

Self Driving Cars: Perception and Control

Prof. Matthew Johnson-Roberson

Prof. Ram Vasudevan

COVID POLICIES

- Vaccines are mandatory at this university.
- Masks are mandatory in class.
 - Anyone without a mask will be offered a mask.
 - Anyone wearing a mask improperly (not over both nose and chin), will be asked to adjust their mask.
 - If anyone refuses to wear a mask properly during the class, they will be asked to leave.
 - If the instructors feel uncomfortable being in the lecture hall with an improperly masked individual, the class will be dismissed and lecture will resume on Zoom.

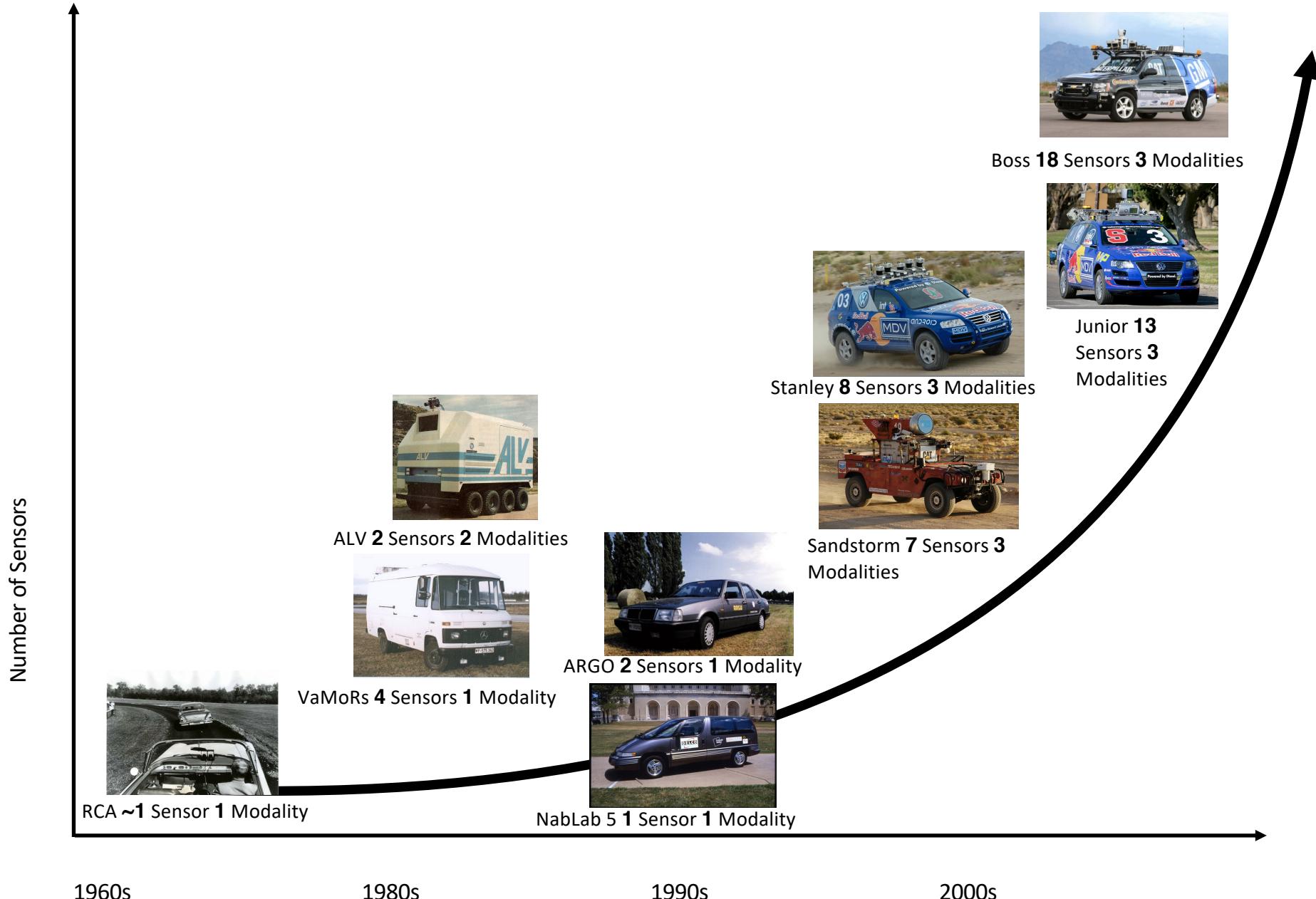
COVID POLICIES

- If you have to blow your nose, drink, or eat something, please step out of the room.
- IF YOU FEEL SICK, if you have been traveling, or if you suspect you have been exposed to someone who has COVID 19, PLEASE DO NOT COME TO CLASS. Lectures are recorded and posted to Canvas.
- If you get sick, please CONTACT US as soon as possible so that we can adjust our expectations for your assignments. This will occur on a case-by-case basis.
- If the county or the university initiates a stay-at-home order, we are prepared to switch to an online-only format.
- In the event of an exposure, all participants will be notified so that we can all get tested. The identity of those who test positive will not be shared.

The History

























Understanding the Taxonomy

The 5 levels of driving automation

For on-road vehicles



Human driver



Automated system

		Steering and acceleration/ deceleration	Monitoring of driving environment	Fallback when automation fails	Automated system is in control
Human driver monitors the road	0 NO AUTOMATION				N/A
	1 DRIVER ASSISTANCE				SOME DRIVING MODES
	2 PARTIAL AUTOMATION				SOME DRIVING MODES
	3 CONDITIONAL AUTOMATION				SOME DRIVING MODES
	4 HIGH AUTOMATION				SOME DRIVING MODES
	5 FULL AUTOMATION				

HARD
MAYBE ALMOST
IMPOSSIBLE

Source: SAE International

Vox

NHTSA LEVELS OF AUTOMATION

LEVEL 0



AND



driver controls
steering and brakes

LEVEL 1



OR



BY VEHICLE



driver controls
steering or brakes

LEVEL 2



AND



BY VEHICLE



driver has to be ready
to take control

LEVEL 3



AND



BY VEHICLE

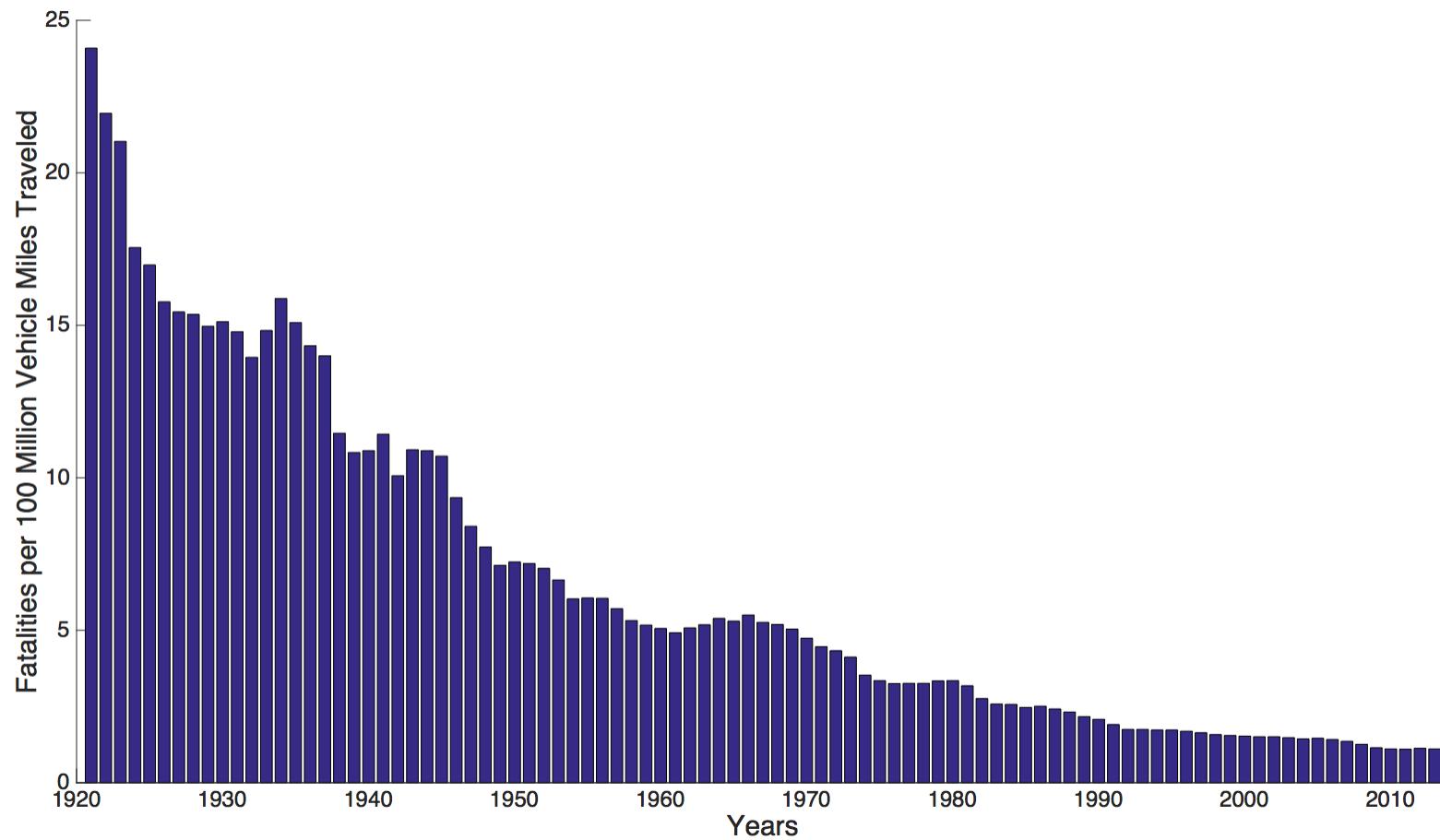


ample warning in
rare conditions that
driver has to
control vehicle

LEVEL 4

vehicle can drive itself empty or with a passenger

Decoding Hype



This class is about fully self-driving systems...

That is an open problem without a solution so we will learn what people are trying.

The Challenges: Sensing

Sensing

- Proprioceptive
- Exteroceptive

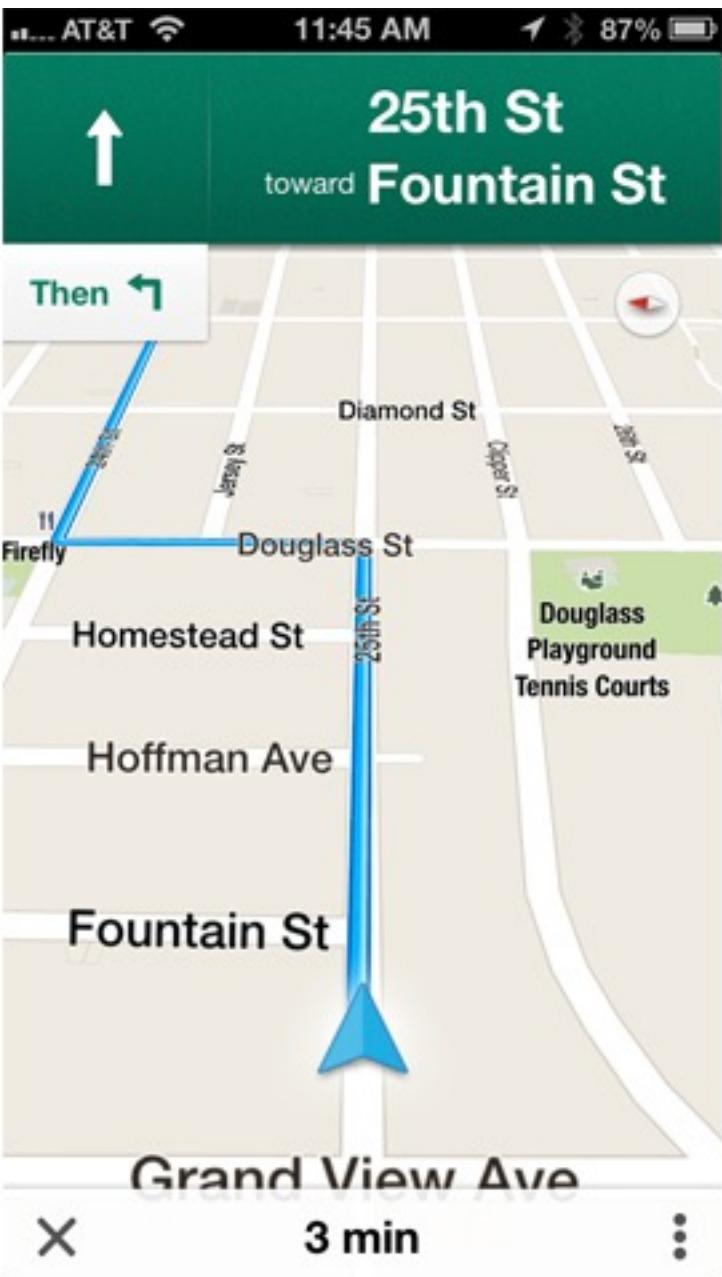
Proprioceptive Sensors

- Inertial Navigation System (INS)
- Wheel Encoders
- Compass

Traditional Exteroceptive Sensor

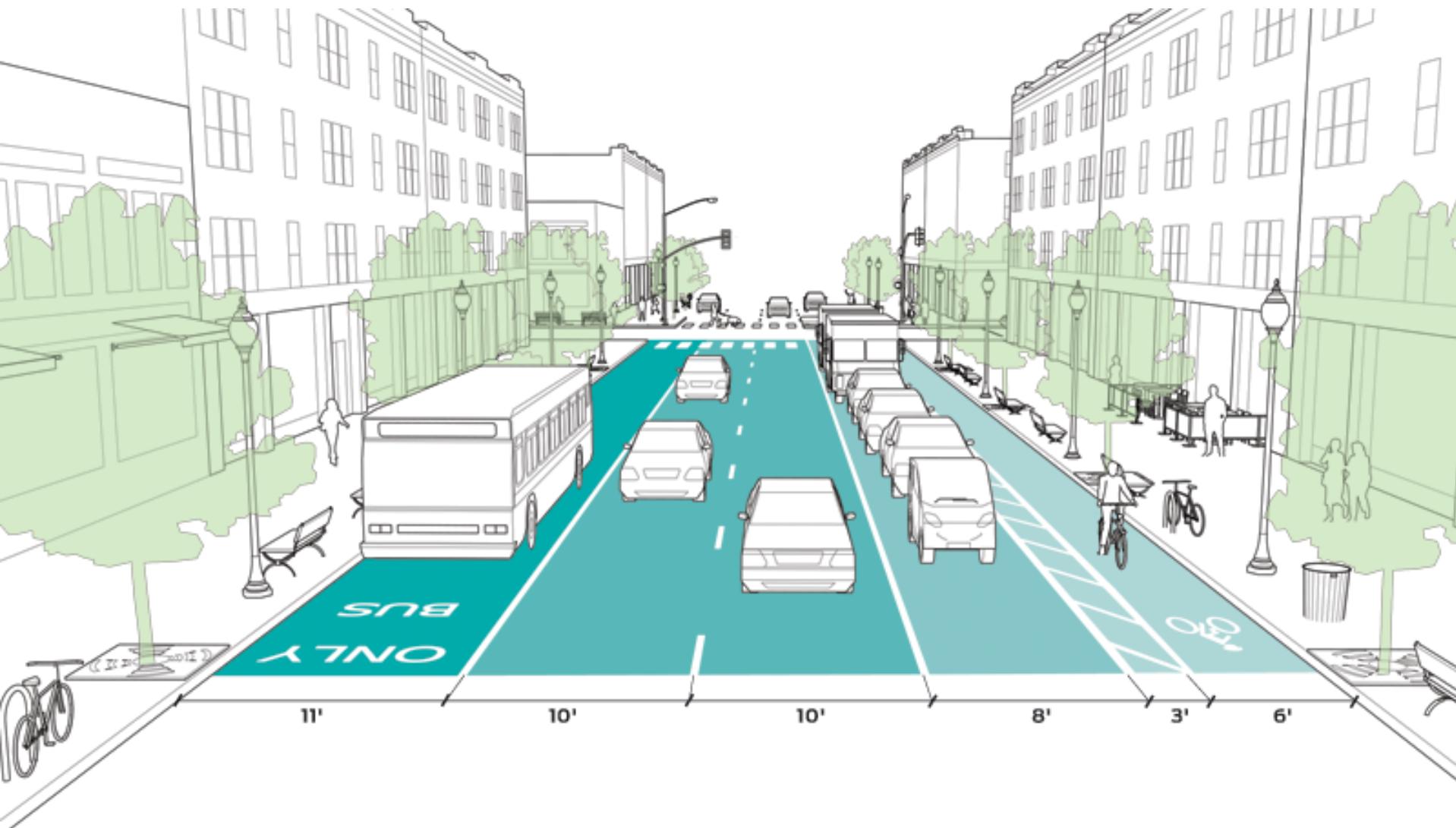
- GPS (Global Positioning System)

Why is this Hard with Traditional Sensors?



GPS / INS

- GPS-enabled smartphones are typically accurate to within a 4.9 m (16 ft.)
- Error reduction using INS fusion ~1m/2m depending on INS accuracy
- Multipath
- Satellite Visibility
- RTK



National Association of City
Transportation Officials

Why Exteroceptive Sensors?

