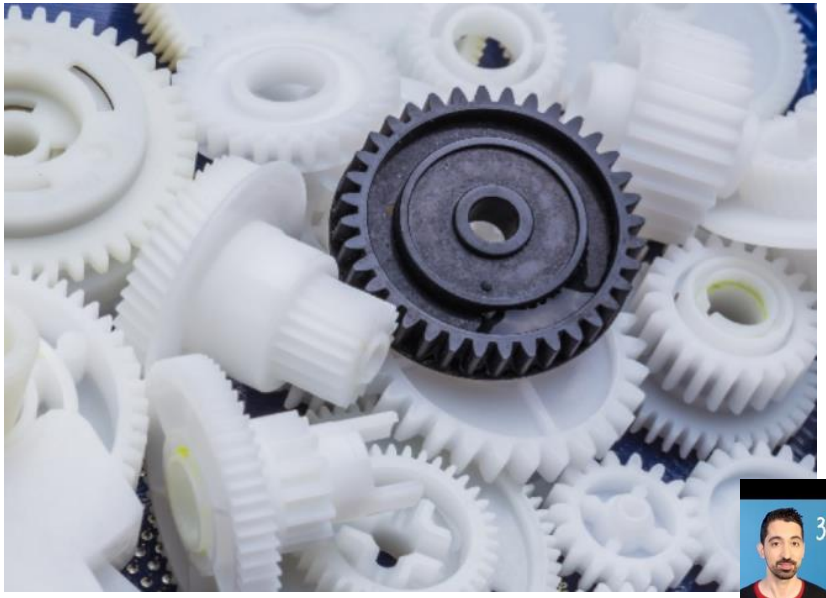
  A doctor reads about a half dozen medical research papers in a month; Watson can read a half million in about 15 seconds and quickly suggest diagnoses and promising course of treatment.

- **AI enabling self-driving cars:**



3-D printing: e.g. remote printing of replacement parts

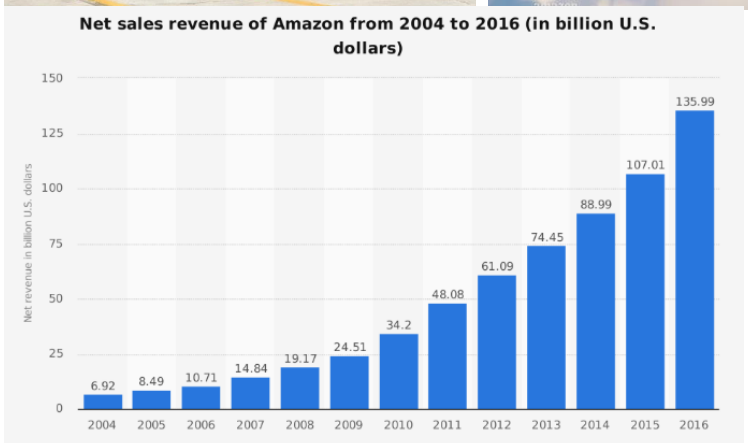
Could have big impact on transportation logistics.



The Amazon technological revolution

"Amazon is shredding the competition, and the competition just doesn't know what to do about it".

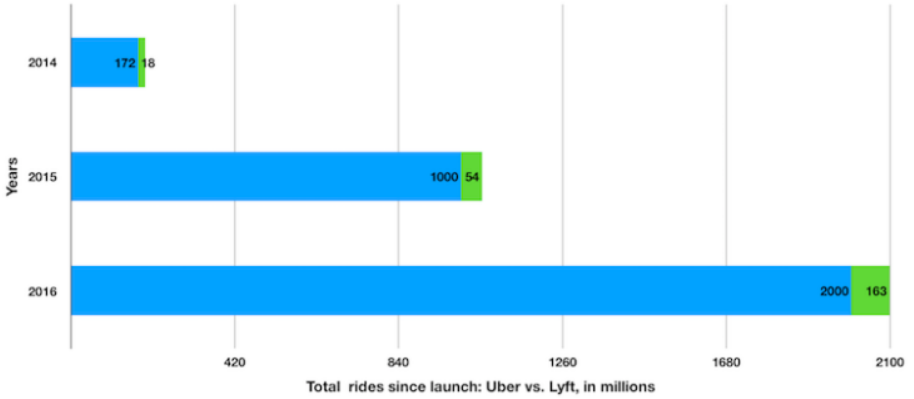
- Amazon built around the internet vs. brick and mortar shopping malls
- Amazon grasped the importance of speedy shipping
- Dramatic sales growth
- Over 100 automated warehouses and diverse fleet of vehicles for delivery—Now testing self-driving delivery vehicles and drones.



