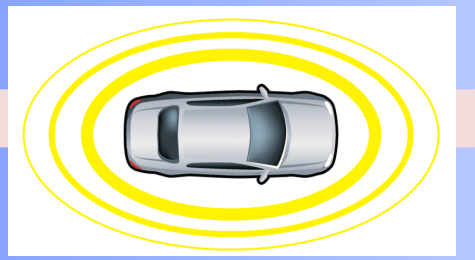
Stan Caldwell, Executive Director

Connected and Autonomous Vehicles

Connectivity

- Includes all types of communication with vehicles and infrastructure (Wi-Fi, DSRC, Cellular, etc.)



Connected Vehicle

Communicates with nearby vehicles and infrastructure

Connected and Autonomous Vehicles

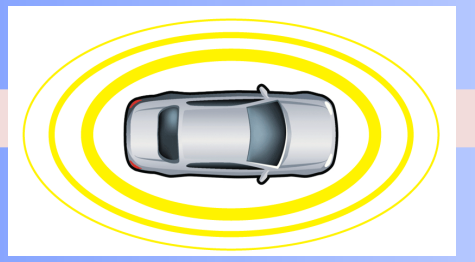
Connectivity

- Includes all types of communication with vehicles and infrastructure (Wi-Fi, DSRC, Cellular, etc.)

Autonomous Vehicle

Operates in isolation from other vehicles using internal sensors

Connected Vehicle



Communicates with nearby vehicles and infrastructure

Connected and Autonomous Vehicles

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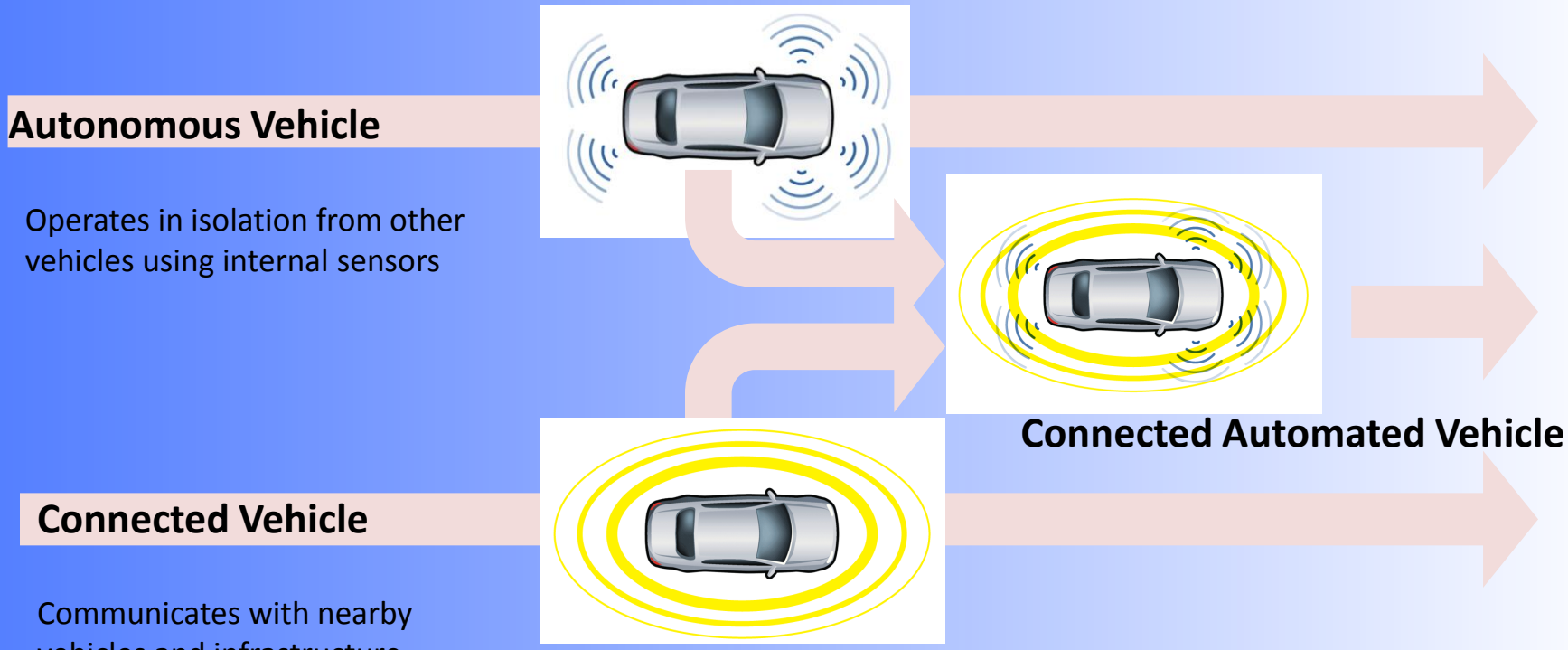


Carnegie Mellon University
30 Years of Self-Driving Car Research

Happy Birthday!

1984
- The Terregator's top speed was a few centimeters per second; it could avoid obstacles.
- NavLab launched. Its goal: apply computer vision, sensors and high-speed processors to create vehicles that drive themselves.

