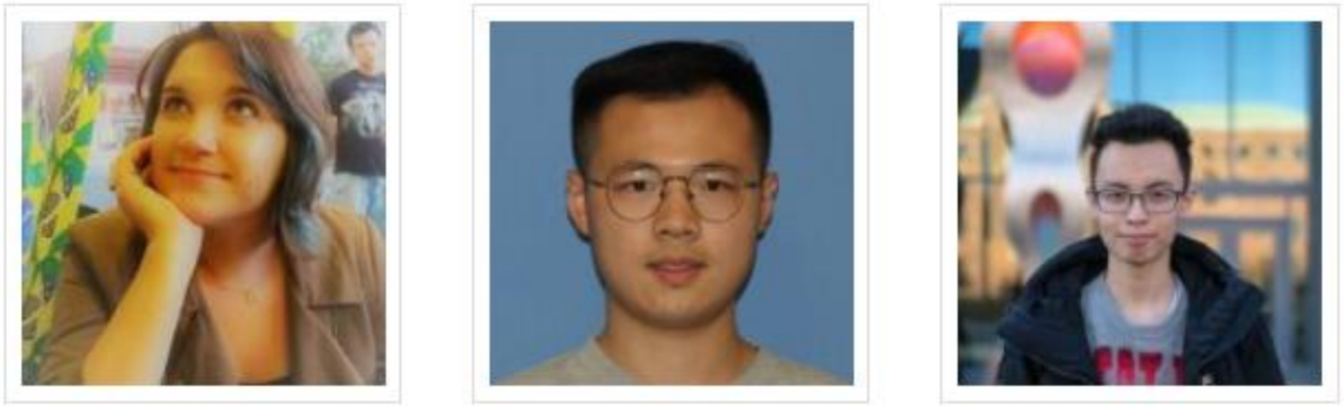
Lecture 1: Course Overview

Professor Katie Driggs-Campbell

January 25, 2021

ECE484: Principles of Safe Autonomy

Welcome from SafeAuto Team!



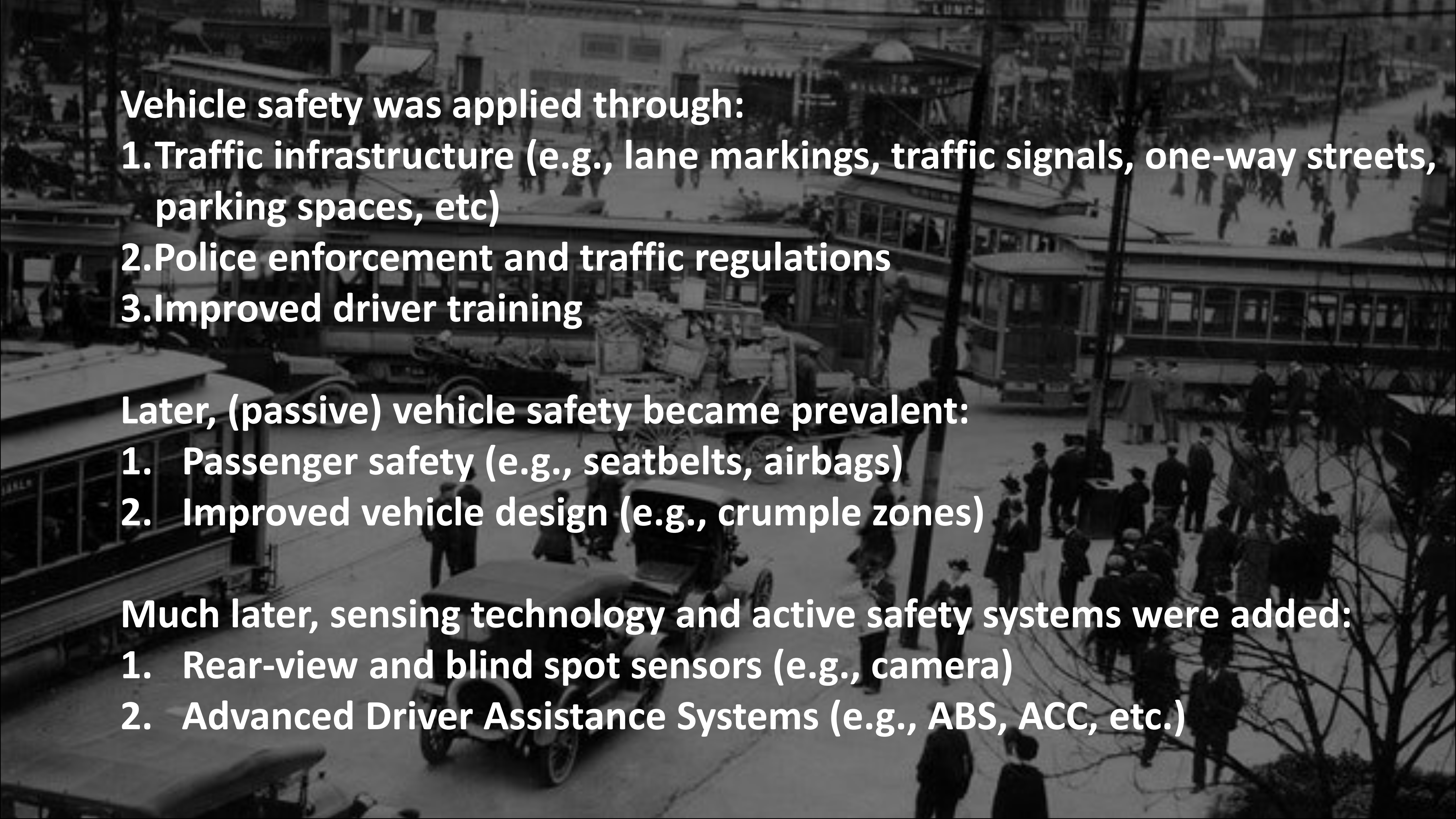
Prof. Katie Driggs-Campbell (krdc) Minghao Jiang (mjiang24) Eric Liang (weihang2)

