Autonomous Vehicles

CPSC 470 – Artificial Intelligence

Brian Scassellati

Trust in self-driving cars may crash after Boeing

Quartz – 2 days ago

Autonomous cars tested against cyber-attacks

NBC News – yesterday

Uber's 250 autonomous cars have driven "millions" of miles and transported "tens of thousands" of passengers

Venture Beat - yesterday

Ford taps the breaks on the arrival of self-driving cars

WIRED – 3 days ago

Cambridge startup teaches driverless cars to behave around cyclists

Forbes - yesterday

Uber has spent more than $1 billion on driverless cars

Bloomberg - yesterday

Waymo is gearing up to put many more self-driving cars on the road

TechCrunch - yesterday

New laser technology aims to make self-driving cars safer

CBS - yesterday


UBER
ADVANCED
TECHNOLOGIES
CENTER
UBERATC.COM/CAR

Timeline

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- 2009: Google Self-Driving Car (SDC)

NavLab (CMU), 1985-2001

1

2

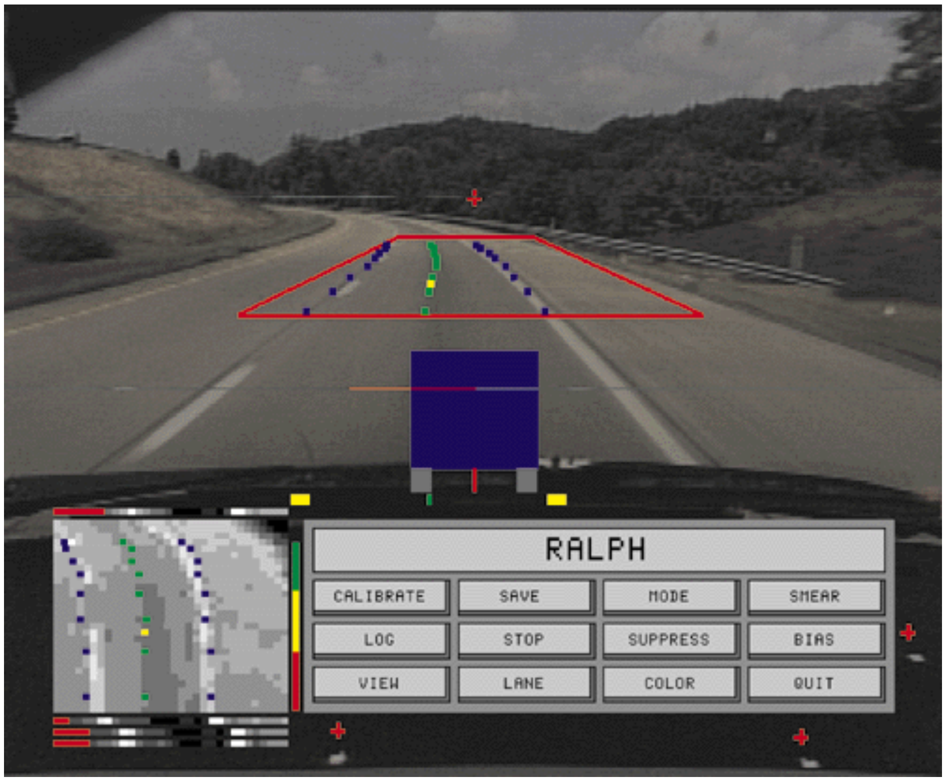
5

7

8

10

“No Hands Across America”



- Dean Pomerleau and Todd Jochem (1996)
- Researchers handled throttle and break, steering was autonomous
- 2,850 miles from Washington, DC to San Diego using NAVLAB 5
- Autonomous operation for 98.1% (2,796/2,850 miles) of the trip

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Grand Challenge Course

Straight Roads

Mountain Roads

Cattle Guards

Open Lake

2004 Grand Challenge

Red Team Racing's Sandstorm

- 150 mile off-road race through the Mojave desert
- Natural and manmade hazards
- Autonomous
- $1M prize
- 15 competitors qualified
- Best team only made it 7 miles
- Many hardware failures