Technology spurs Ride-Hailing: Uber Case

- Uber Founded in 2009, providing technology enabled transportation service on demand 24/7
- Dramatic market growth; challenging conventional transport systems
- Uber operates in nearly 80 countries (dominates in U.S.)
- Four billion rides provided in 2017
- Recent Uber challenges; but ride-hailing industry robust worldwide
- Many other ride-hailing providers: e.g. Lyft, Didi, Grab, Taxify…
- Uber testing self-driving cars in multiple cities

Number of rides Uber vs Lyft, in millions



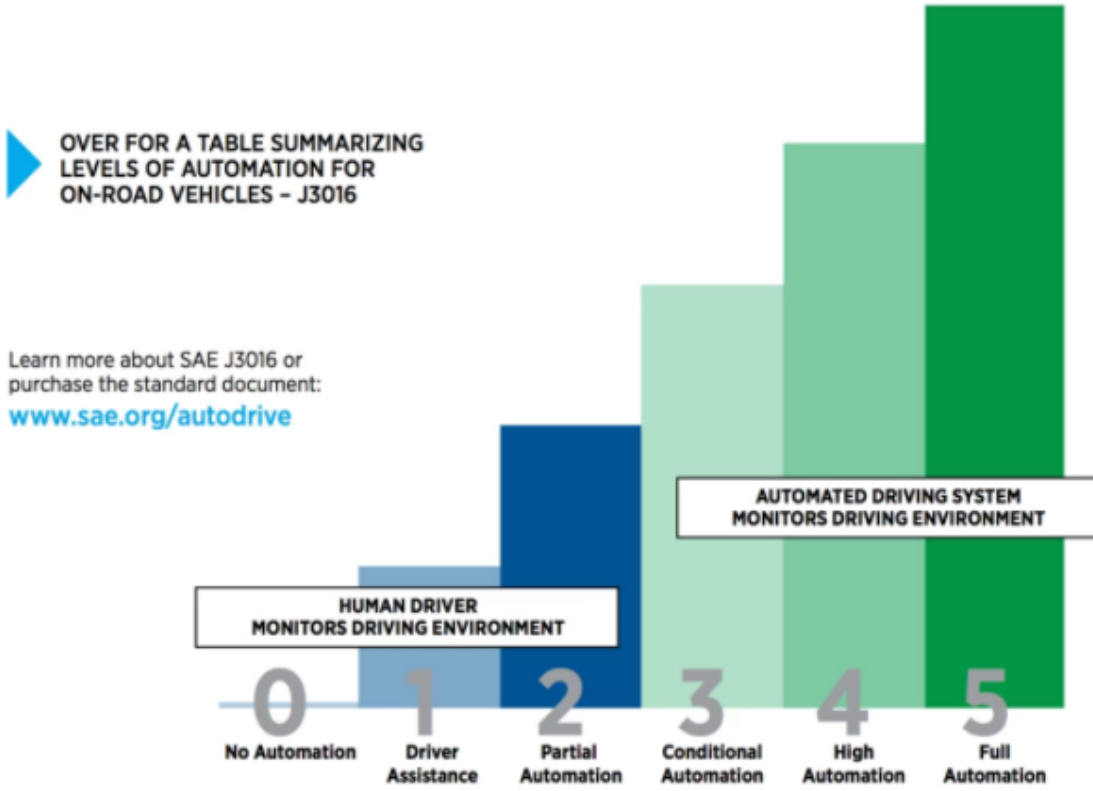
Source: Forbes

Topic 2: Self-Driving Cars (Autonomous)