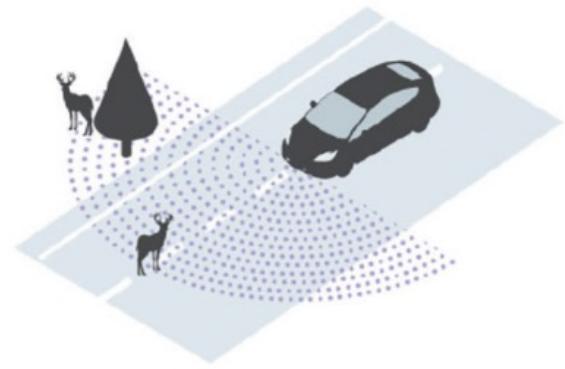
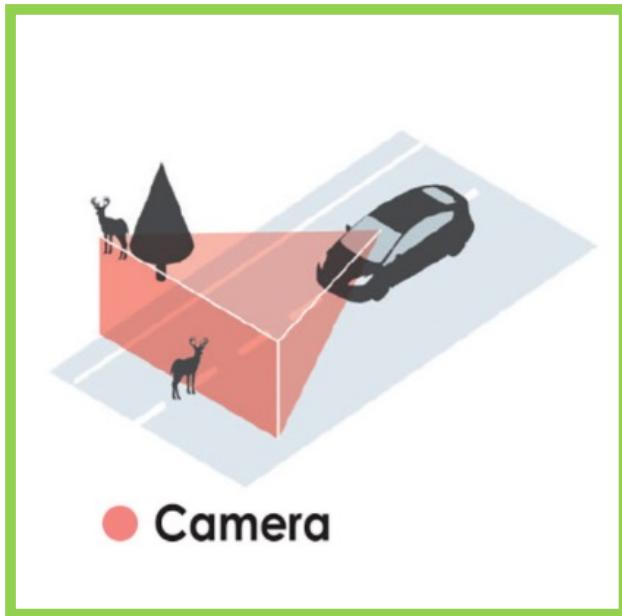




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State of the Art Exteroceptive Sensors



Hasn't AI solved this problem?

AlphaGo



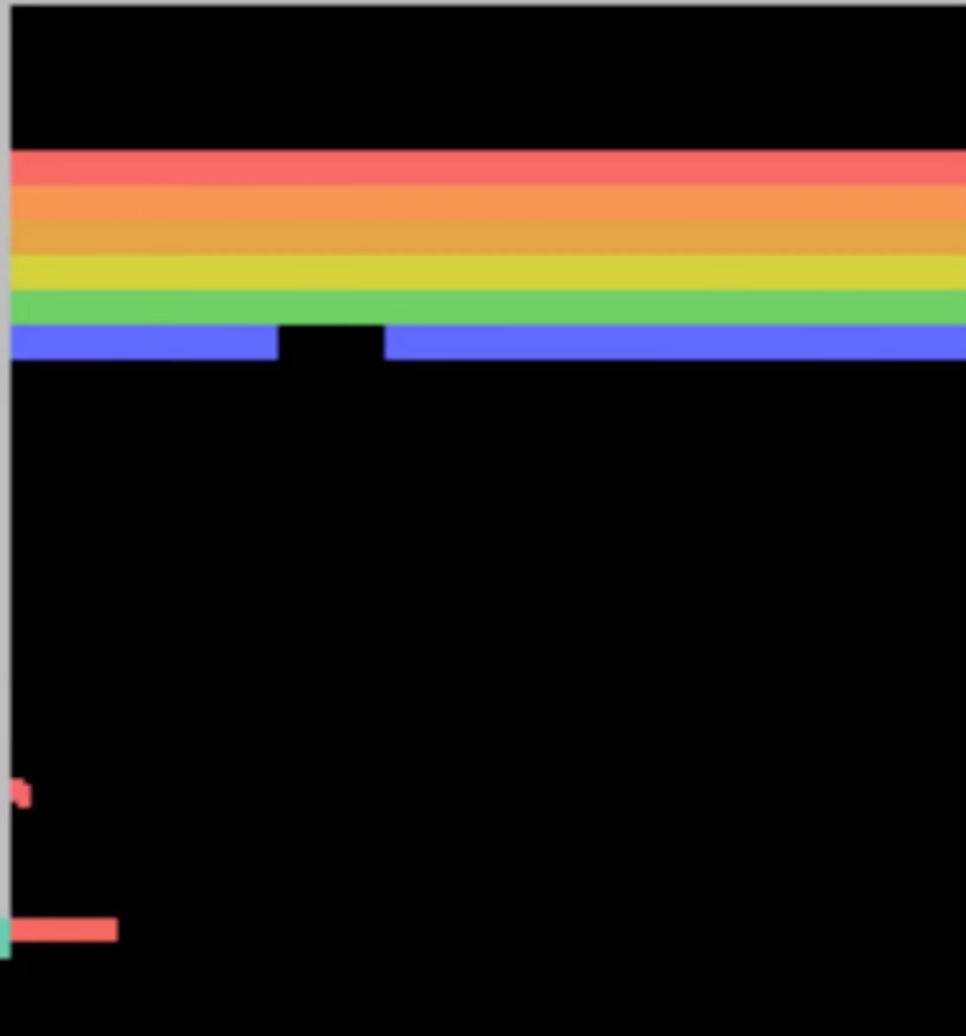


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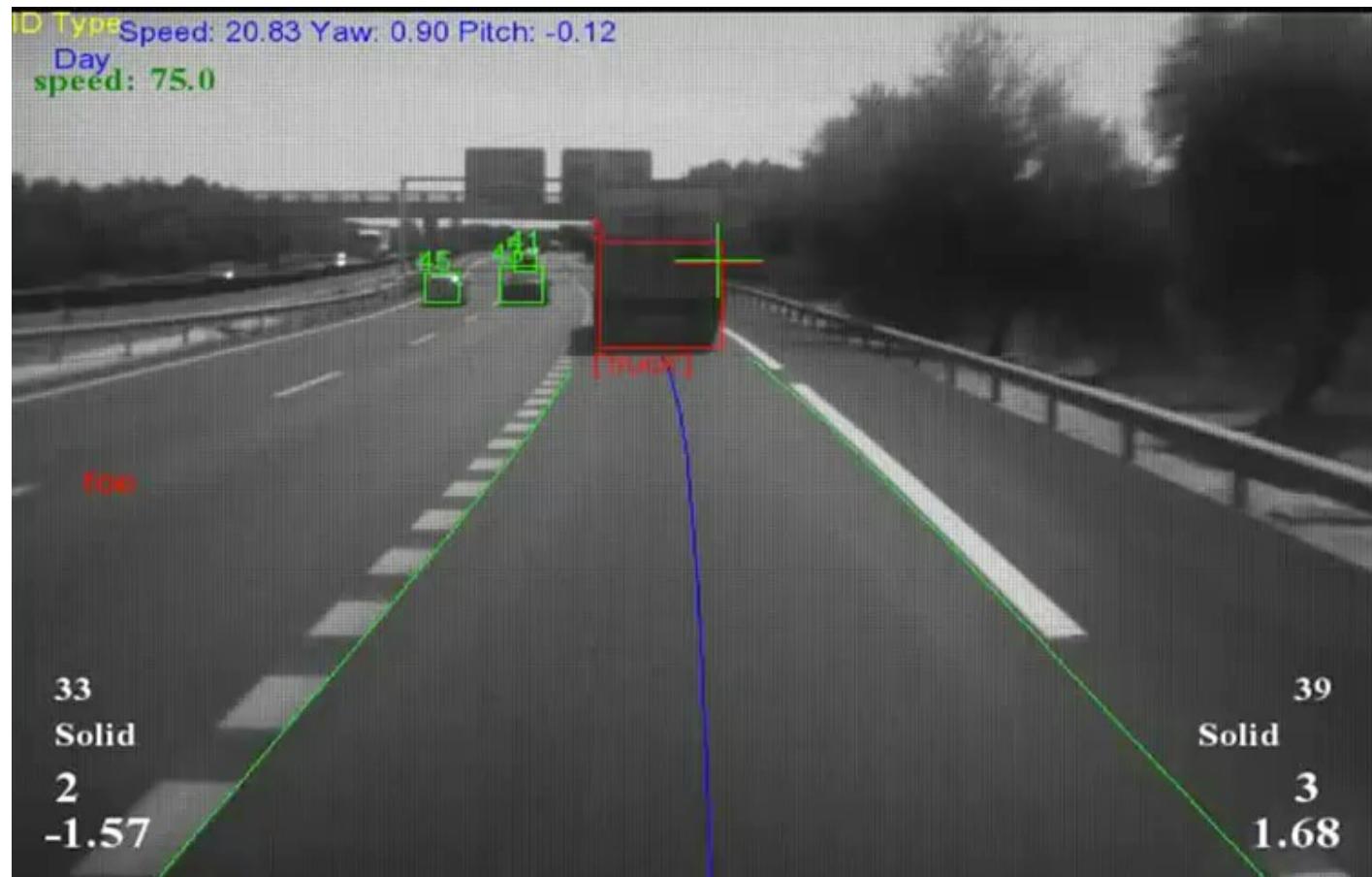


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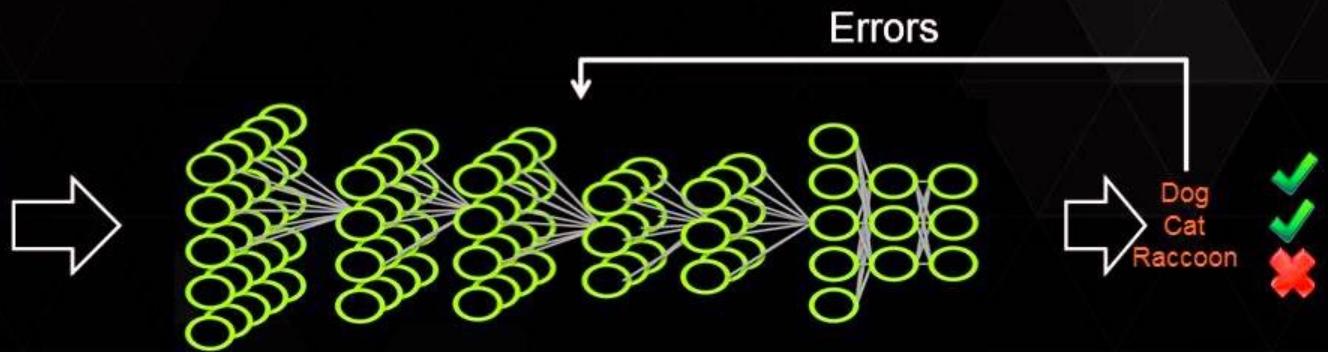


NVIDIA DRIVE™ PX DEEP NEURAL NETWORK COMPUTER VISION

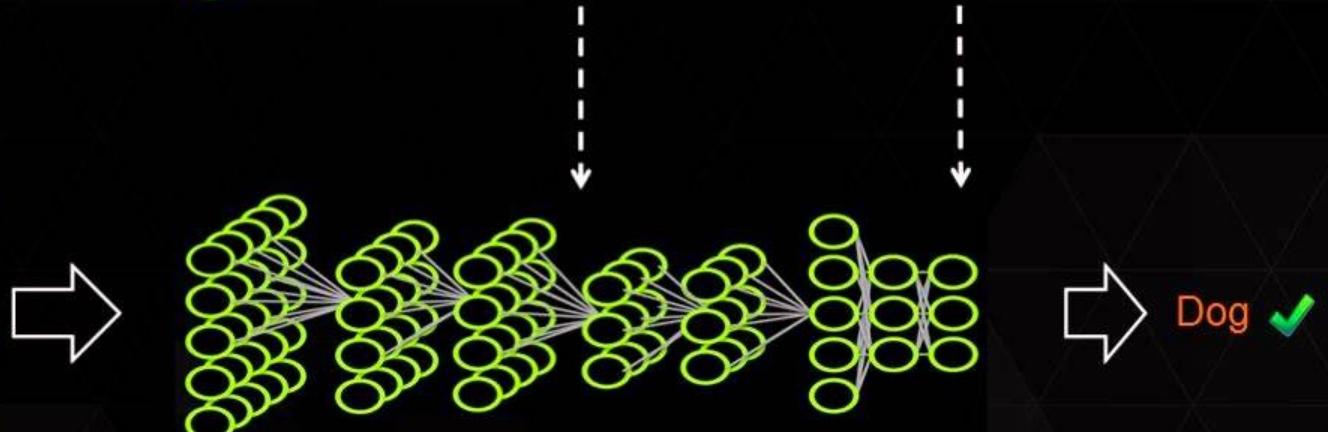


DEEP LEARNING APPROACH

Train:



Deploy:





How often can you be wrong?

Car

	Method	Setting	Code	Moderate	Easy	Hard	Runtime	Environment	Compare
1	iDST-VC			90.55 %	90.88 %	81.04 %	4 s	GPU @ 2.5 Ghz (Python + C/C++)	<input type="checkbox"/>

Pedestrian

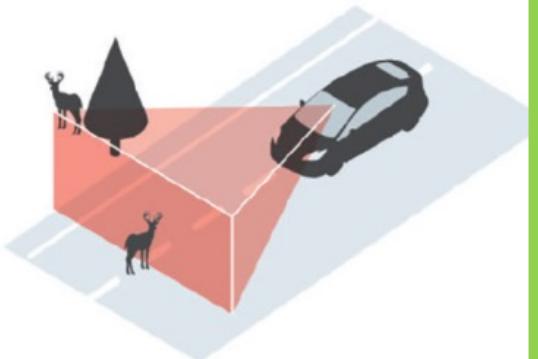
	Method	Setting	Code	Moderate	Easy	Hard	Runtime	Environment	Compare
1	SWC			78.65 %	87.06 %	73.92 %	0.5 s	GPU @ >3.5 Ghz (Python + C/C++)	<input type="checkbox"/>

Cyclist

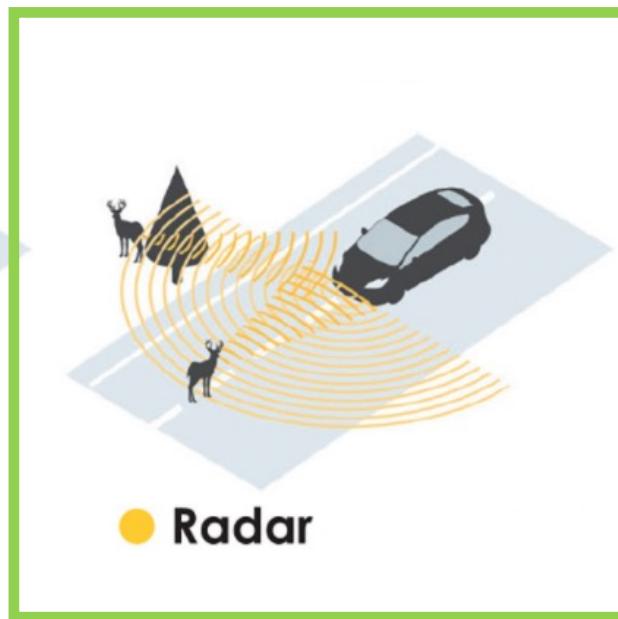
	Method	Setting	Code	Moderate	Easy	Hard	Runtime	Environment	Compare
1	SWC			77.58 %	86.02 %	68.44 %	0.5 s	GPU @ >3.5 Ghz (Python + C/C++)	<input type="checkbox"/>