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2005 Grand Challenge Winner: Stanford's Stanley

- 5 SICK laser range finders
- 2 radar sensors
- Color camera
- GPS, compass
- IMU

Key Concepts

- Recognition that this wasn't just a hardware problem

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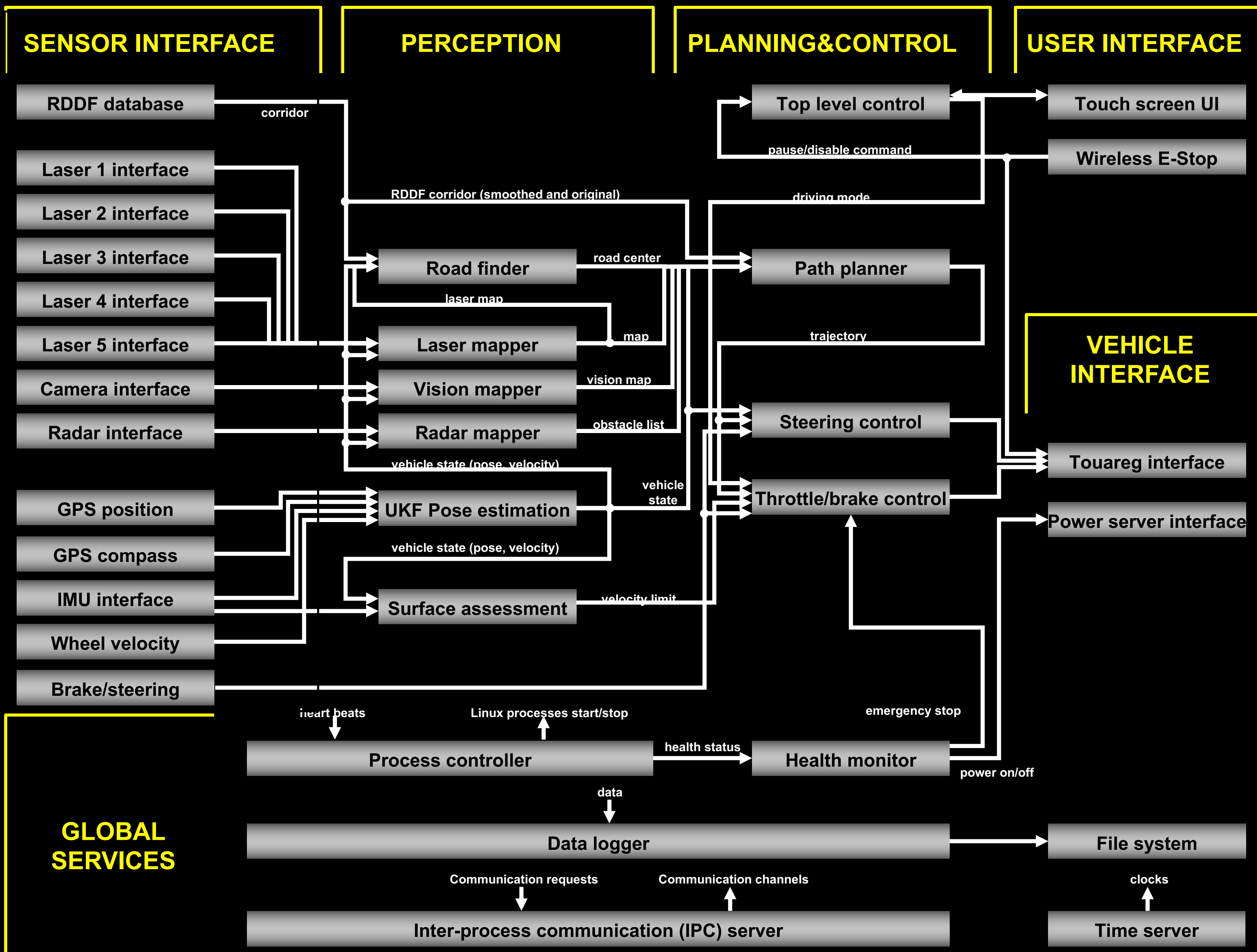
  - Modular architecture was necessary for improvement.