1986
Humans or computers controlled NavLab1, a Chevy van. Top speed: 20 mph.

1990
NavLab 2, a US Army HMMWV, wrangled rough terrain at 6 mph. Highway speed: 70 mph.

1995
NavLab 5, a Pontiac Trans Sport, traveled from Pittsburgh to San Diego in the "No Hands Across America Tour."

2000
NavLab 11, a Jeep, was equipped with Virtual Valet.

2005
Sandstorm and Highlander placed 2nd and 3rd in the DARPA Grand Challenge.

2007
Carnegie Mellon's "Boss" won the DARPA Grand Urban Challenge by outmaneuvering other vehicles along the 55-mile course.

2014
Carnegie Mellon's **14th self-driving vehicle** is a Cadillac SRX that:
- avoids pedestrians and cyclists
- takes ramps and merges
- recognizes and obeys traffic lights
- looks like other Cadillac SRXs

www.engineering.cmu.edu

Autonomous Vehicle Sensing

DARPA Challenge 2007 (Defense Advanced Research Projects Agency)

Autonomous Vehicles

2007 GM Lab

2012 GM Lab

Carnegie Mellon

Trunk Space

Pittsburgh Demonstration

9-4-14

33 miles along Route 19 in multi-lane, dense traffic with lights and two interstate highways

Challenges

- Exogenous: The complexity & uncertainty of the real world
  - Weather, lighting, and road conditions; construction; accidents; obsolete information, loss of GPS.
- Endogenous: Online and safe recovery from failures of sensors, actuators, computing or communications.
  - Sensors and actuators
    - Calibration, wear and tear, outright failure.
- Assurance: How to verify and validate safety & correctness?
- Interactions: Vehicular Networks
  - communicate securely and coordinate carefully
- Reliability
  - cost and maintenance, customer acceptance
- Incremental deployment
  - Semi-autonomy → on-demand autonomy → full autonomy
- Legal implications

There Are Six Levels of Vehicle Automation

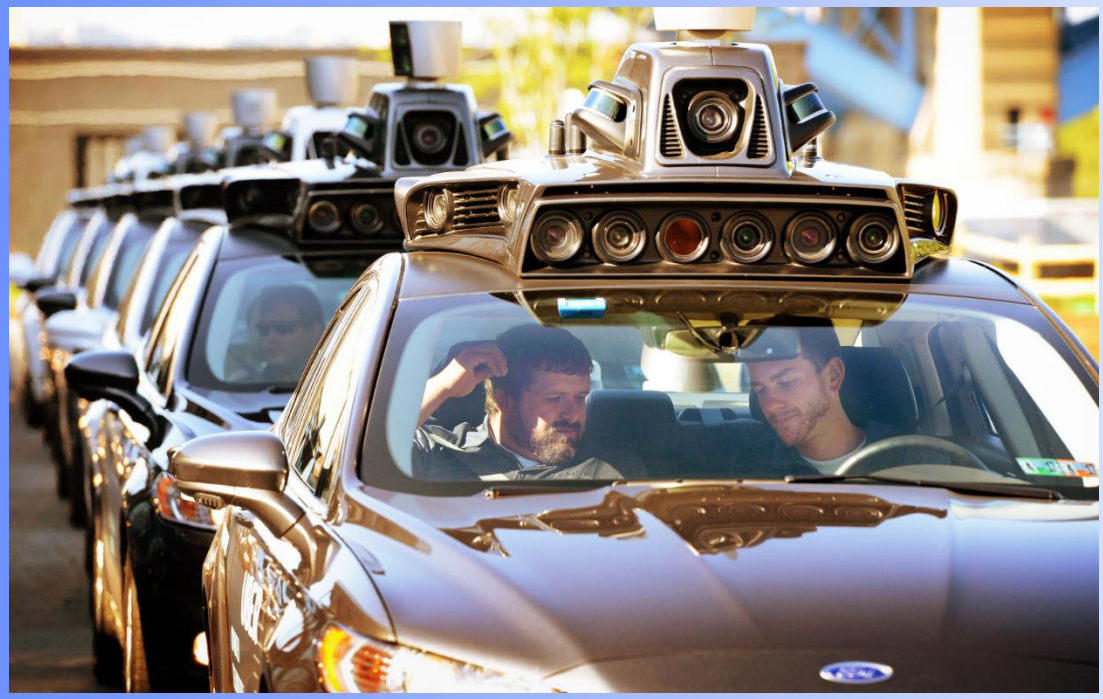
Level	Name	Who is Driving?	Who is Monitoring?	Who Intervenes?
0	No Automation	😀	😀	😀
1	Driver Assist	😀🤖	😀	😀
2	Partial Automation	🤖😀	😀	😀
3	Conditional Automation	🤖	🤖	😀
4	High Automation	🤖	🤖	🤖😀
5	Full Automation	🤖	🤖	🤖

Source: Adapted from NHTSA and SAE J3016

The Integration of the Shared Economy with Connected Automaton

- Last Mile
- On Demand Transit
- Modal Shift
- Carless and Car-free Lifestyle

Uber Cars: September 15, 2016 Post Gazette Photo




EZ10


Peloton
Peloton
53'

Early Deployment of Connected Automation

- Real-World Testing from New Mobiltiy Companies
  - Uber, Tesla, Waymo, Navya, Peloton, etc.
- Integration of Connected Automation in Traditional Automotive Companies
  - GM, Ford, Delphi,
- Investments of Traditional Automotive Companies into New Mobility Companies
  - GM/Lyft and Ford/Argo AI
- Smart Belt Coalition
  - Pennsylvania, Ohio and Michigan
  - Connected Work Zones and Platooning

Policy Implications