http://www.cvlibs.net/datasets/kitti/eval_object.php?obj_benchmark=2d

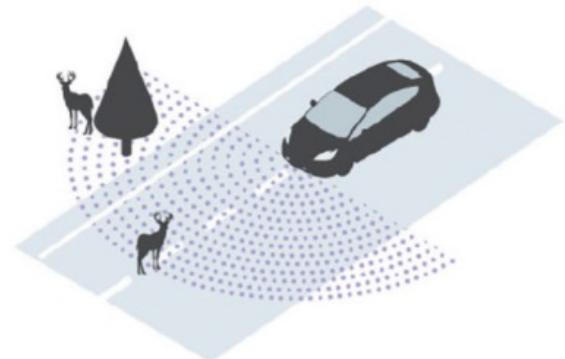
State of the Art Exteroceptive Sensors



● Camera



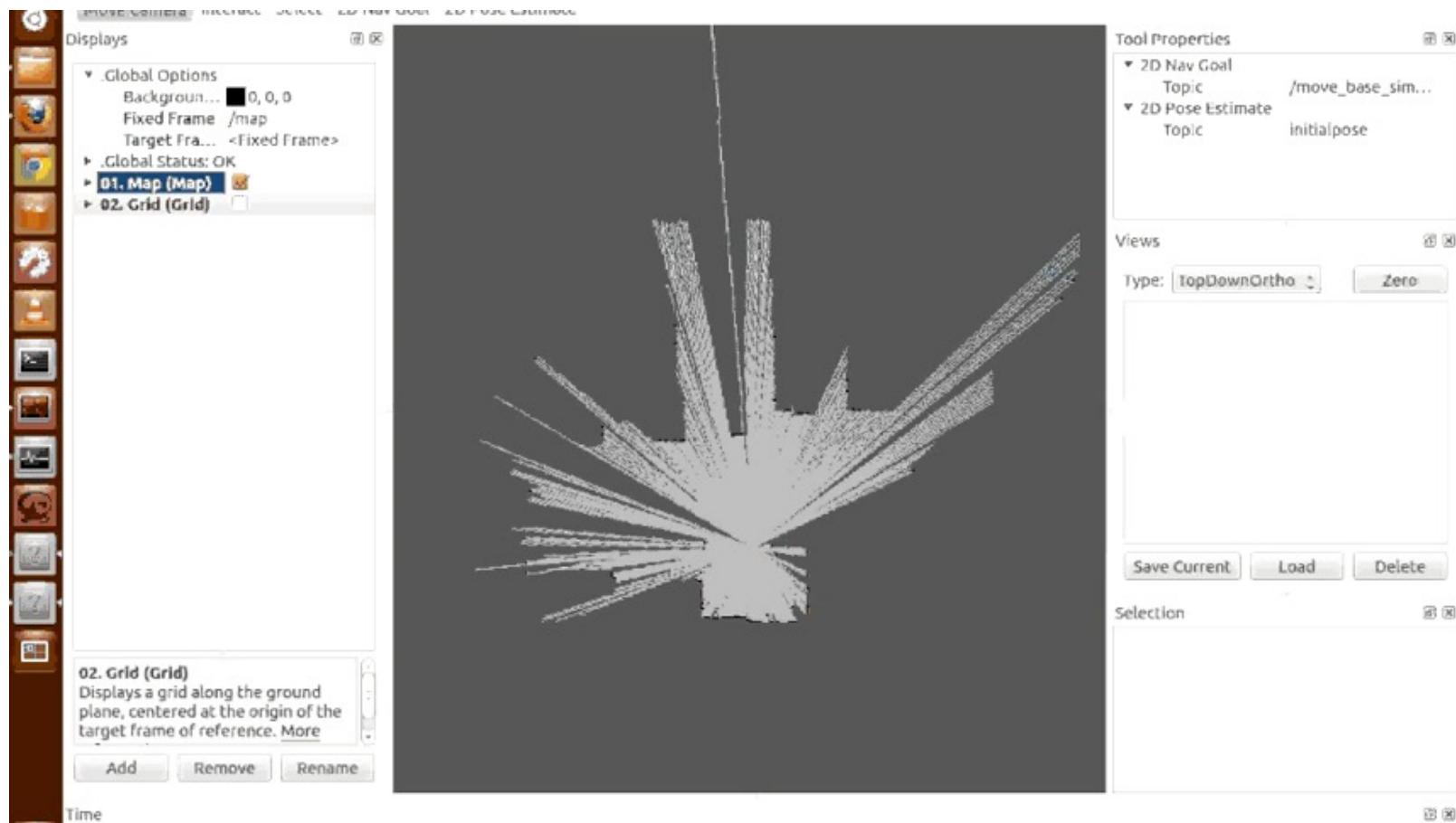
● Radar

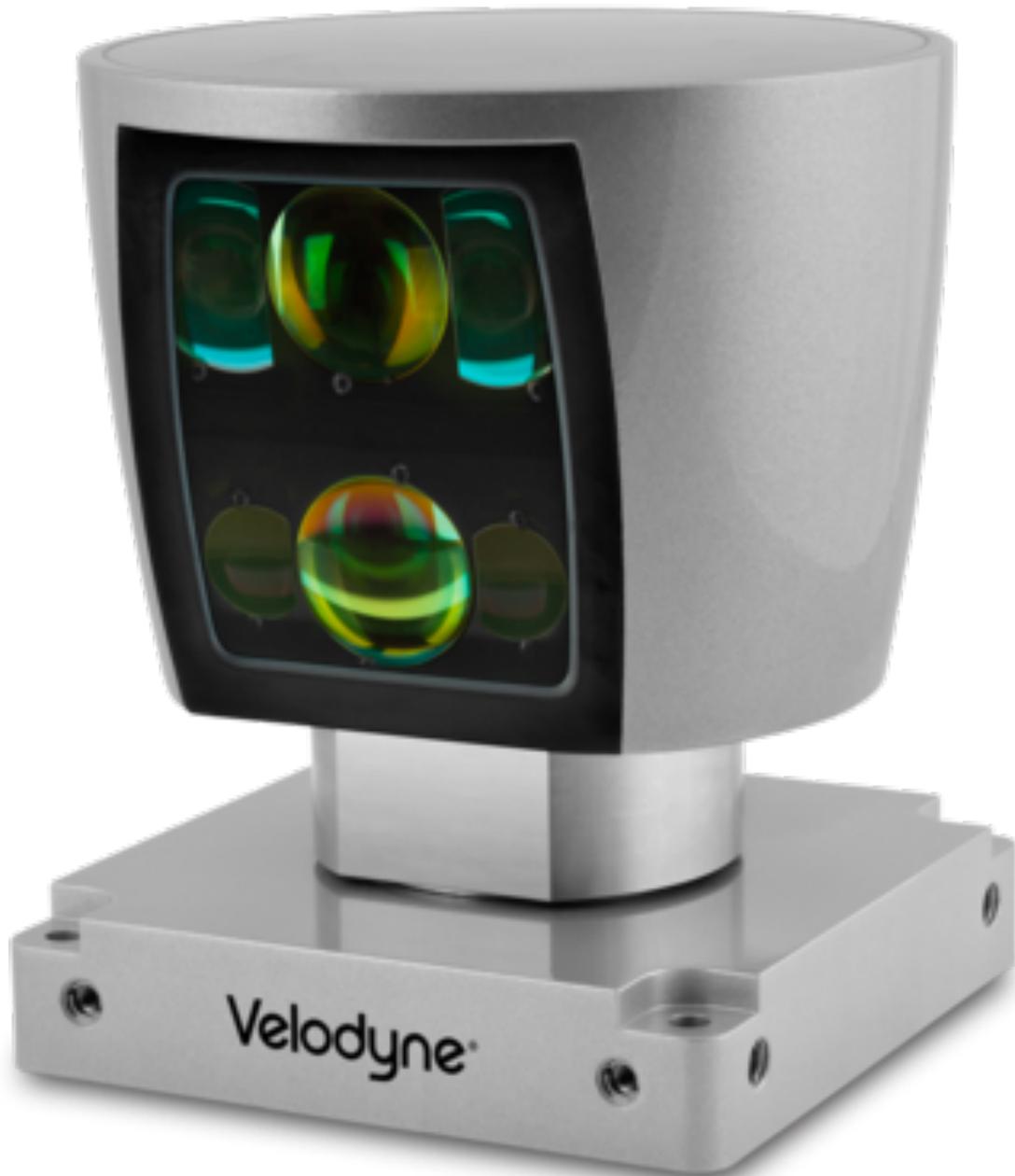


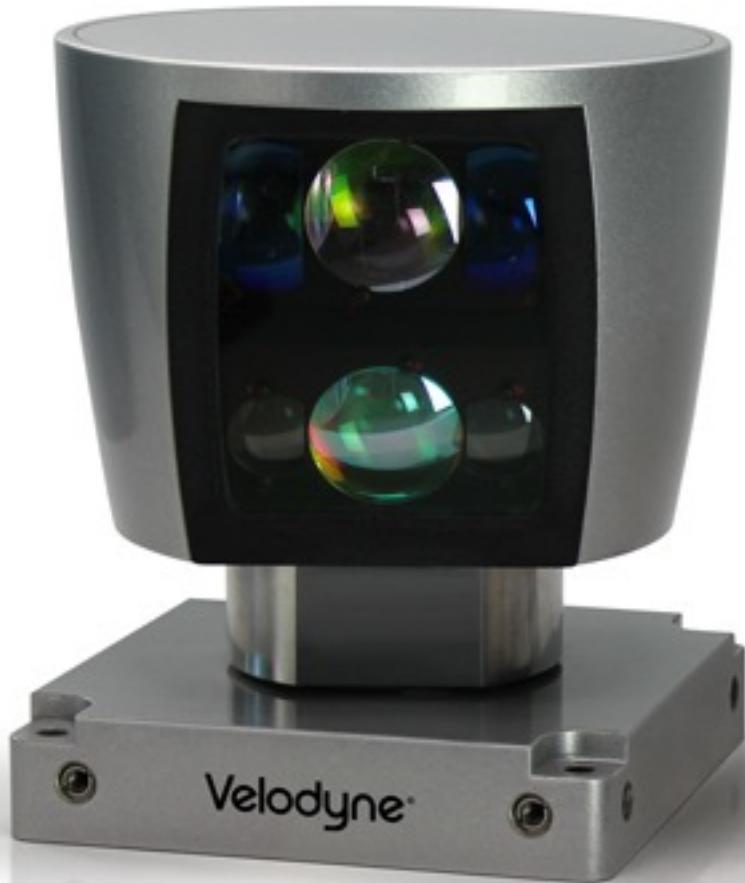
● LiDAR











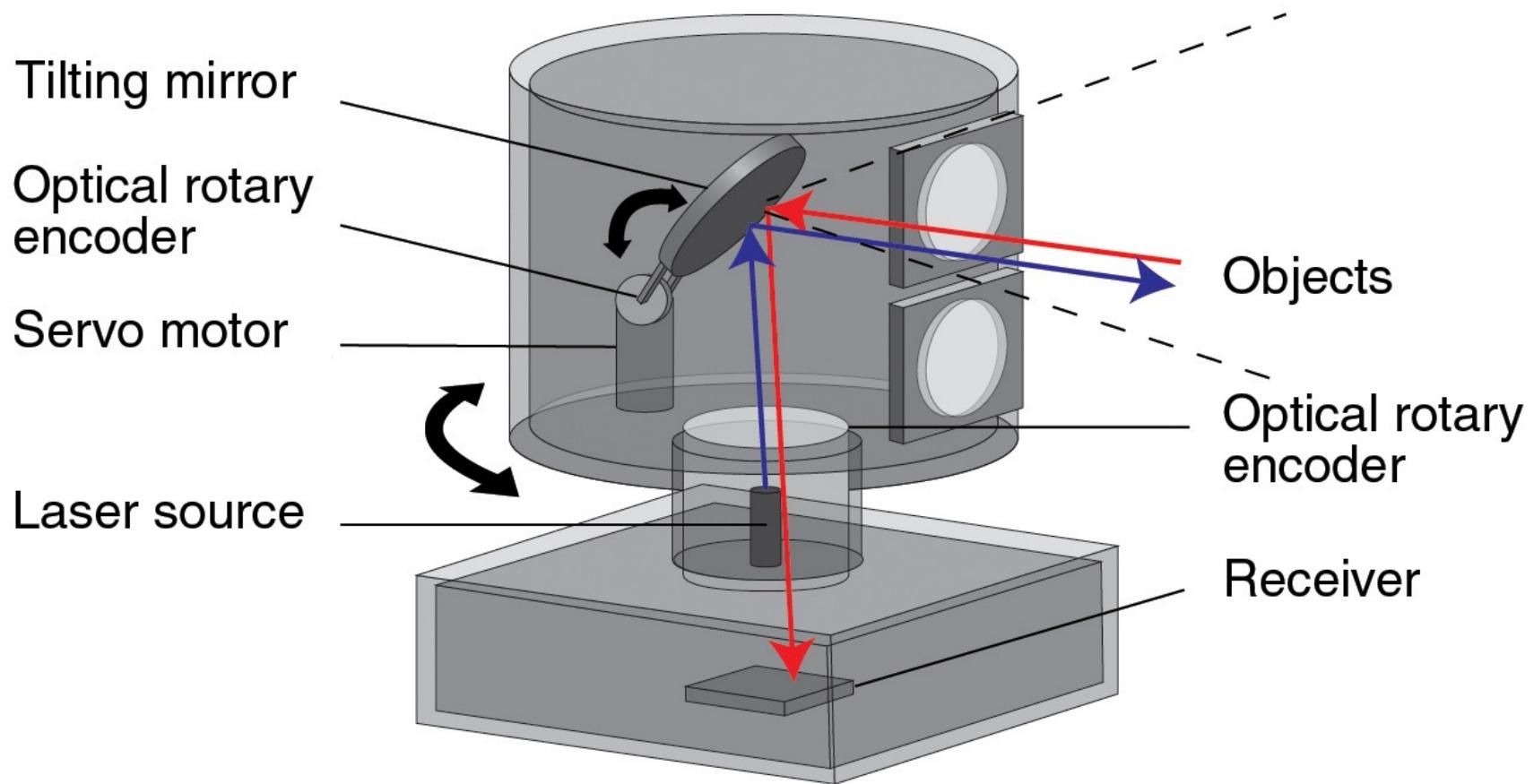
HDL-64E

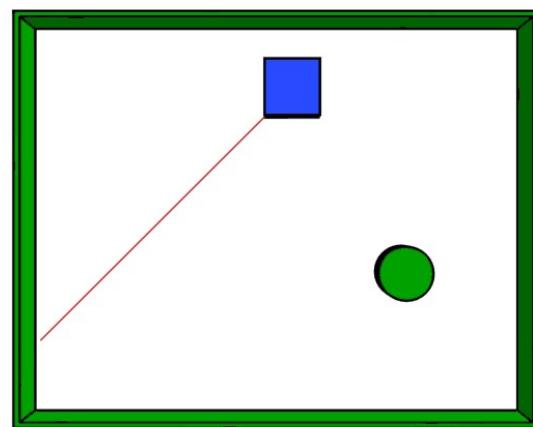
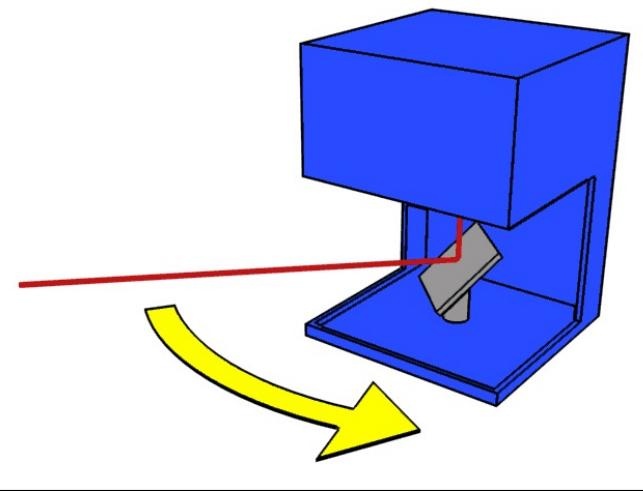