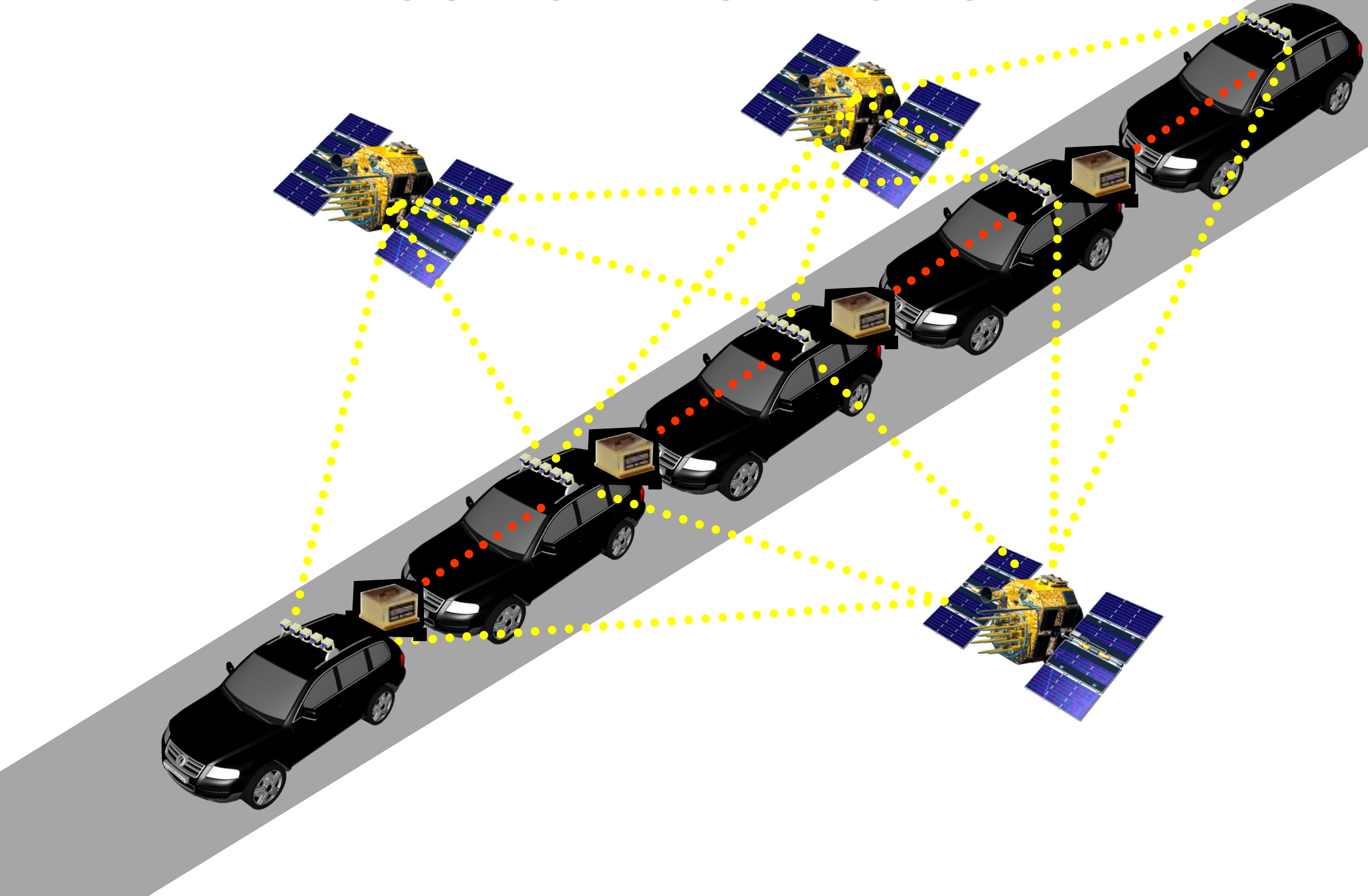
Stanley Software Architecture



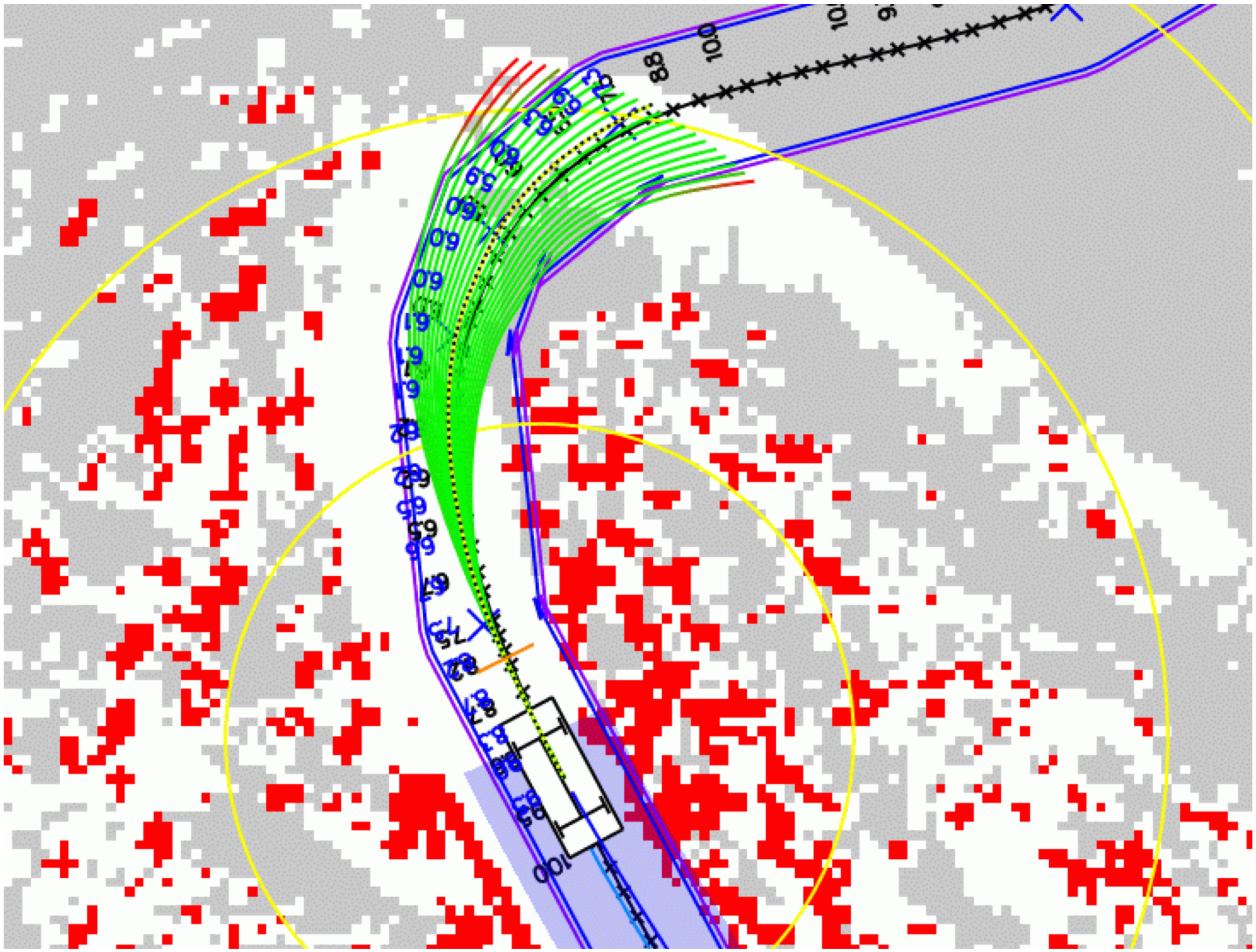
Key Concepts

- Recognition that this wasn’t just a hardware problem
  - Modular architecture was necessary for improvement.
- More robust navigation
  - Multi-sensor approach to localization