Stages of Automation

International Society of Automotive Engineers (SAE) in 2014

- **Level 1** some steering, braking, or acceleration tasks are performed by the car but everything else is fully under human control
- **Level 2 Partial automation** like autopilot systems on some Tesla vehicles, the vehicle can perform basic driving functions but driver needs to stay alert at the wheel at all times
- **Level 3 Conditional automation** still requires a human driver in seat, but complete hands off under certain traffic conditions
- **Level 4 High automation** car can drive itself most all the time without human input (ex. conditions like severe weather)
- **Level 5 Full automation** in all conditions



Evolution of assisted driving to truly autonomous driving

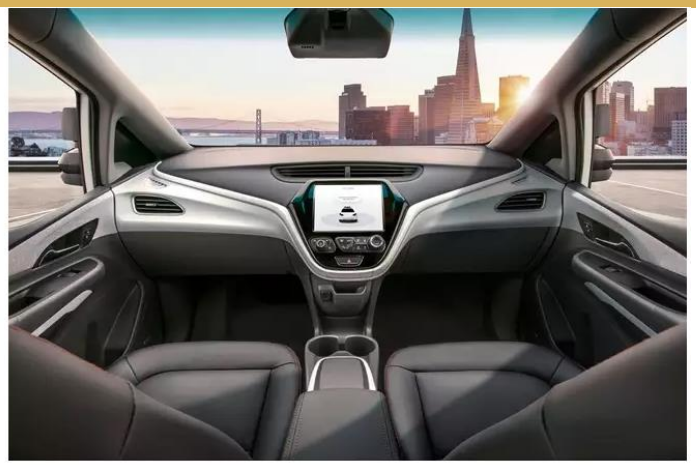
Levels 2-3 Partial automation

2

3

Level 4 and 5 near or full autonomous

4



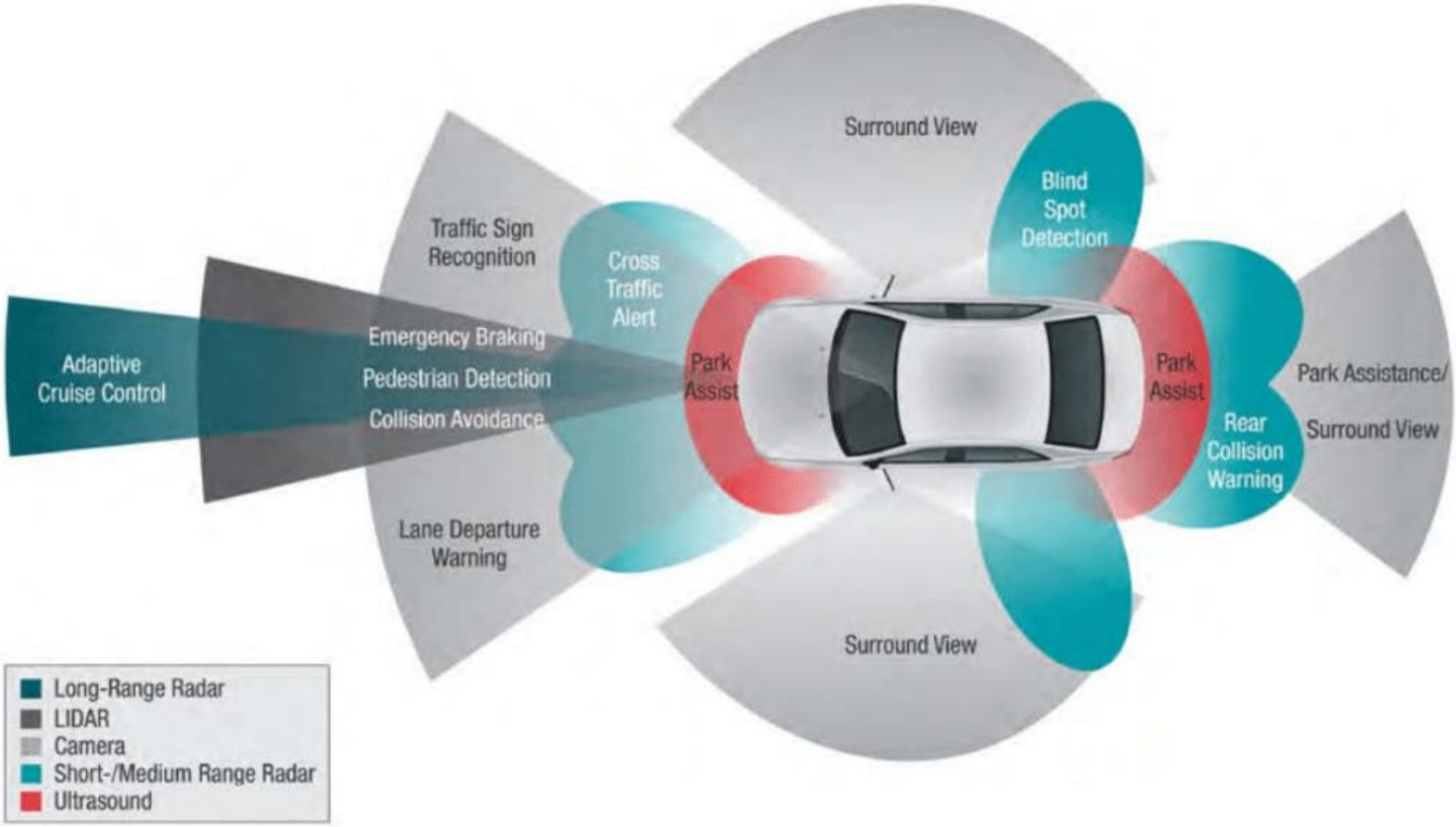
GM CRUISE AV

You won't find a steering wheel or pedals in the GM's self-driving ride for the 2019 model year.

GM

5

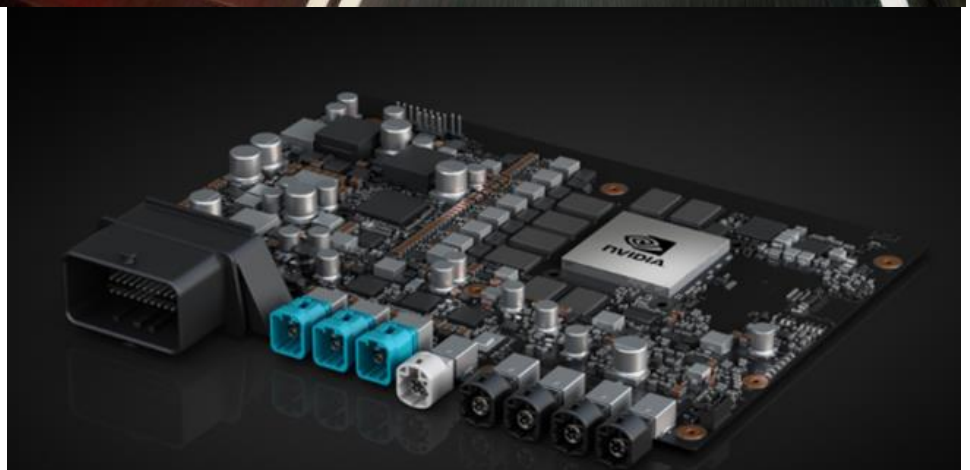
Automated Driving: Enabling Technologies