HDL-32E

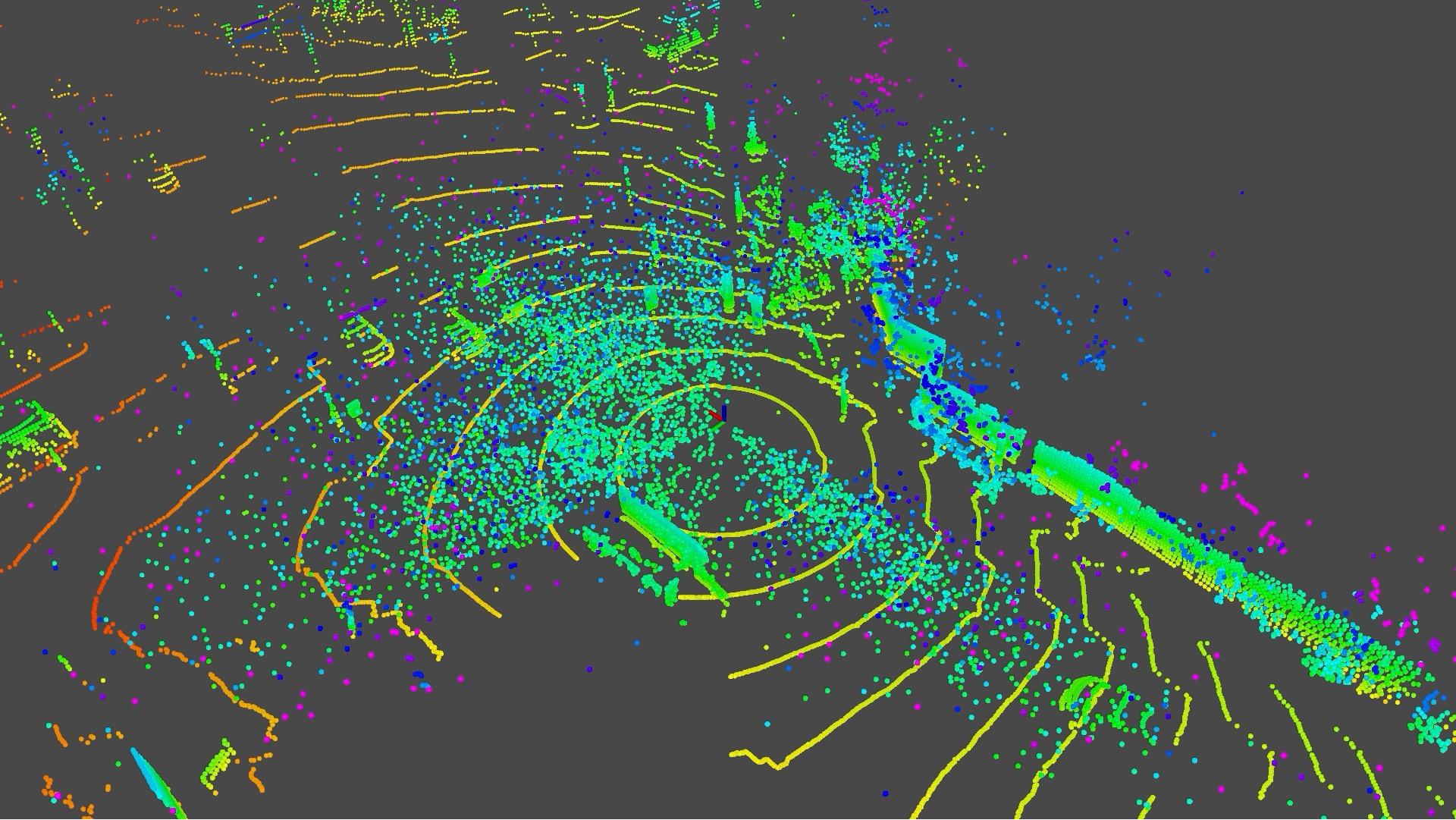


VLP-16





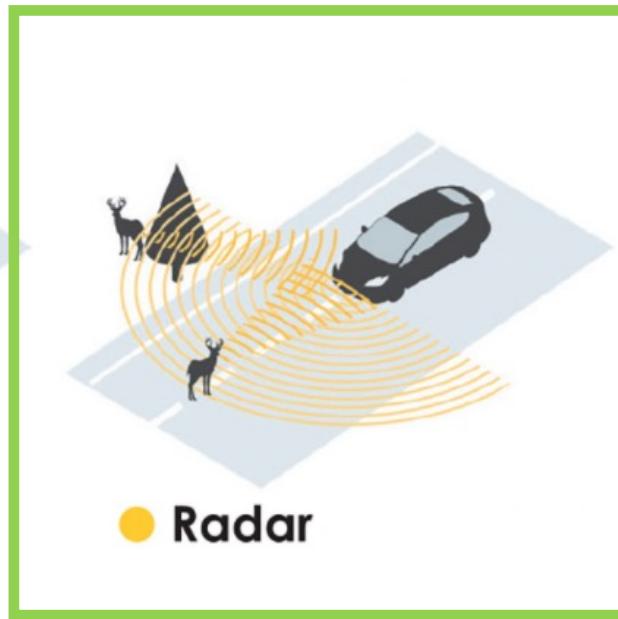




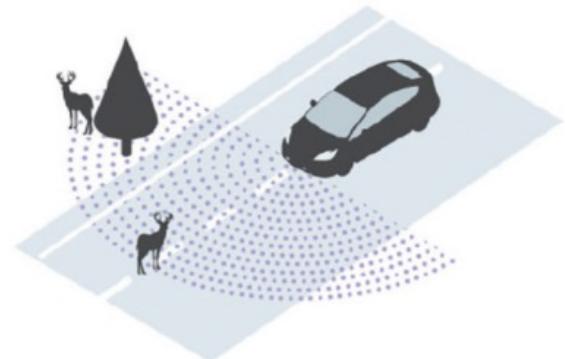
State of the Art Exteroceptive Sensors



● Camera



● Radar



● LiDAR

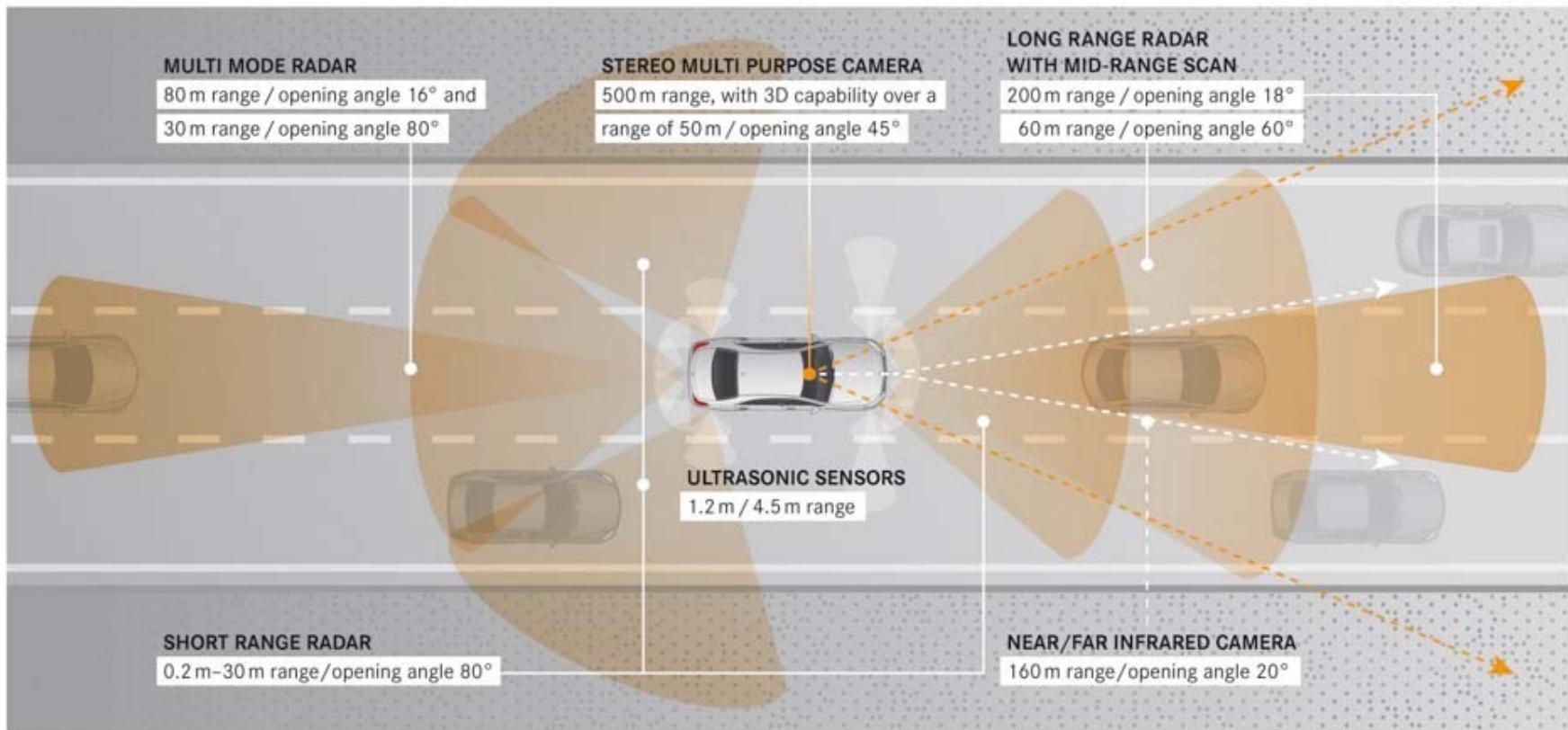
RESTAURANTE
THE GRANNY'S HOUSE
MADEIRA
CUISINE & PIZZERIA



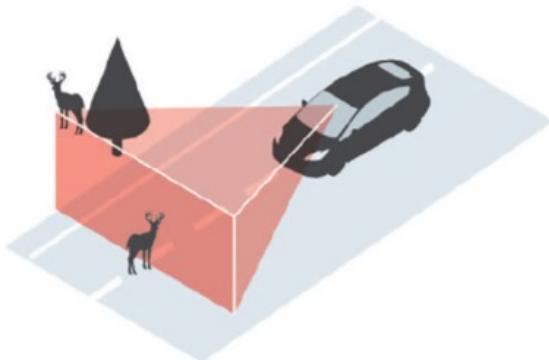


RADAR

- Weather
- Velocity
- Penetration
- Low resolution



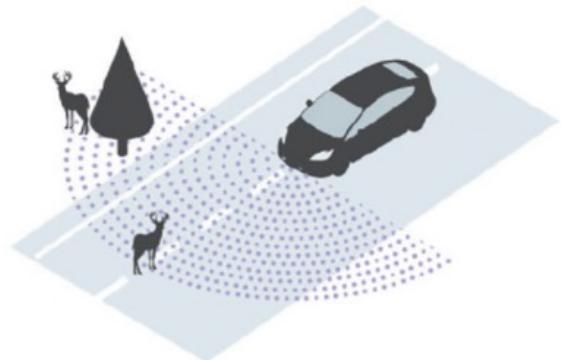
What Can We Do with All of these Sensors?