Professor Katie Driggs-Campbell
TAs: Eric Liang and Minghao Jiang

Information about the course:
https://publish.illinois.edu/safe-autonomy/

Today’s Lecture

- What is this course about?
- How will this course work?



Vehicle safety was applied through:

1. Traffic infrastructure (e.g., lane markings, traffic signals, one-way streets, parking spaces, etc)
2. Police enforcement and traffic regulations
3. Improved driver training

Later, (passive) vehicle safety became prevalent:

1. Passenger safety (e.g., seatbelts, airbags)
2. Improved vehicle design (e.g., crumple zones)

Much later, sensing technology and active safety systems were added:

1. Rear-view and blind spot sensors (e.g., camera)
2. Advanced Driver Assistance Systems (e.g., ABS, ACC, etc.)

Autonomous systems *will* be awesome!

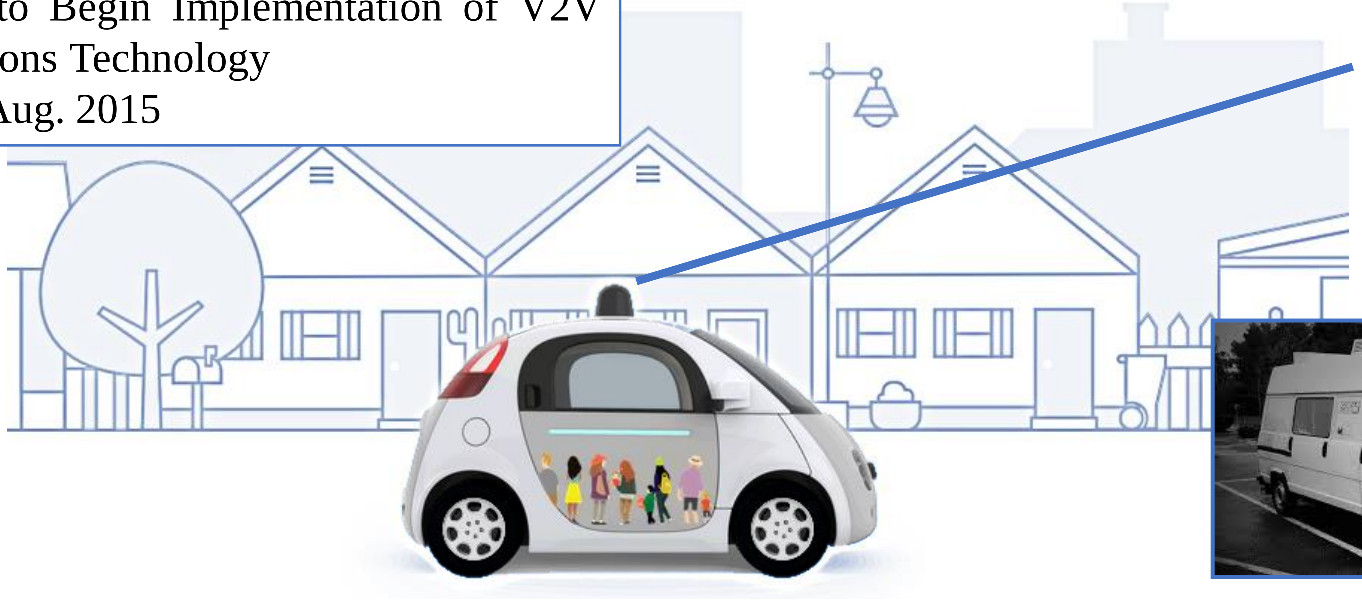
Driverless cars will make us more productive
→ Average American drives 13,474 miles (300 hrs) per year