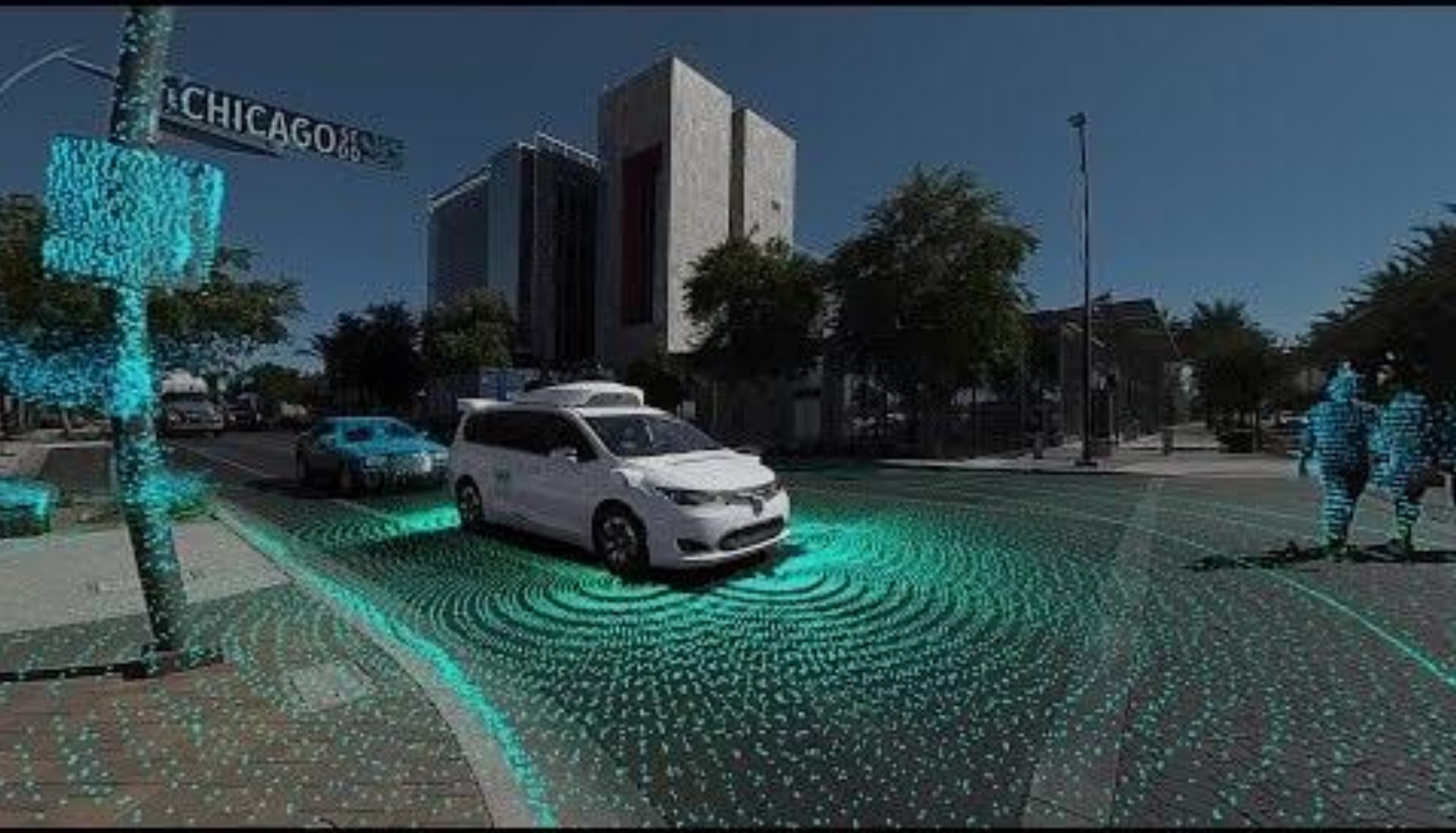


Source: Texas Instruments ADAS Solutions Guide

AI key to fully self-driving cars

- **Data is fused from multiple cameras as well as Lidar, radar and ultrasonic sensors** allowing algorithms to accurately understand the full 360-degree environment around the car and respond appropriately.
- The **Nvidia AI** computer can compute **300+ trillion operations per second.**




CHICAGO

Who is in the game? Who is leading?