● Camera

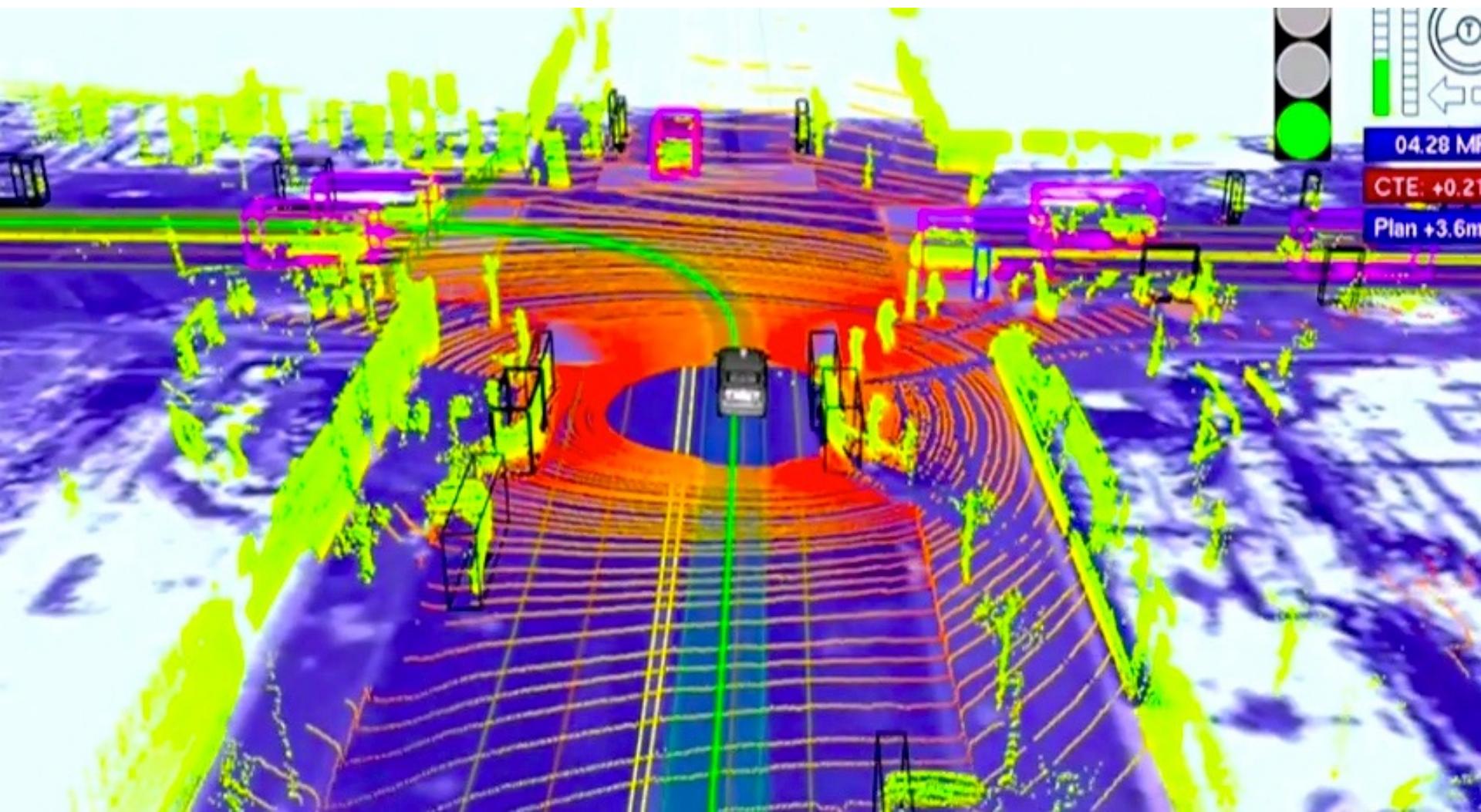


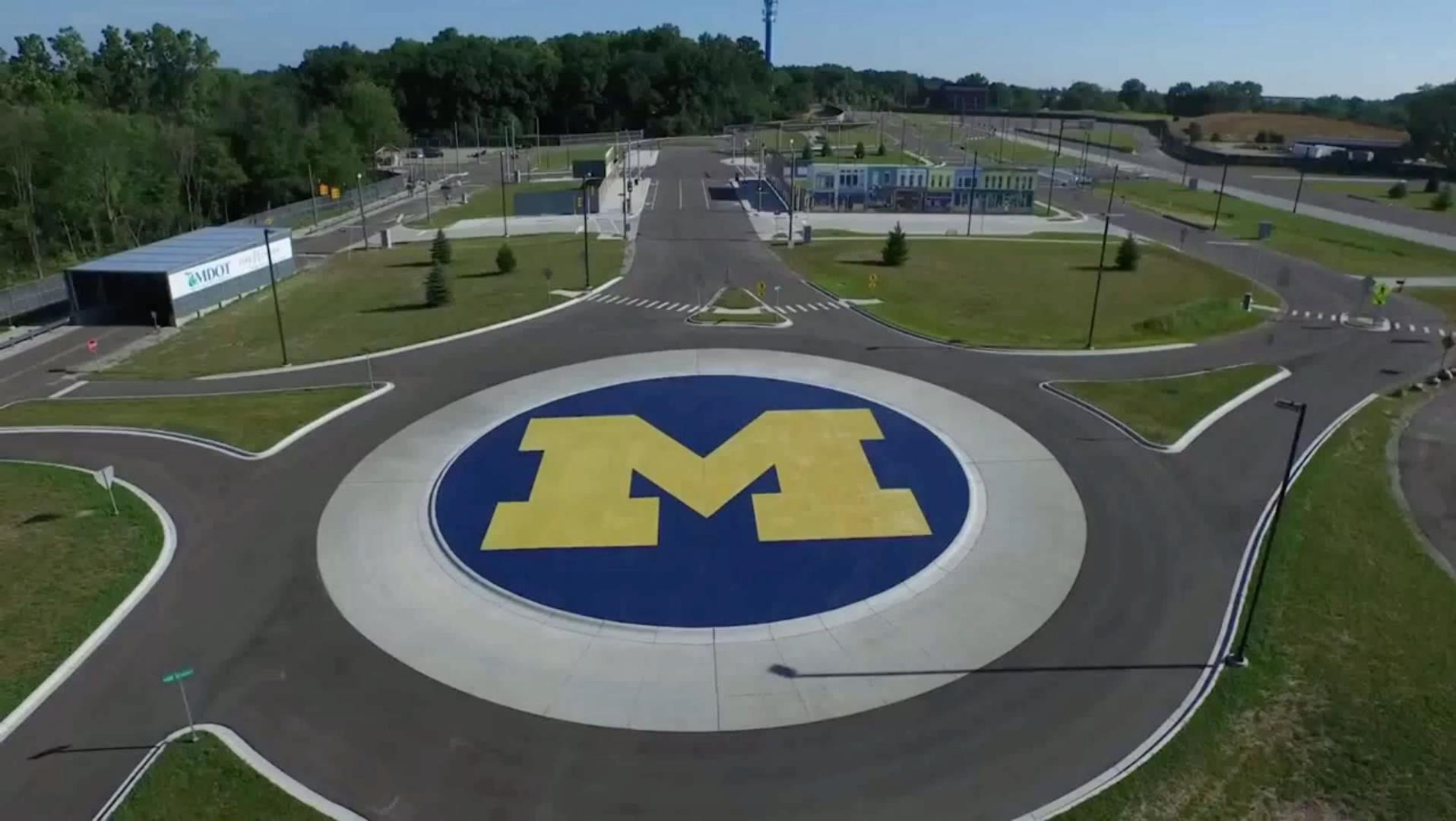
● Radar



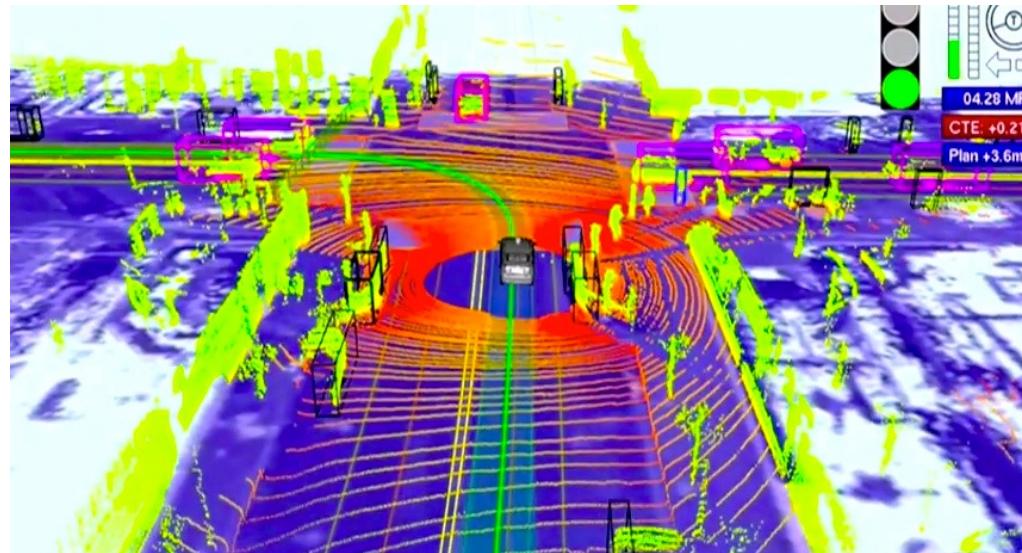
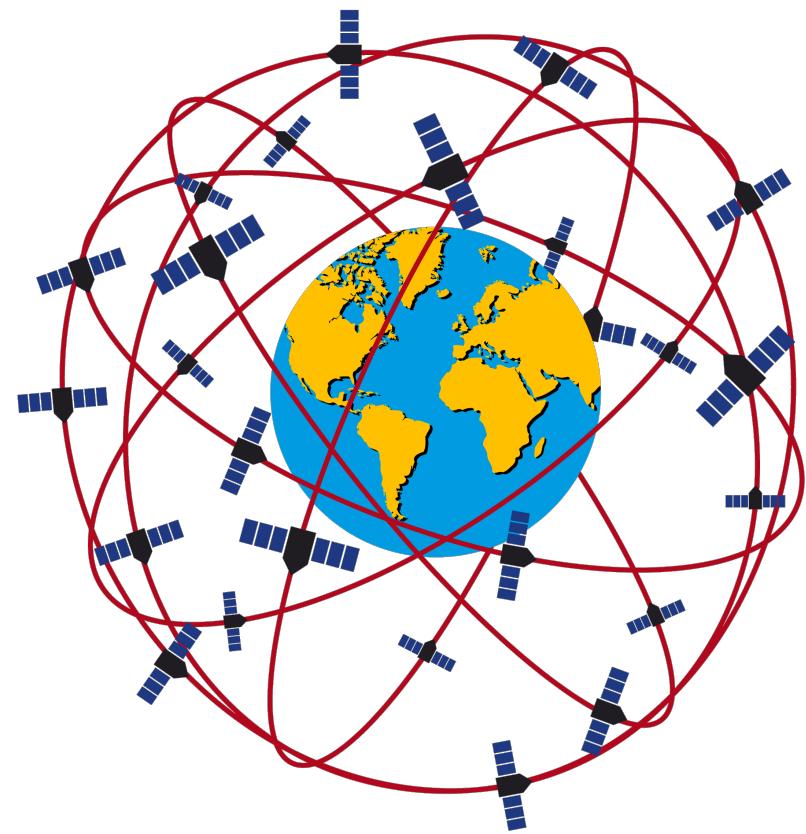
● LiDAR

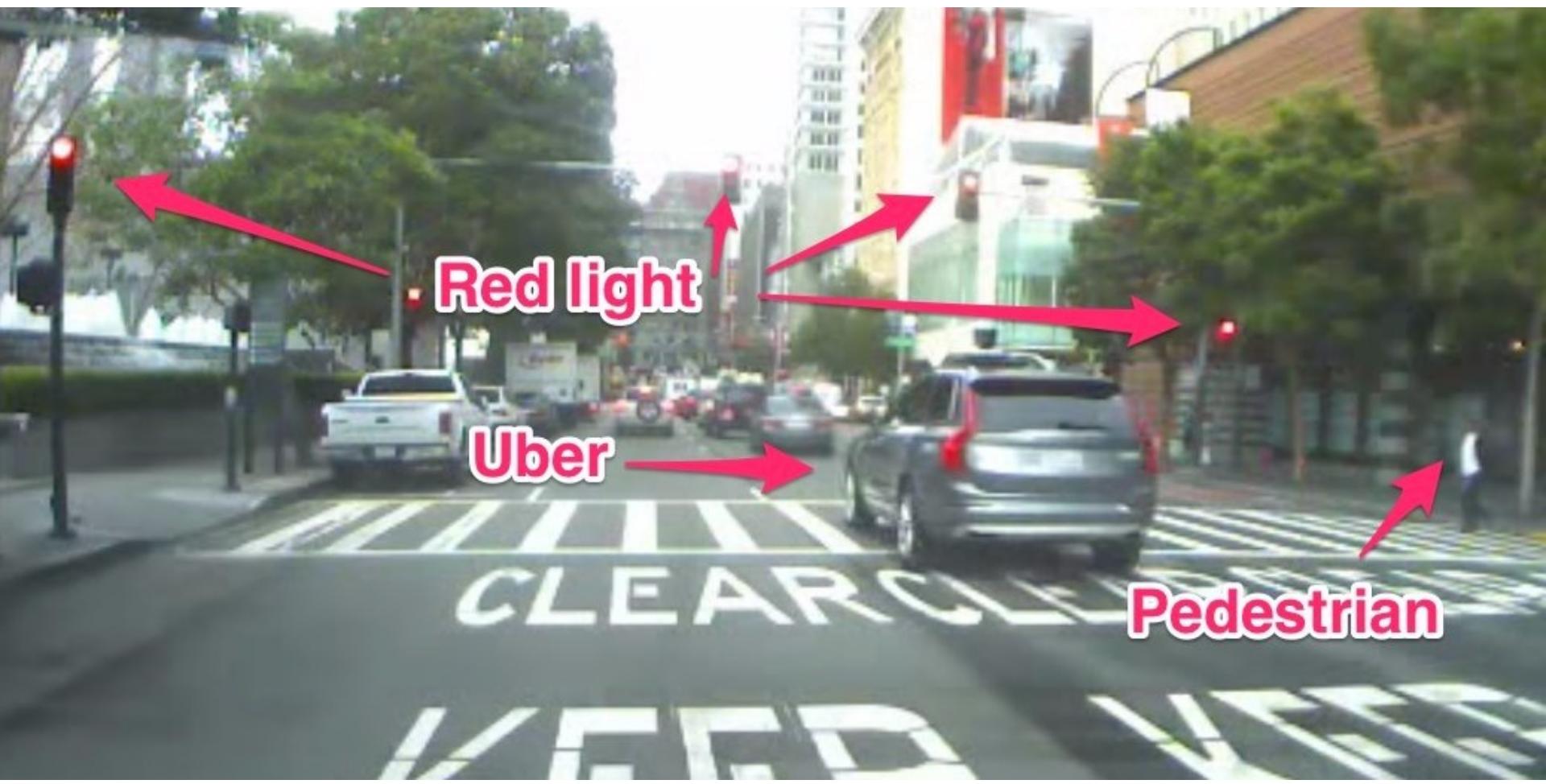
HD Maps

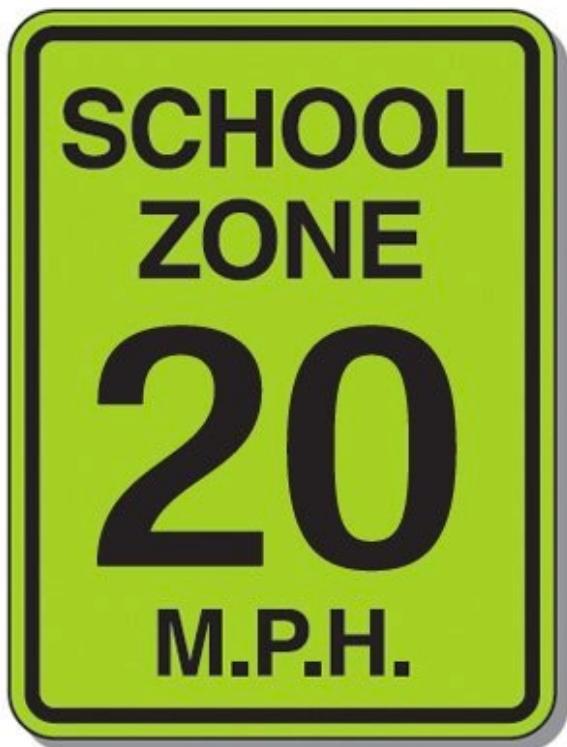




HD Maps

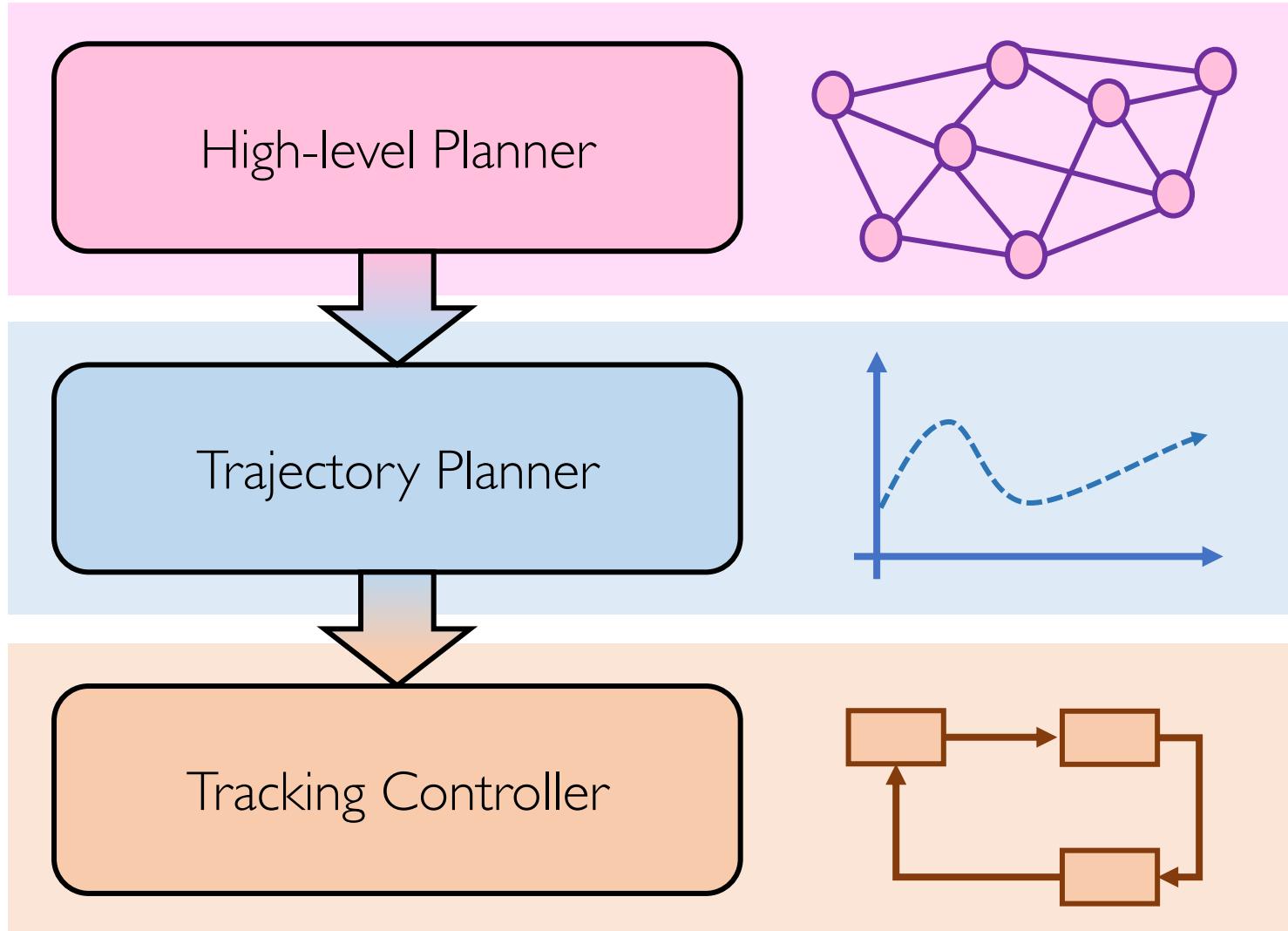






The Challenges: Control

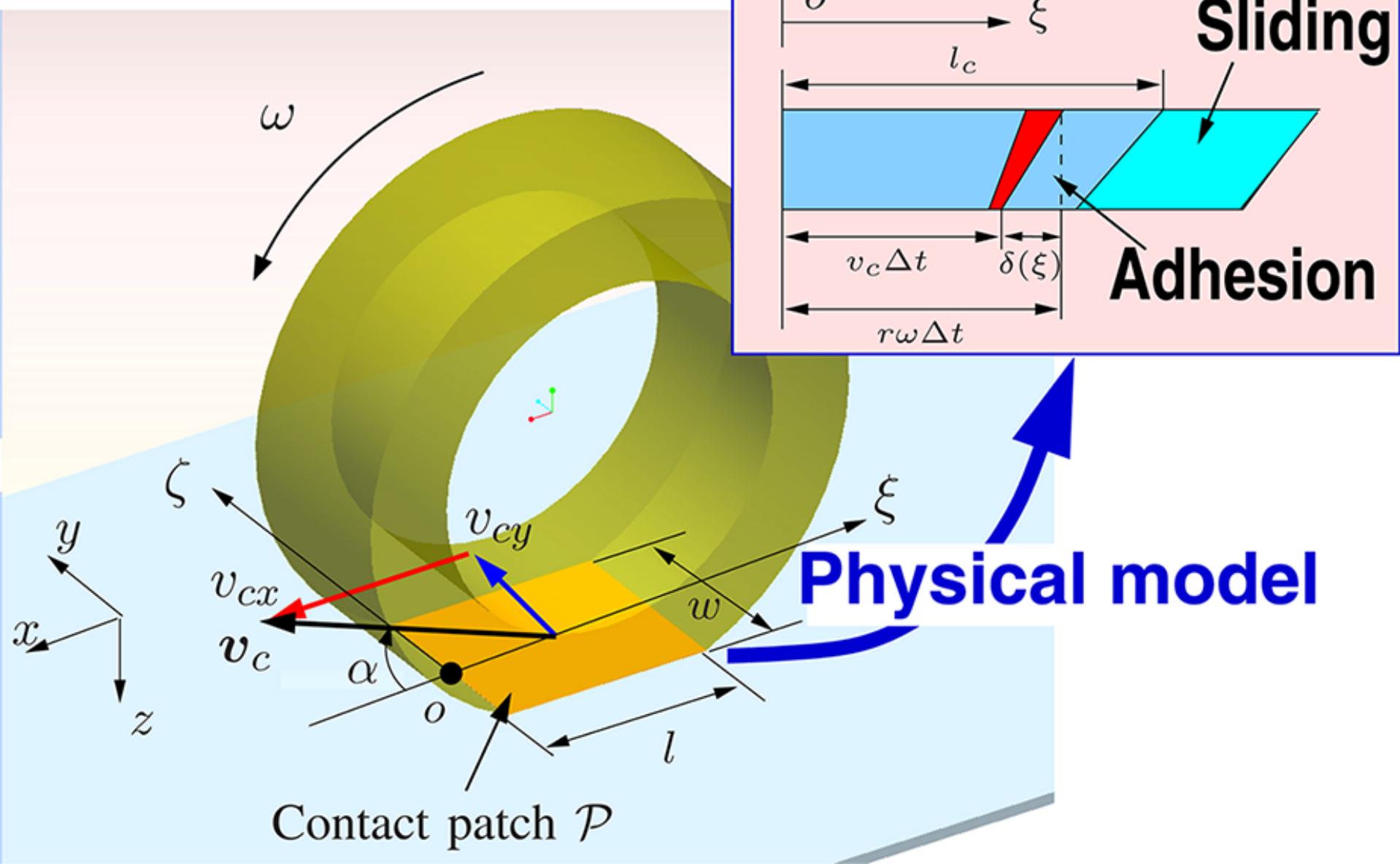
Planning and Control Hierarchy



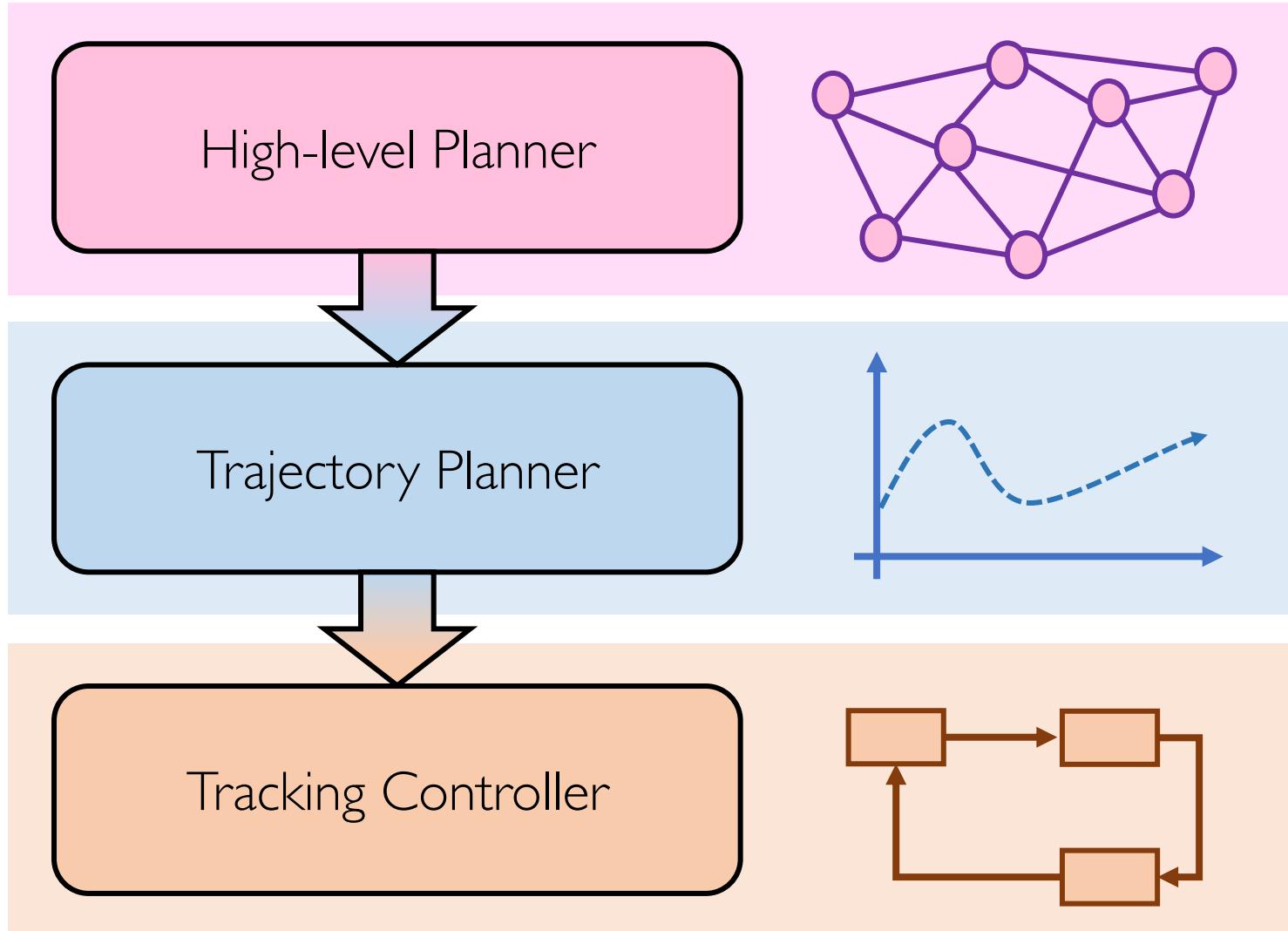
Why Apply A Planning Hierarchy?