Our cities will be greener
→ 40% of city surface is parking

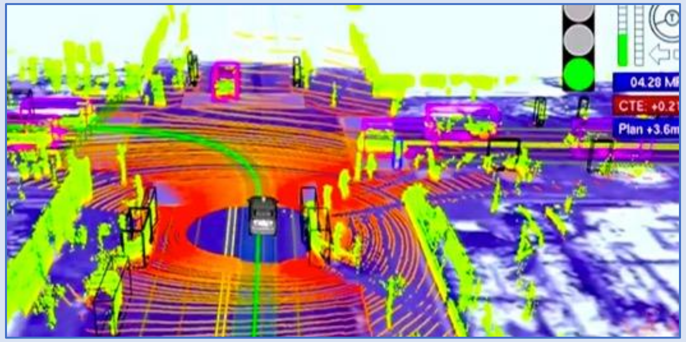
Travel and deliveries will be safer
→ 32K+ fatalities and 3M+ injuries every year

Cars are *communicating* more and more

USDOT Issues Advance Notice of Proposed Rulemaking to Begin Implementation of V2V Communications Technology
— NHTSA, Aug. 2015



Cars are *sensing* more and more



driverless cars date back to the 80s/90s in the Eureka/ Prometheus Project

There is a greater societal push than ever before…

THE WALL STREET JOURNAL.

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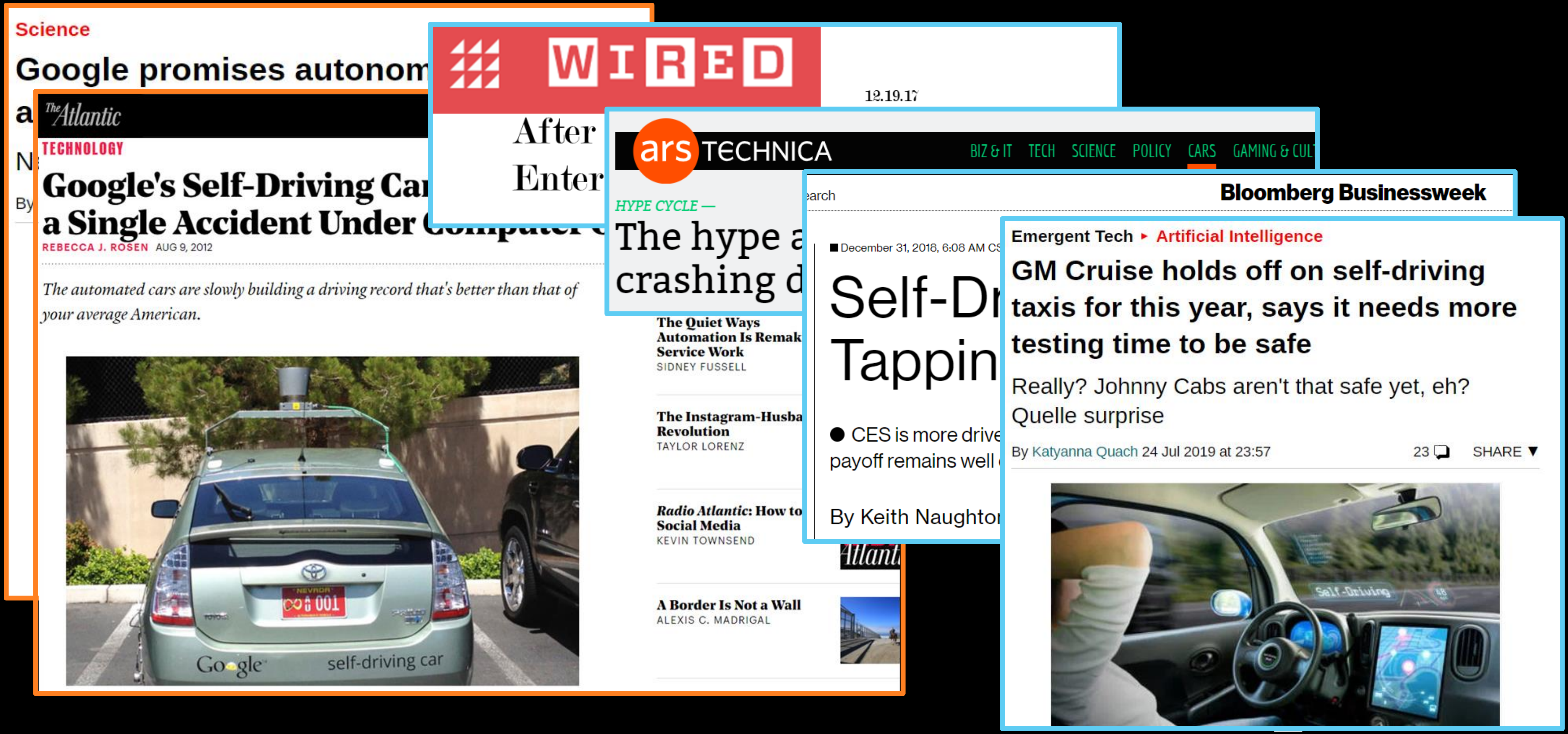
U.S. Proposes Spending $4 Billion to Encourage Driverless Cars