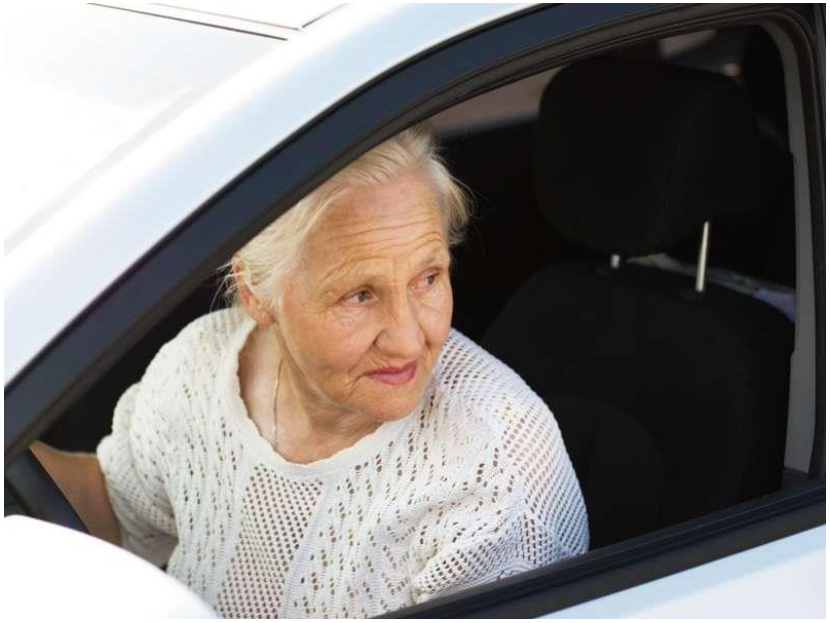
50+ Companies registered in California for testing; Google (WAYMO) out front on road testing (some 5 million miles) and first self-driving service in AZ

Benefits of Self Driving Vehicles

Safety

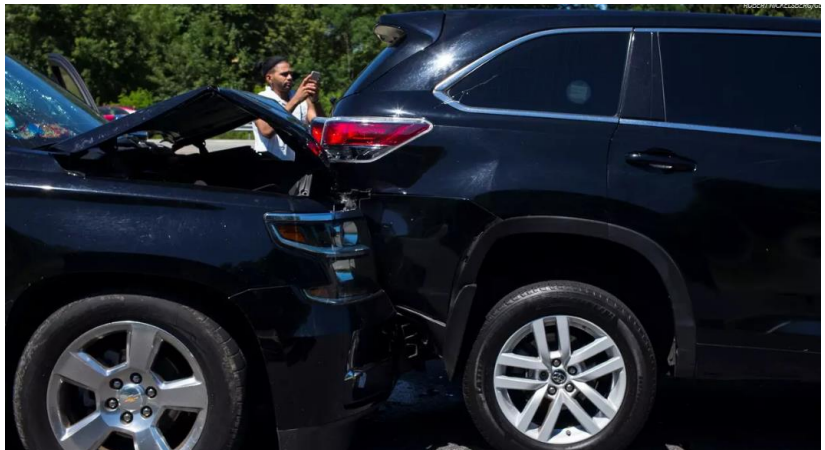
- Nearly 40,000 highway deaths yearly
- Over 90 percent due to human error

Mobility for all ages



Safety experience to date

- Since 2014, there have been 65 reported minor crashes involving self-driving cars on California roads, and 1 fatal crash (Tesla).
- Most happened when a human-driven car rear-ended a self-driving car stopped at signal or driving at low speed.



- **Tesla's 2 Driver Fatalities**
  - **1st driver fatality in Florida-** National Transp. Safety Board (NTSB) said largely driver fault, failed to respond to multiple warnings; **2nd in California** under investigation.
  - NTSB says **Tesla crashes have declined** since introduction of **'autopilot'.**
- **Uber- pedestrian fatality** in Arizona, preliminary report NTSB.
- **NTSB warns** manufacturers not to over promise on driverless technology
- **Transparency** important to build public trust.

Tesla Crashes

Florida fatality-Radar did not pick up white truck; Tesla driver however faulted by NTSB for not heeding multiple warnings to take control of car

Tesla Fatality in Florida 2016

Tesla Fatality in California 2018 plus crash into police cruiser and firetruck!