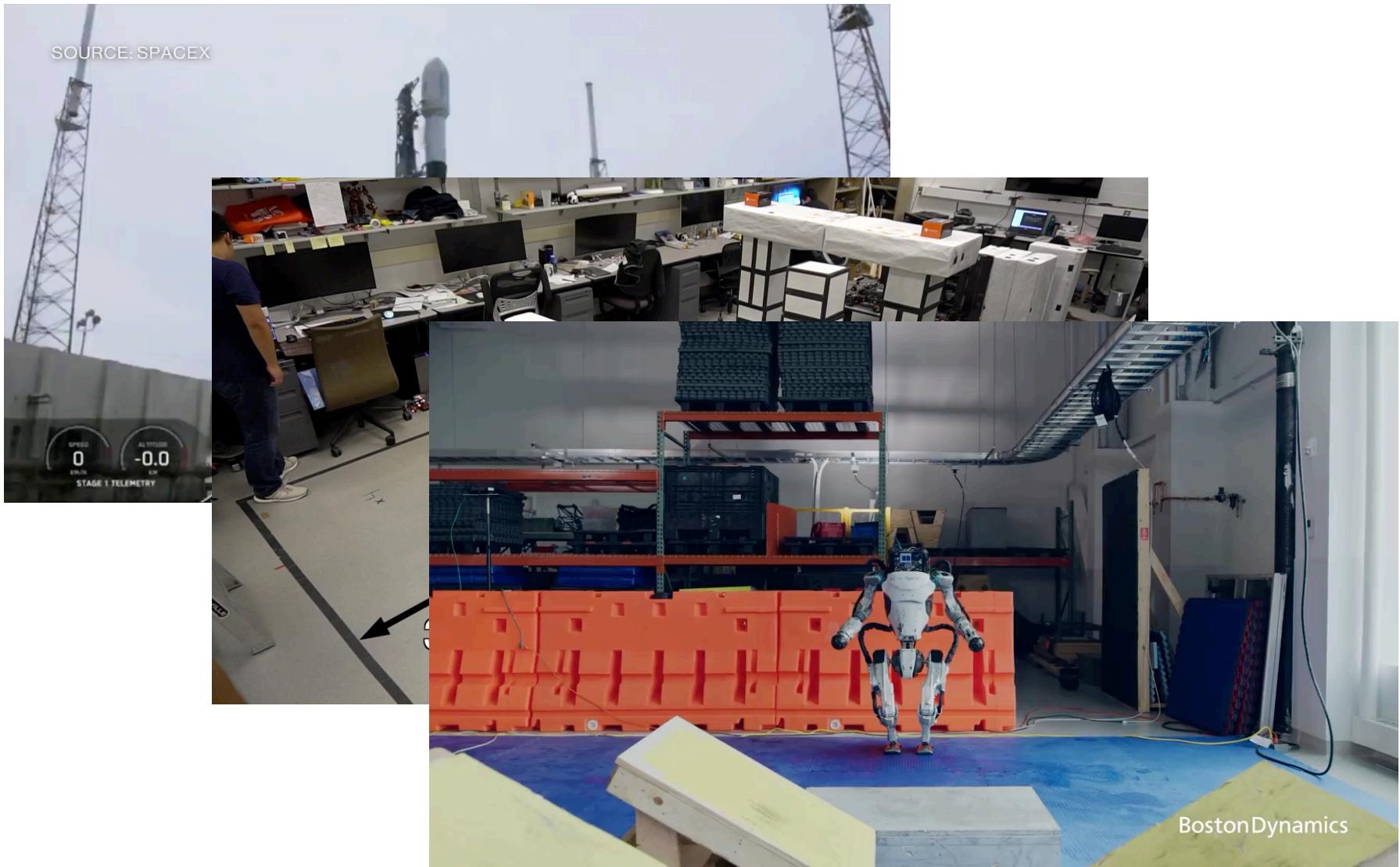
Vehicle Models are Complex



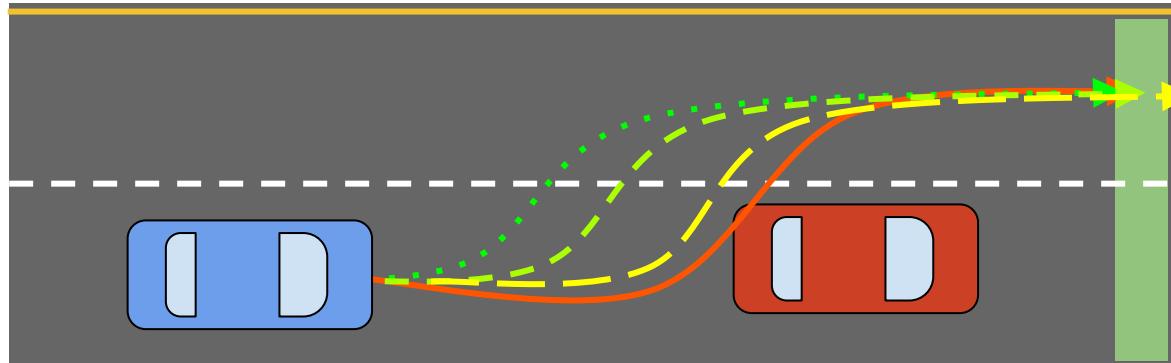
Planning and Control Hierarchy



Optimization has Transformed Traj. Planning and Tracking



How to Deal with Limited Model Fidelity



Performance

Safety

The Failures Can Be Catastrophic!



The Challenges: Prediction

Intersection of Brickell Avenue & Southwest 8th Street

City of Miami, Florida

12:35 pm - 1:05pm

March 28, 2012

This seems hard...are there
alternatives?

Semi-Autonomy?

How do you know you need help?

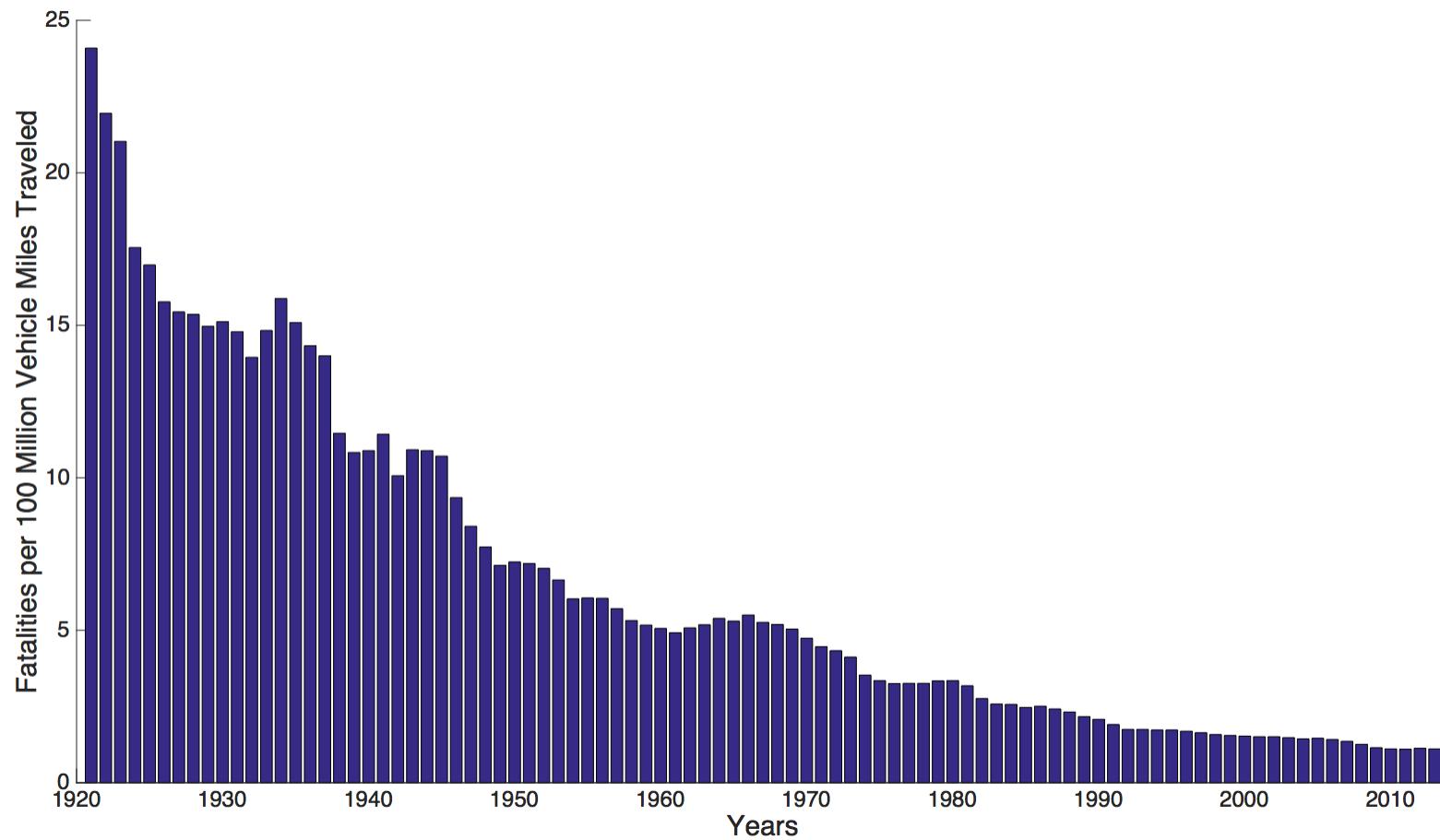


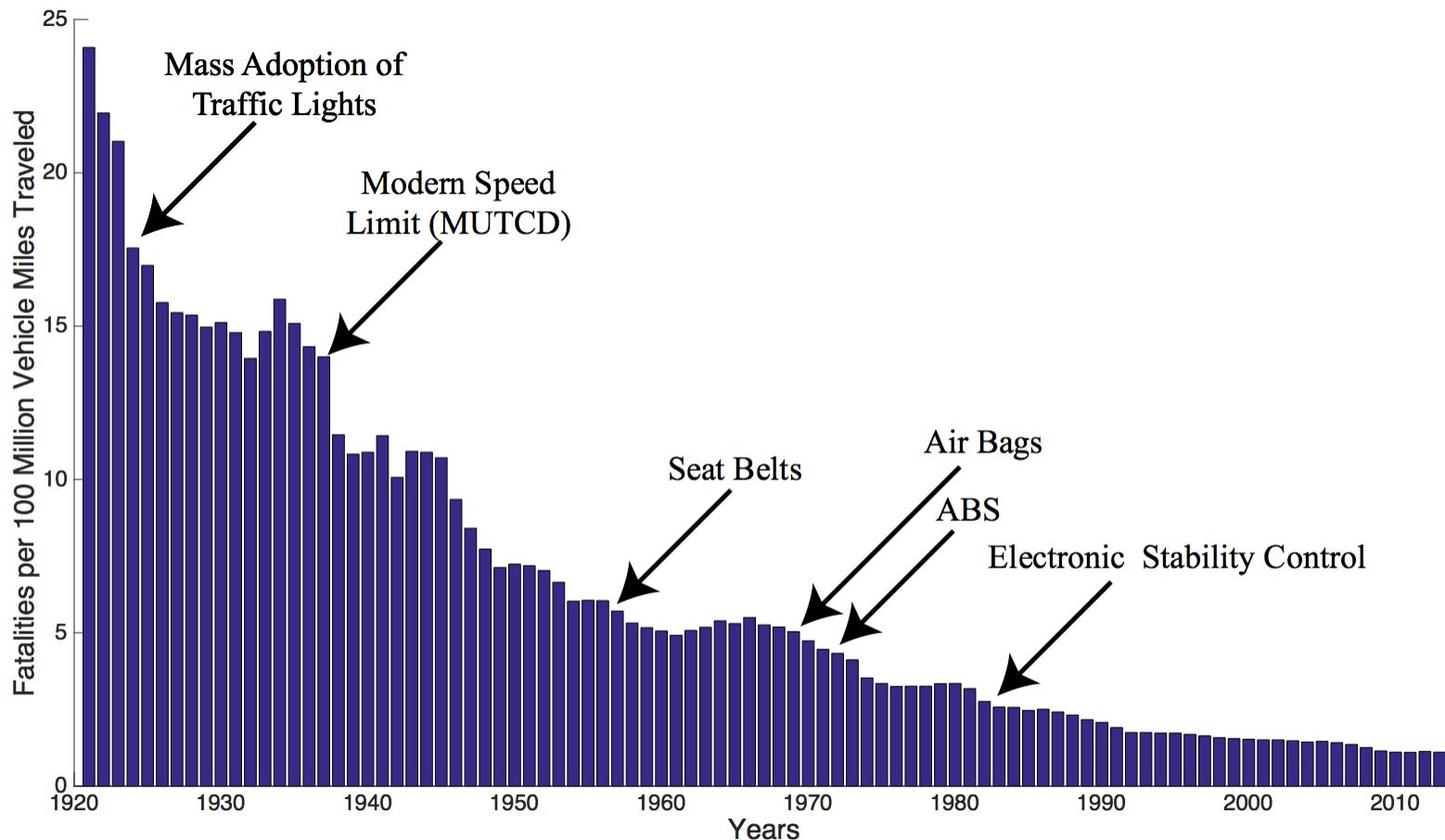
How do you know you need help?