Obama administration aims to remove hurdles to making autonomous cars more widespread

Autonomous Vehicles in the News



Prediction Scorecard as of 2020

FORECASTS: http://www.driverless-future.com/?page_id=384 March 27, 2017

NVIDIA to introduce level-4 enabling system by **2018** *(2017)*
NuTonomy to provide self-driving taxi services in Singapore by **2018**, expand to 10 cities around world by **2020** *(2016)*
Delphi and MobilEye to provide off-the-shelf self-driving system by **2019** *(2016)*
Ford CEO announces fully autonomous vehicles for mobility services by **2021** *(2016)*
Volkswagen expects first self driving cars on the market by **2019** *(2016)*
GM: Autonomous cars could be deployed by **2020** or sooner *(2016)*
BMW to launch autonomous iNext in **2021** *(2016)*
Ford's head of product development: autonomous vehicle on the market by **2020** *(2016)*
Baidu's Chief Scientist expects large number of self-driving cars on the road by **2019** *(2016)*
First autonomous Toyota to be available in **2020** *(2015)*
Elon Musk now expects first fully autonomous Tesla by **2018**, approved by **2021** *(2015)*
US Sec Trans: Driverless cars will be in use all over the world by **2025** *(2015)*
Uber fleet to be driverless by **2030** *(2015)*
Ford CEO expects fully autonomous cars by **2020** *(2015)*
Next generation Audi A8 capable of fully autonomous driving in **2017** *(2014)*
Jaguar and Land-Rover to provide fully autonomous cars by **2024** says Director of Research and Technology *(2014)*
Fully autonomous vehicles could be ready by **2025**, predicts Daimler chairman *(2014)*
Nissan to provide fully autonomous vehicles by **2020** *(2013)*
Truly autonomous cars to populate roads by **2028-2032** estimates insurance think tank executive *(2013)*
Continental to make fully autonomous driving a reality by **2025** *(2012)*