Uber self-driving car pedestrian fatality

Federal/State Regulators

Federal oversight

- NTSB crash investigations
- USDOT working on 3rd generation of rulemaking
  - Flexible policy allowing wide testing on public roads
  - AI can be considered driver under Federal law!
  - Prepared model state legislation
- Congress now considering legislation, "Self-Drive Act"

State activity (normally Motor Vehicle Administrations issue rules)

- California has been in forefront allowing testing by over 50 entities
- Arizona very active
- 20 other states have authorized self-driving car testing
- Michigan has large test track

Topic 3: Likely Next Steps and Societal Implications

2018 commercial availability status

- **Level 1-** extensive road experience across all auto manufacturers last decade
- **Level 2-** Certain Tesla; BMW, Cadillac, Volvo, Audi, Mercedes

Level 3 imminent

- Audi A8 Traffic Jam Pilot (TJP)
  - TJP uses a central driver-assistance controller with AI software to totally oversee steering, throttle and braking functions below 35 mph.

Deployment in next few years:
Focused on Level 4; primarily 'ride-hailing'

- **Google (Waymo) out front**- level 4 **now** in early testing in Phoenix geofenced suburban area. Waymo announced purchase of 20,000 electric self-driving vehicles from Jaguar for their planned ride-hailing service. Ordered upwards of 60,000 autonomous cars from **Fiat/Chrysler.**
- **GM-** level 4 autonomous ride-hailing in multiple geofenced urban environments in **2019 and beyond;** new $2.2B investment from SoftBank
- **Uber-** announced purchase of 25,000 autonomous Volvo vehicles between **2019-2021,** level 4 following current ride-hailing model
- **Ford-** Level 4 deployment for urban ride-hailing (w/ Lyft) by **2020.**
- **Tesla-** anticipates Level 4 autonomous personal vehicle in **coming year(s)**
- **Renault-Nissan** (with Microsoft) – **2020+** for Level 4 personal autonomous cars in urban conditions, **2025** for Level 5
- **Volvo –** announced **2021**(Level 4) and first to assume full liability!
- **BMW- 2021** level 4+

Timeline to fully autonomous vehicles

Level 4- Autonomous ride-hailing services piloted and becoming operational in major cities by multiple vendors over next 5 years; personal owned autonomous (level 4) vehicles gradually after 2020

Level 5- Fully autonomous testing 2020+; early adapters 2025

Other applications

Automated shuttles, e.g. senior communities, business parks

Delivery trucks- testing underway

Truck self driving platoons being tested

Vehicle To Vehicle And Vehicle to Roadway Communications

Societal Implications of Self-Driving Cars

Potential implications of self-driving vehicles

- Life long mobility for aging population
- Non-drivers will have the same mobility opportunities as drivers
- Safety: Many fewer fatalities and injuries
- Time saving: leisure time, conduct business, etc. while in-transit
- Fewer people owning vehicles; vehicles on demand (ride-hailing) cheaper than owning
- Ride-hailing fleets will increasingly be electric; potential environmental benefits
- Transportation logistics innovations; e.g. home delivery
- City transportation systems and lifestyles could be transformed
- Upwards of 5 million commercial vehicle operators and warehousing logistics jobs; many could face job losses?

Questions

- How many have used ‘ride hailing’ services like Uber and Lyft?
- Will you likely use these services more in the future? If they are predominantly self driving vehicles, how will that affect your decision to use?
- Will you likely buy latest self-driving technology with your next car purchase or lease?
- How comfortable will you be with allowing your car to take over most or all driving functions?

Other Comments and Questions?

Readings on Technological Revolution and job destruction

- "***The Second Machine Age:*** *Work, Progress and Prosperity in a Time of Brilliant Technologies*"; Brynjolfsson and McAfee, MIT
- "***The Wealth of Humans:*** *Work, Power and Status in 21st Century*", Ryan Avent (at The Economist)
- **Oxford University** study- "*The Future of Employment: How Susceptible Are Jobs To Computerisation*"

Sources on self-driving vehicles

- You Tube- ***How Self-Driving Cars will transform our cities and lives***
- YouTube-***"How Self-Driving Cars Work"***
- **Popular Science- Jan 18, 2018:** "*Here's where your new car lands on the self-driving scale*"
- Forbes article- ***What I Learned About Self-Driving Cars At CES*** *(Psst ... They're -- Almost -- Here) Jan. 2018*

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