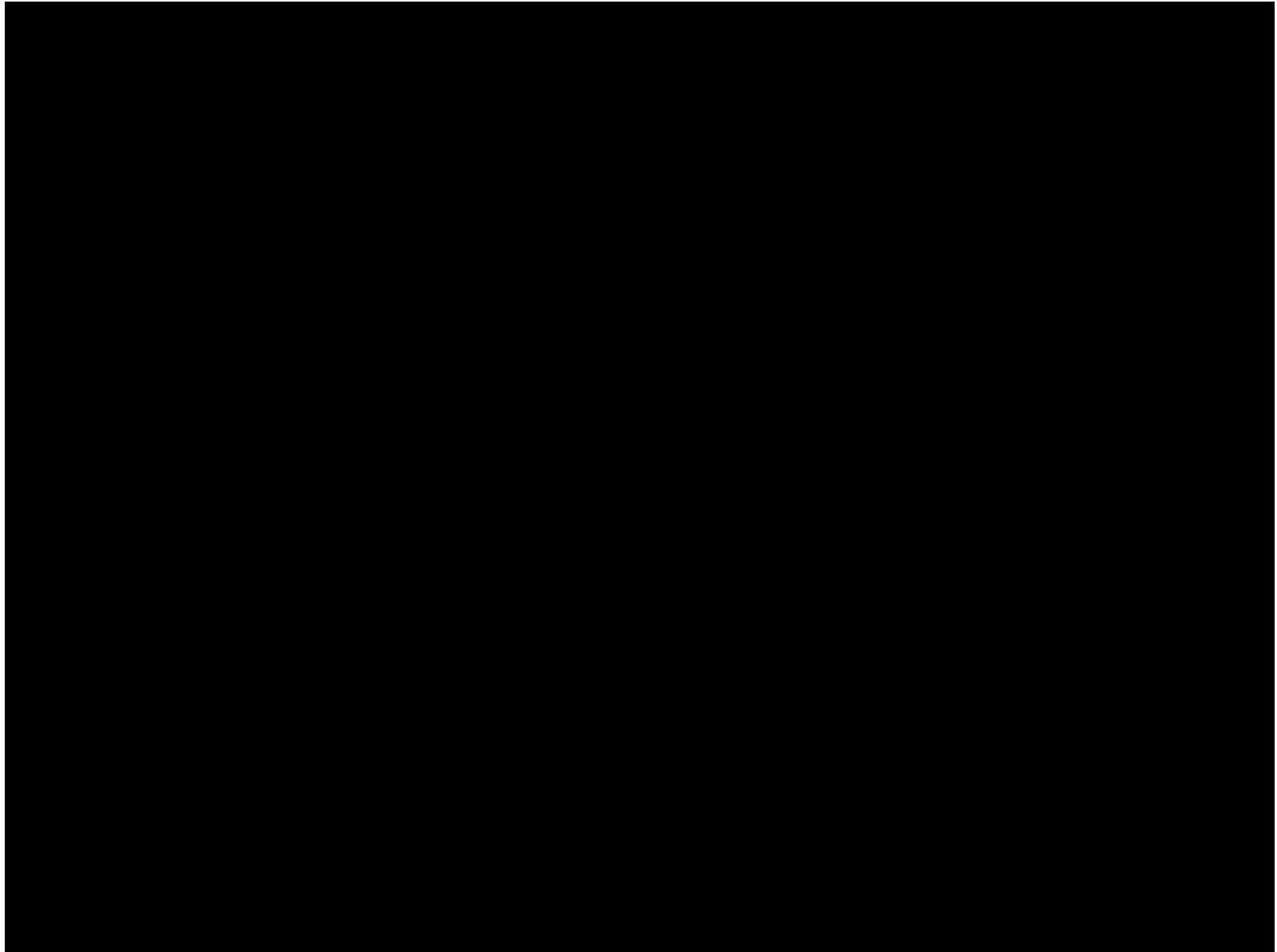




What about these things as safety features?





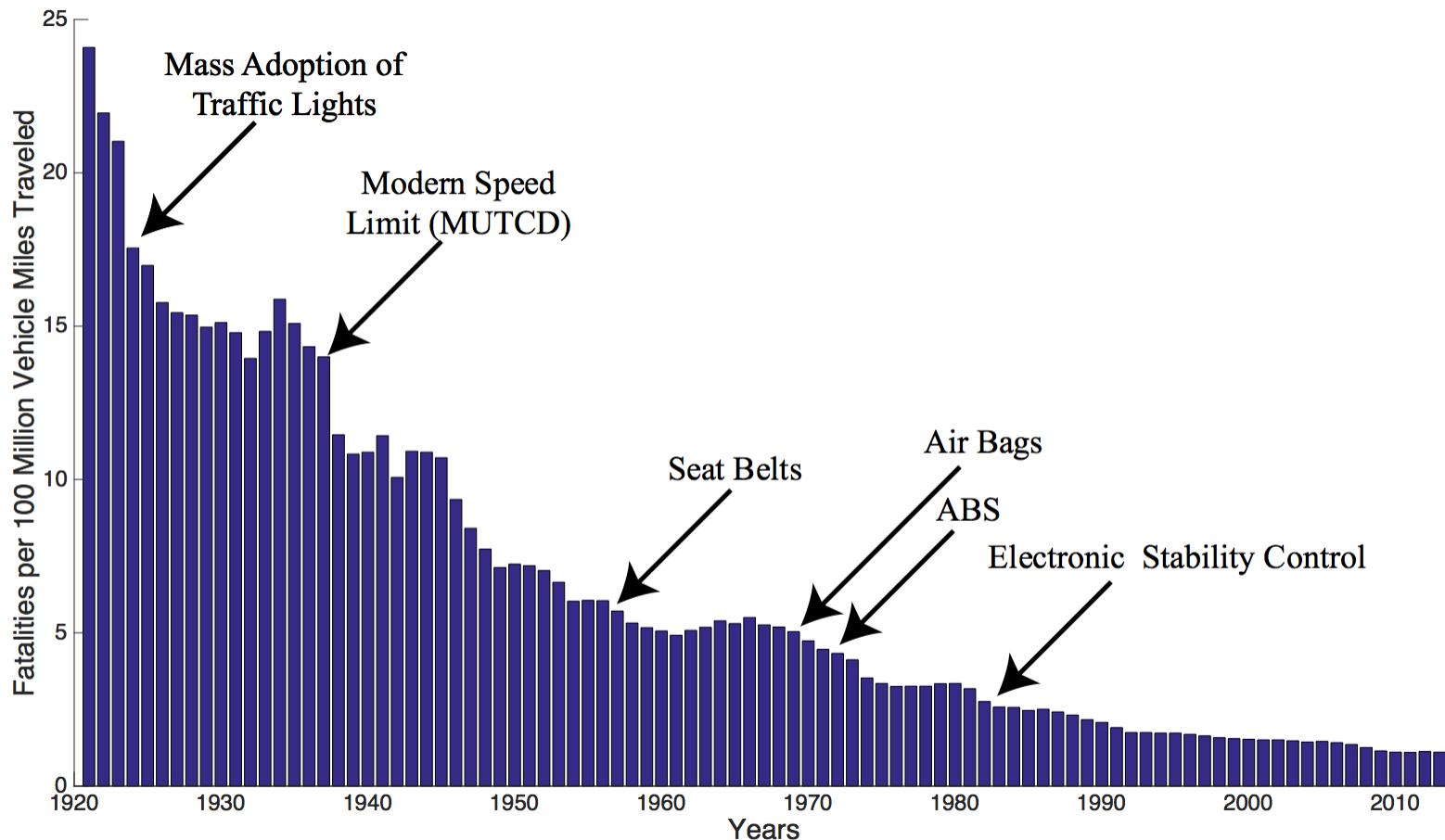


Driver Alert Systems

- Lane departure warnings
- Forward Collision Warning
- Pedestrian collision warning

Active Safety Systems

- Lane keep assist
- ACC
- Emergency breaking
- Seatbelt tightening



Where does that leave level 3

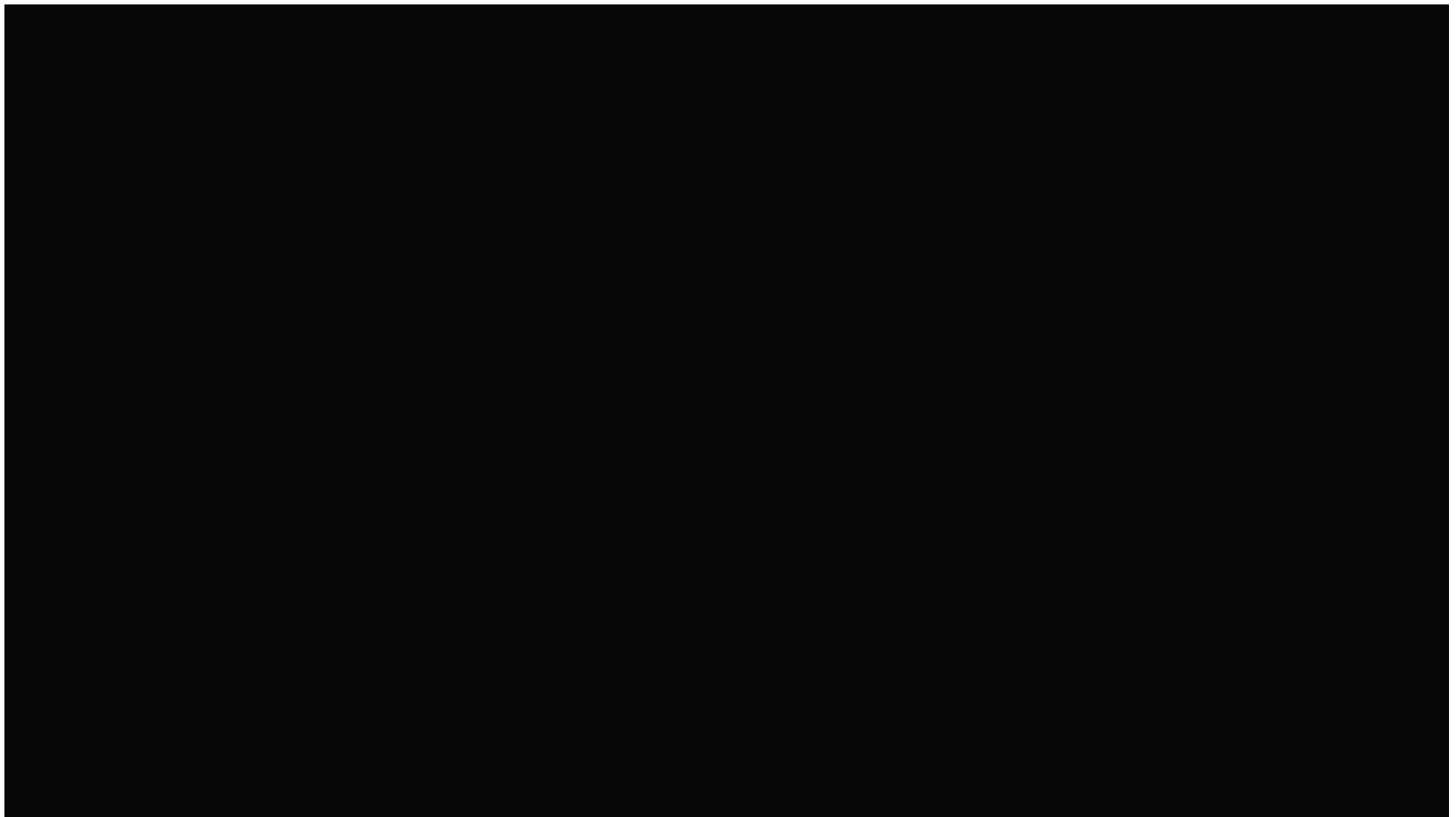
- Geo-fencing
- Scenario-fencing
- Active driver awareness monitoring
- Convoying

What is technically unsolved?

- Hand-off
- High reliability/Low false positive rate



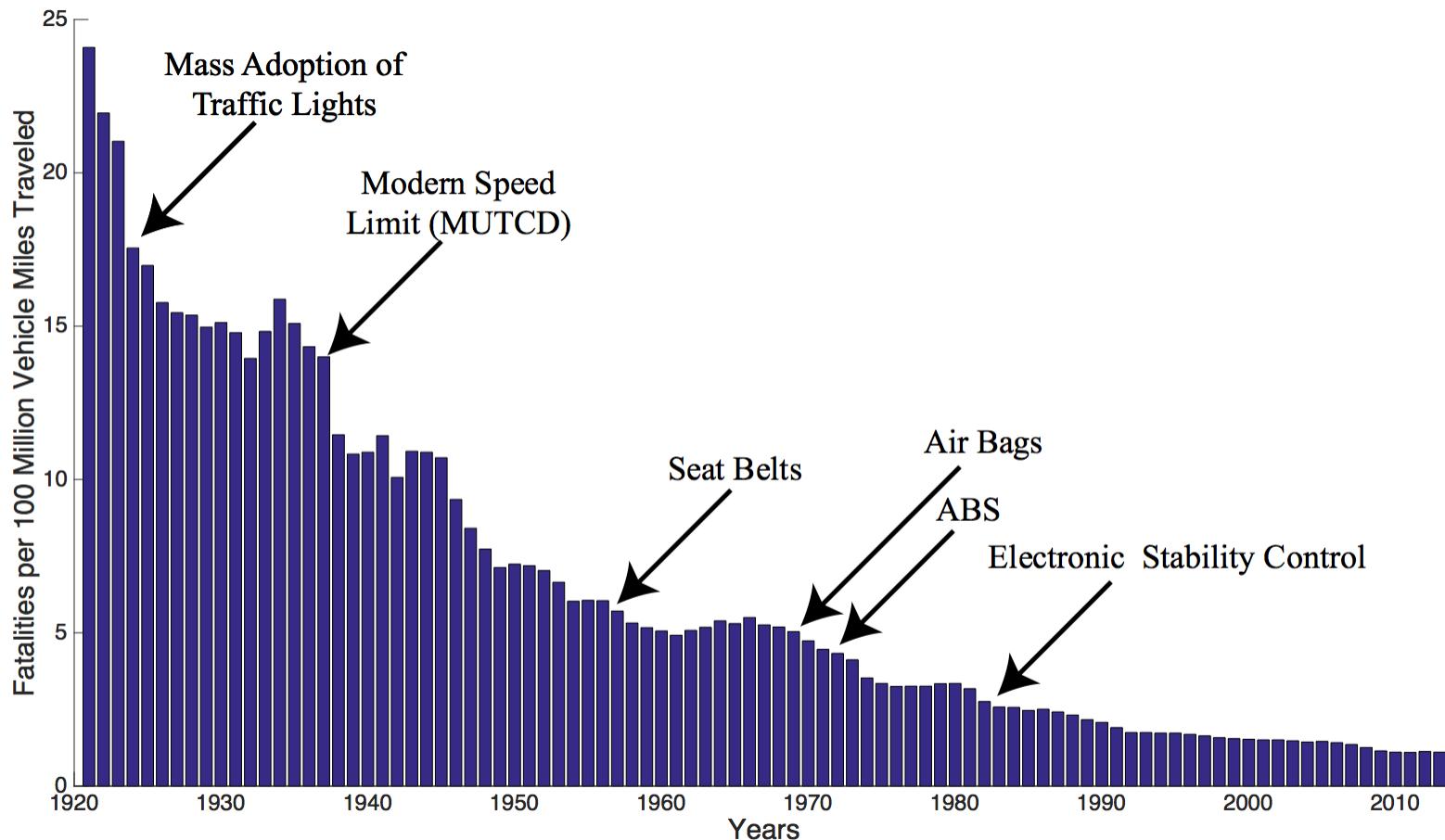


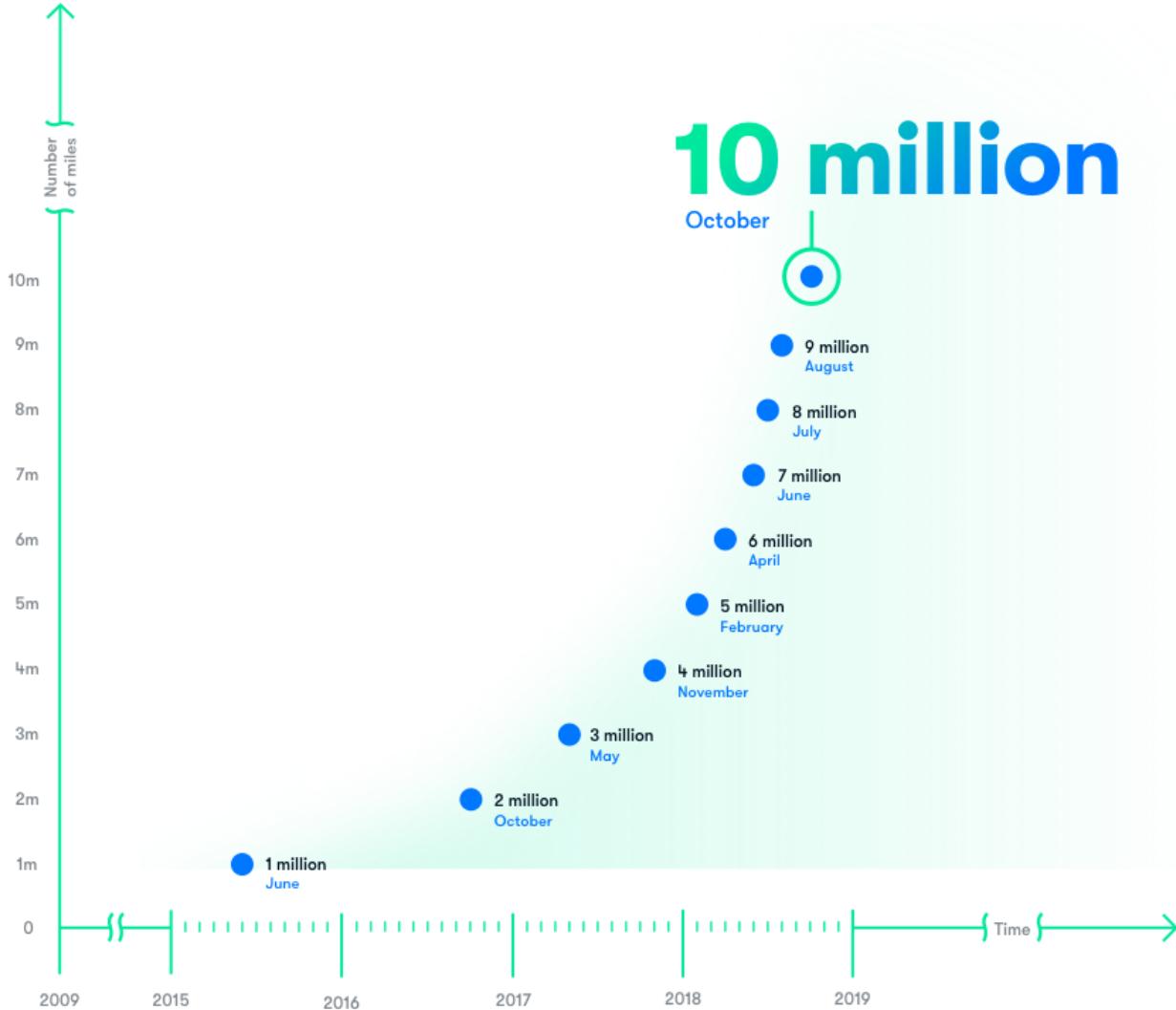


UBER

abc 15
ARIZONA

wmuth





10 million miles and counting



Are We Close... Can We Tell from
Media Coverage?