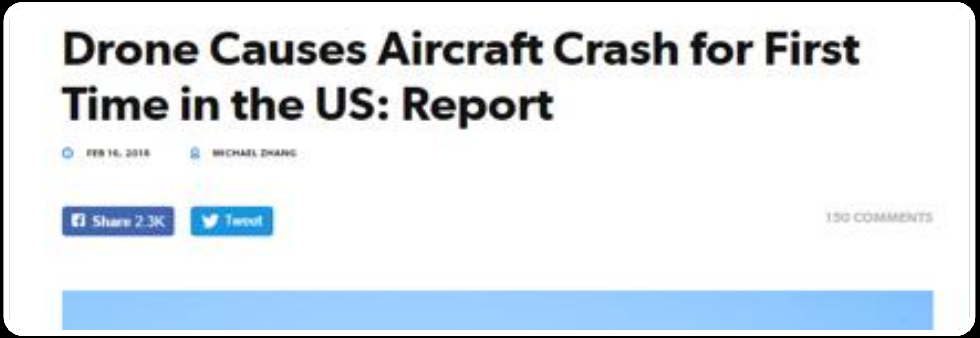
http://rodneybrooks.com/predictions-scorecard-2020-january-01/

THE TOP 263

Gartner Hype Cycle for Emerging Technologies, 2019

COMET LABS

Many Open Challenges in Autonomy



Breakout Room Discussions

- First off, introduce yourselves!
- What do you think the coolest part of autonomy is? How do you think it will impact the world?
- Discuss some of the aspects of autonomy that you think are particularly challenging

Discussion Notes

- incompetence versus negligence
  - which is easier to solve?
- Autonomy in surgery is cool too! Many broad applications
- How to handle the ethical considerations? Security issues?
- Other autonomy applications: active collaboration between agents?
- How does communications augment or hurt autonomy?
- Challenges: decision-making in complex environments!
- Social questions: job, policy, mandates
- saving time and space and changing cities
- Camera vs lidar → use all! Redundency!
- How will rules and what not change! How do our perceptions of safety change?
- How to deal with adversarial / edge cases
- How do we validate complex autonomous systems? How to make guarantees for black-box systems?
- Is active learning effective for these systems?

low probability, high risk events

Hazardous Event Frequencies	
Disengagement Rate	0.12 per 1000 km
Collision Rate	12.5 per 100 million km
Fatality Rate	0.70 per 100 million km

30 billion miles of test driving necessary to attain the level of assurance necessary to make autonomous vehicles acceptable to society.

On a Formal Model of Safe and Scalable Self-driving Cars by Shai Shalev-Shwartz, Shaked Shammah, Amnon Shashua, 2017 (Responsibility Sensitive Safety)

Sense

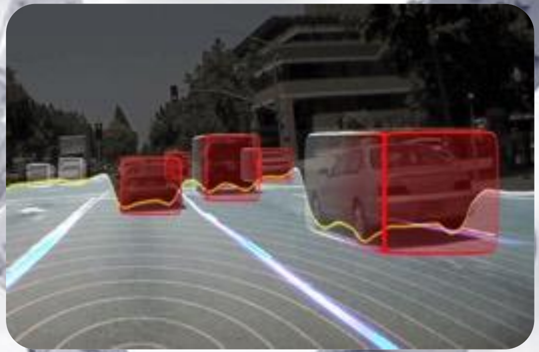
camera, LIDAR, GPS, computer vision, machine learning, neural networks, data