GOOGLE

FEATURED VIDEOS

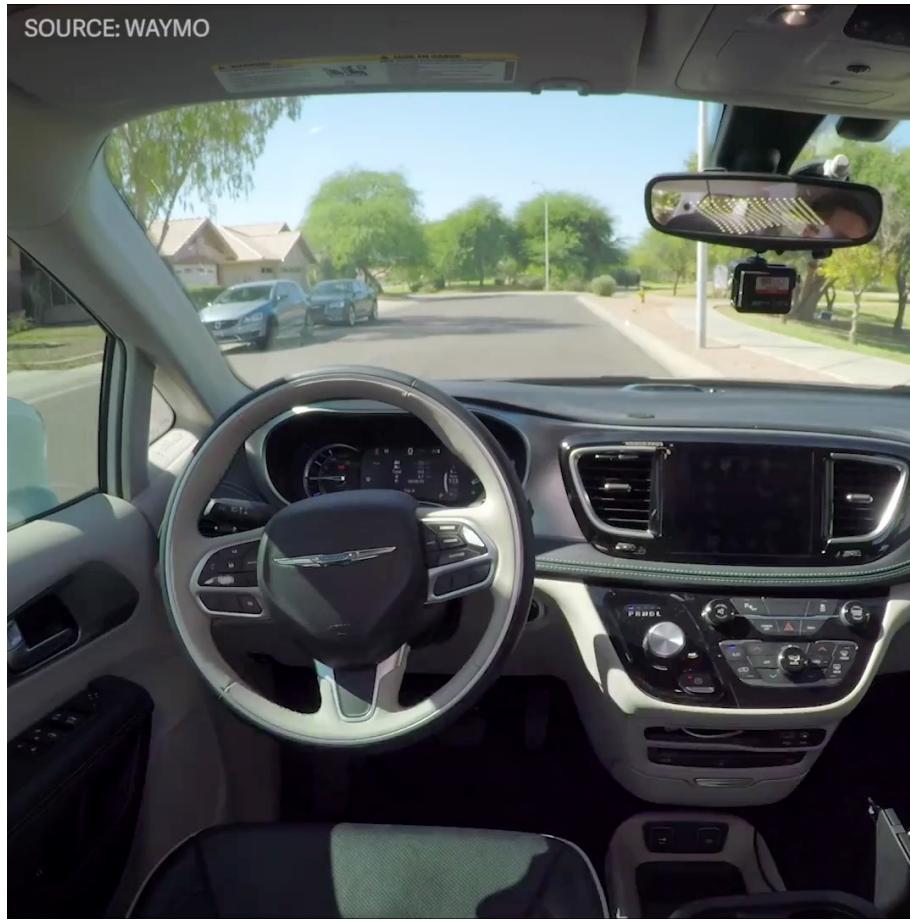
TECH

Waymo is first to put fully self-driving cars on US roads without a safety driver

Going Level 4 in Arizona

By Andrew J. Hawkins | @andyjayhawk | Nov 7, 2017, 11:00am EST

SOURCE: WAYMO



Waymo's Self-Driving Cars Are Near: Meet the Teen Who Rides One Every Day

Alphabet is experimenting with prices and finalizing its business model before unleashing its autonomous fleet in Phoenix this year.



EXCLUSIVE AUTONOMOUS VEHICLES CITIES AI

Waymo's Big Ambitions Slowed by Tech Trouble

By Amir Efrati Aug 28, 2018 7:00 AM PDT • Comments by Soham Bhatia, Eddie Xue and 4 others

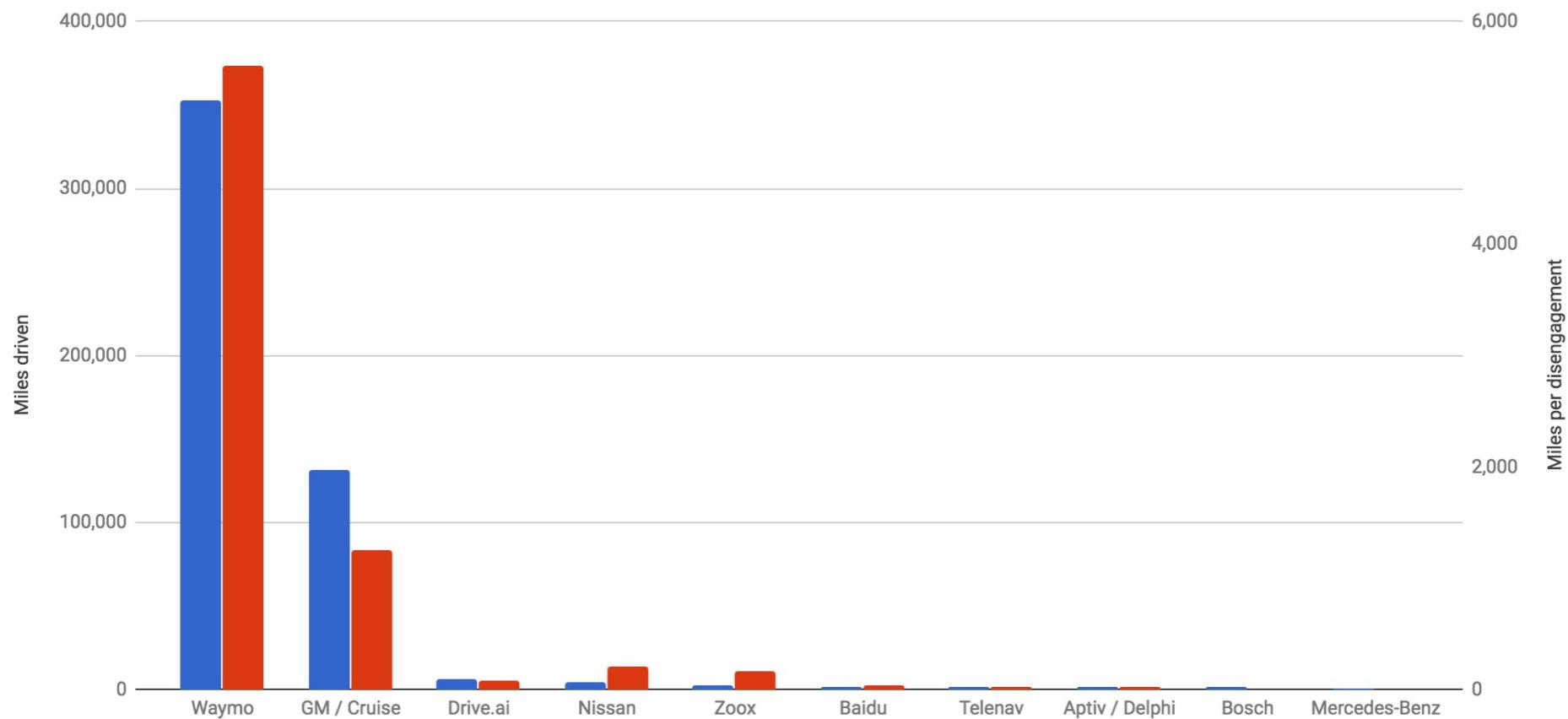
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- safety operators often have to regain control of vehicles when they're in driverless mode

California driverless car testing statistics

December 2016 to November 2017

■ Miles driven ■ Miles per disengagement



Case Study



FORTUNE

THIS
CEO
IS
OUT
FOR
BLOOD

THE
END OF
DRIVING

(as We Know It)
BY MICHAEL
LEV-RAM

STOCK
PICKS THE
PROS OWN
THEMSELVES

BY JEN
WIECZNER

IS TONY
FADELL
THE NEXT
STEVE JOBS
OR . . . THE NEXT
LARRY PAGE?

BY ADAM
LASHINSKY

ELIZABETH
HOLMES
AND HER
SECRETEIVE
COMPANY,
ATHERANOS,
AIM TO
REVOLUTIONIZE
HEALTH CARE

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Is there a way to see through the
hype of Tech / Finance Journalism?

Business case

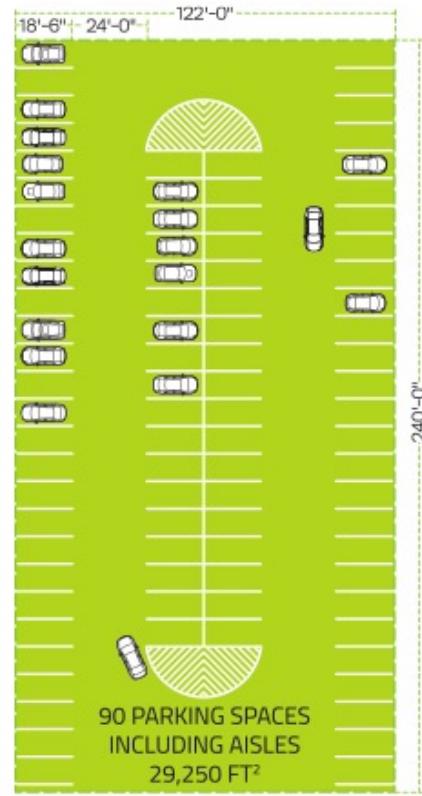
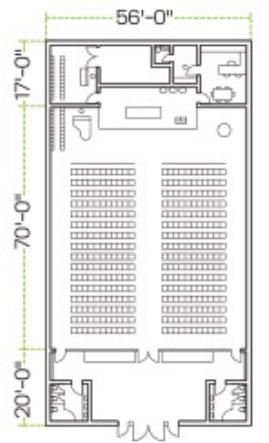
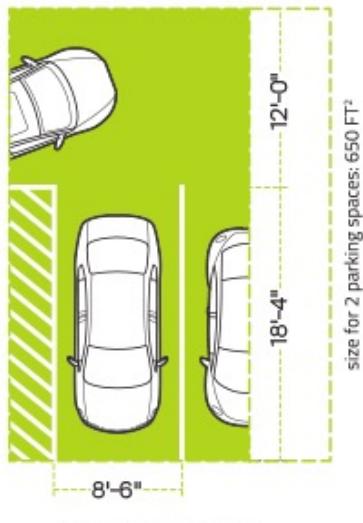
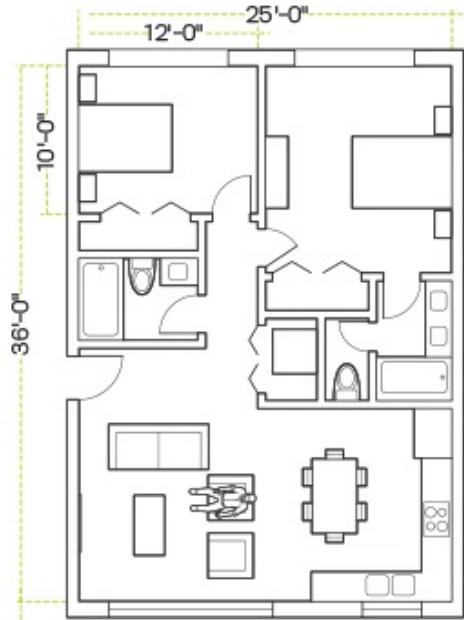
- Good sensors are expensive
- How much are safety features worth to the consumer?
- How much does it increase sales?
- What is the right first market?



© Copyright: Scania

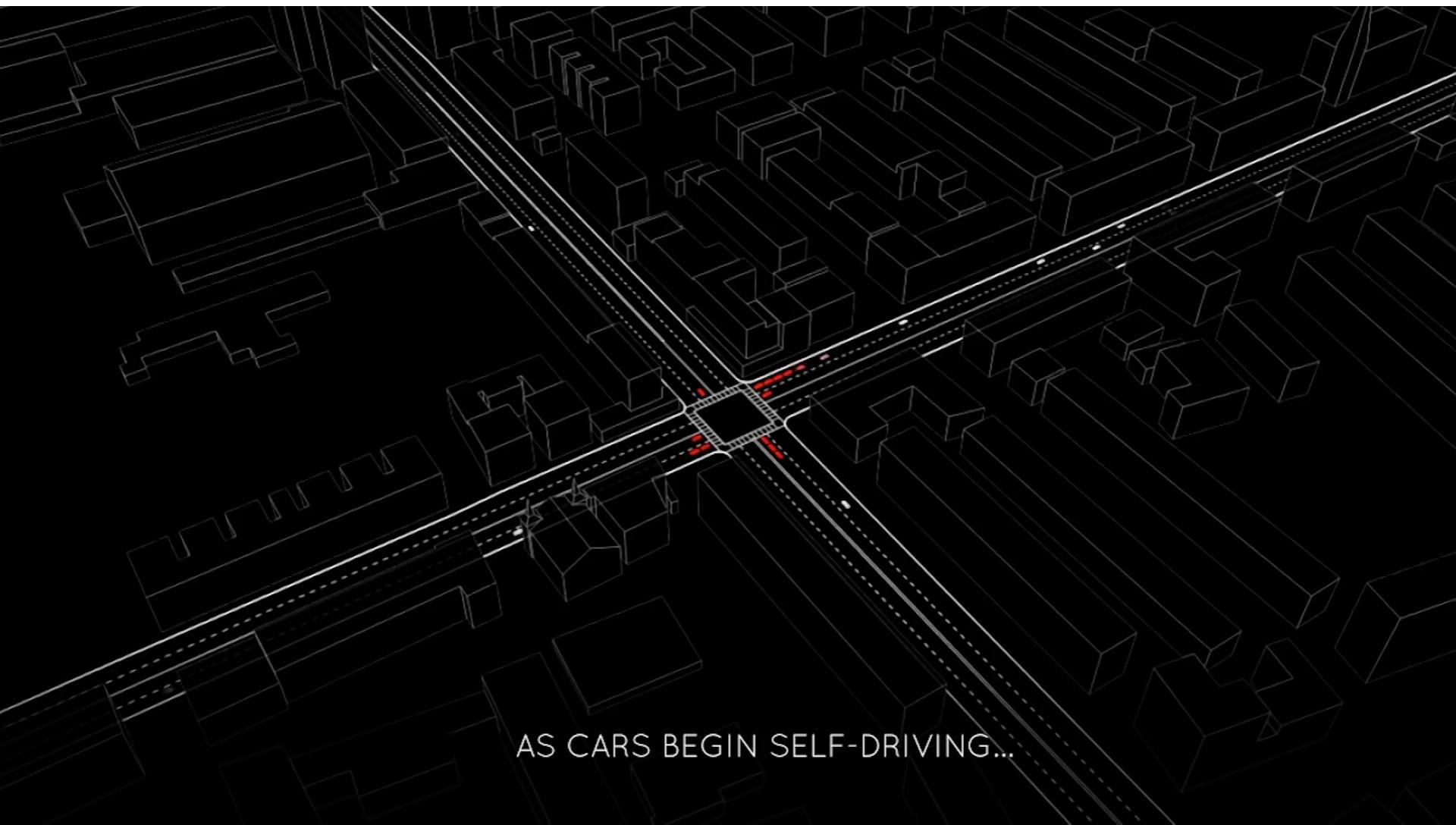


What are the Implications if This
Ever Comes to Fruition?



Mother Jones





AS CARS BEGIN SELF-DRIVING...

Legal implications

- The driver is responsible?
- Liability
- How is this tested and regulated?

Social implications

- Are we OK dying by robot?
- If this decreases the statistics of road death but randomizes the losses is that OK?
- Acceptance?

Course Logistics

Syllabus

- CANVAS for assignment notifications, logging grades, course organization.
- MathWorks Grader for Homework submission and grading.
- Piazza for discussions, asking questions about homework/coursework, etc.

Email Policy

**DO NOT EMAIL TECHNICAL
QUESTIONS TO US. THEY WILL BE
IGNORED.**

Email Policy

- Please ask your questions to us via Piazza so that everyone can benefit from the answer. If your question is related to grading, then please speak to us during office hours.
- If you are unable to ask your grading related question during office hours, then **email the GSIs - not Ram or Matt - but include ROB 535 in the subject line of your email.**
- If, somehow, your question doesn't match one of the above cases speak to us after class.

Grading

- **Homework 65%** 4 total homeworks
- Encouraged to work together in groups but *everyone* must write up their own solutions which should list all of your collaborators; homework will be submitted digitally.
- **Final Project 30%** a group autonomous vehicle competition on perception and control tasks.
- **Participation 5%** Class/GSI/Piazza

Homework Policy

- **NO LATE HOMEWORK**
- **A "48-hours one-time late submission bonus" is available. You can use this bonus to submit one HW at most 48 hours after the deadline. SAVE THIS UNTIL YOU NEED IT**
- **No "late submission bonus" is allowed when submitting your final project.**