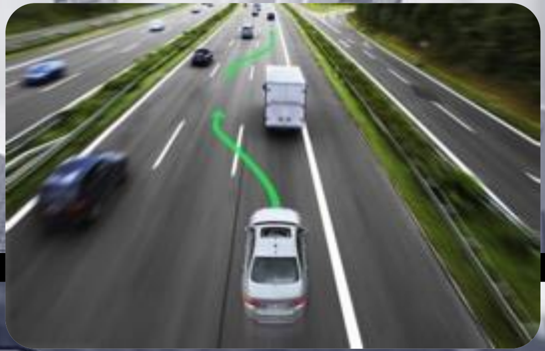
Think

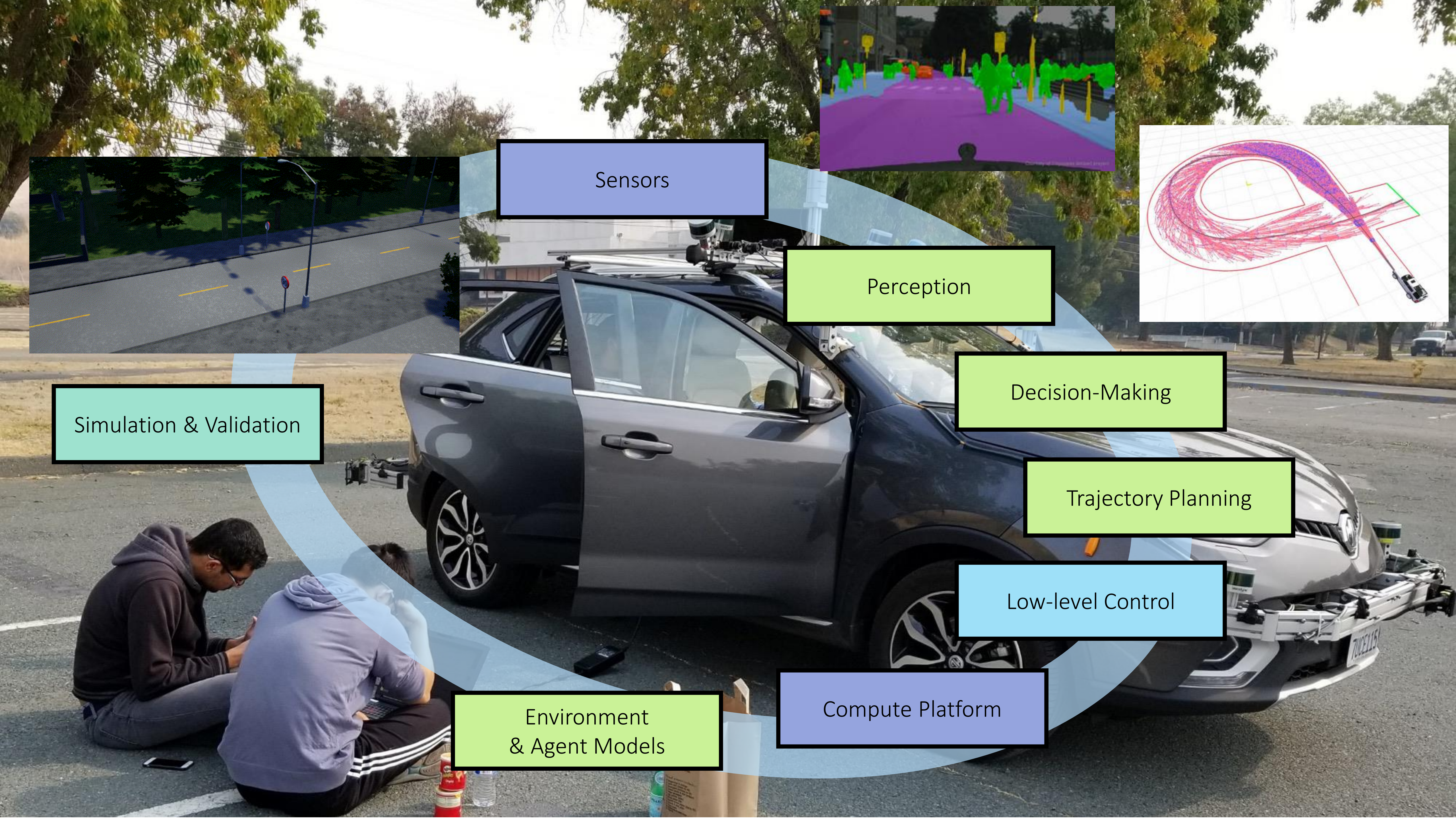
navigation, path planning, physics, code

Act

computers, networks, engine, steering, brake




Sensors
Perception
Decision-Making
Trajectory Planning
Low-level Control
Compute Platform
Environment
& Agent Models
Simulation & Validation

An honest scientific approach

1. Create detailed mathematical models of the autonomous systems and its environment
2. Enumerate the precise requirements of the system and the conditions on the environment under which it is supposed to work
3. Analyze the system to either
   - prove that all behaviors meet the requirement (perhaps with high probability)
   - find counter-examples, corner cases, etc., debug and repeat

- Currently, there are fundamental flaws in making this work for autonomous systems
- **Why study this approach?**
  - Careful reasoning can expose flawed assumptions and potentially bad design choices
  - Found success in other industries: microprocessors, aviation, cloud computing, nuclear, …
  - Working deliberately towards a <u>more perfect understanding</u> is a worthwhile intellectual struggle

Why are we here?

Know
Components of an autonomous system and safety standards.
→ How to use software modules for perception, planning, control, ROS, OpenCV, …

Do
Code and analyze algorithms for perception, localization, planning, control, & verification
→ Plan, propose, organize and execute a team project

Understand
Models, algorithms, data, biases, assumptions for building trustworthy autonomous systems
→ Theoretical properties of algorithms and their limitations

Get Inspired
Become the Isaac Newton of Autonomy
→ "To do things right, first you need love, then technique." – Antoni Gaudí

Today’s Lecture

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- How will this course work?

Communication

- Up to date information will be posted on the course website: https://publish.illinois.edu/safe-autonomy/
  - schedule, resources (slides, notes, papers), MPs, etc
- We will use **discord** for communication and office hours
  - Office hours will be held here
  - Use to ask course staff questions, form teams, discuss with other students
  - Please set reasonable expectations for response timing
- Gradescope will be used for submissions and grading

Schedule

- Overview and simple safety
- Perception basics (sensing, vision)
- Vehicle modeling and control
- Planning and decision making
- Filtering and localization
- Safety analysis
- Guest lectures
- Project pitches and presentations

Next week: Panel featuring engineers from Cruise, Waymo Trucks, and Aurora (formerly Uber ATG)

Featuring speakers from Tesla, Nuro, and more!

Course materials

- Lecture notes, slides, code, video lectures, lab manuals created and curated from recent research publications
- No textbook, but we recommend a few reference books:
    1. Probabilistic robotics, By Sebastian Thrun, Wolfram Burgard, and Dieter Fox, 2005
    2. Principles of Cyber-Physical Systems, Rajeev Alur, MIT Press, 2015

Course Grade Components

- 5 Team MPs: 40%
  - ROS + Python, Ubuntu, BYOD, or use lab workstations
  - Includes a few written questions on basic concepts
  - Instead of lab sections, some lectures will be dedicated to MP tutorials
- Team Project: 35%
  - In-class presentations (pitch, final presentation)
  - ~2 milestones to check progress
  - Final report in place of final exam
- Midterm: 15%
  - Oral exam 😱
  - Questions given one week before, randomly selected
- Participation: 10%
  - Attendance (or office hour check-ins for asynchronous students)
  - Questions answered on discord
  - Question submission for quest speakers

Grade Boundaries	
A	>90
B	>80
C	>70
D	>60
F	<59
+/- TBD	

Zoom Protocols

- If I am disconnected or have internet issues, please wait 15 minutes to see if issues can be sorted out
  - If unable to fix issues, a video will be posted to cover the lecture material
- If you are presenting and there are connectivity issues, we will ask that you try to reconnect for the duration of your timeslot and, if unable to complete the presentation, re-do the presentation for the course staff at a later time
- If you are unable to attend lecture (participating asynchronously), you must check-in with course staff to briefly chat about the course material

Teamwork makes the dreamwork

- Form your group of 2-5 now!
  - Try to make your group diverse, make new friends
- Each MP will build a component of an autonomous system over ~2 weeks
- MP grading consists of two parts: demo and report
  - Demo is due *before* Thursdays at 5pm (by appointment or in OH)
  - Report (with written questions) is due on Fridays at 5pm
- We will provide a VM that contains everything you'll need to run the simulations
- TAs will run tutorial lectures for each MP

Projects: explore, inspire, and impress

Hardware Track

Build on existing modules and implement system on test-vehicle

- Reliable parallel parking
- Lane following and pedestrian avoidance outdoor track
- Intent estimation and reaction

Simulation Track

Build significant feature in simulator and provide detailed safety analysis.

- Explore new simulation capabilities (e.g., Unity)
- Develop advanced decision module
- Enable multi-agent interactive simulations

<ins>Expected Outcomes:</ins> Technical papers, unique project experience, jumpstart grad research, incubate startup ideas, new course materials

Projects: explore, inspire, and impress

- We will provide a fully equipped Polaris GEM e2 vehicle (test vehicle and simulation) and basic autonomy modules
- Action Items:
  - If interested in working with hardware, become an IRL member asap!
    - Safety Driver training in the next few weeks
  - Team formation form due this week!
  - Project Pitch (in-class, likely parallel track) in one month
  - Two milestones due through out the semester
  - Project Presentations second to last week of class
  - Final report (and video demo) in place of final

Summary

- Autonomy is cool! But needs to be executed carefully.
  - This course should be a ton of fun!
- Join course Discord, check Gradescope signup, check out website.
- Form your team. Decide track.
  - Sign-up to be member of IRL for in-person labs