Position Estimation

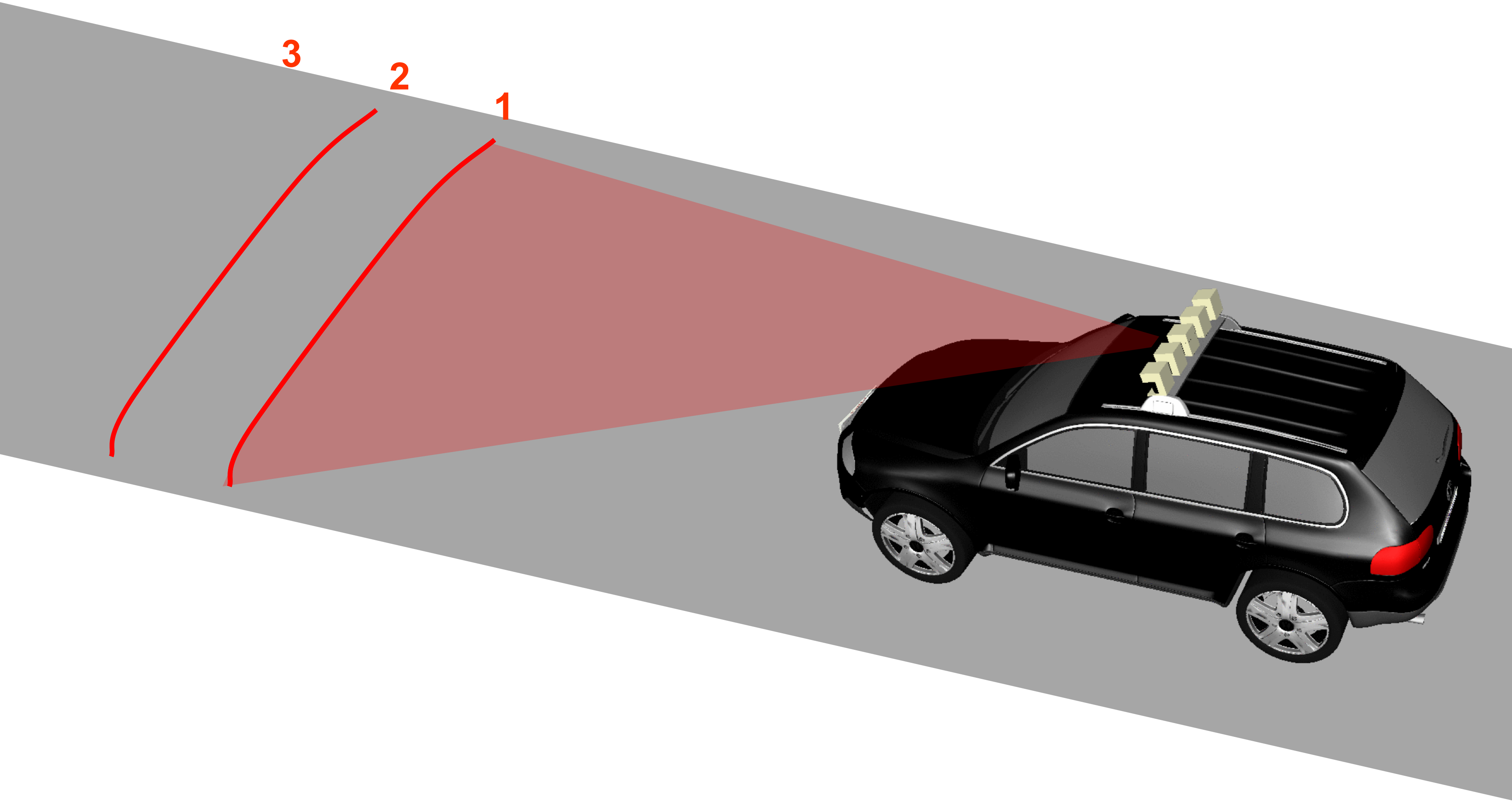


Planning = Rolling out Trajectories

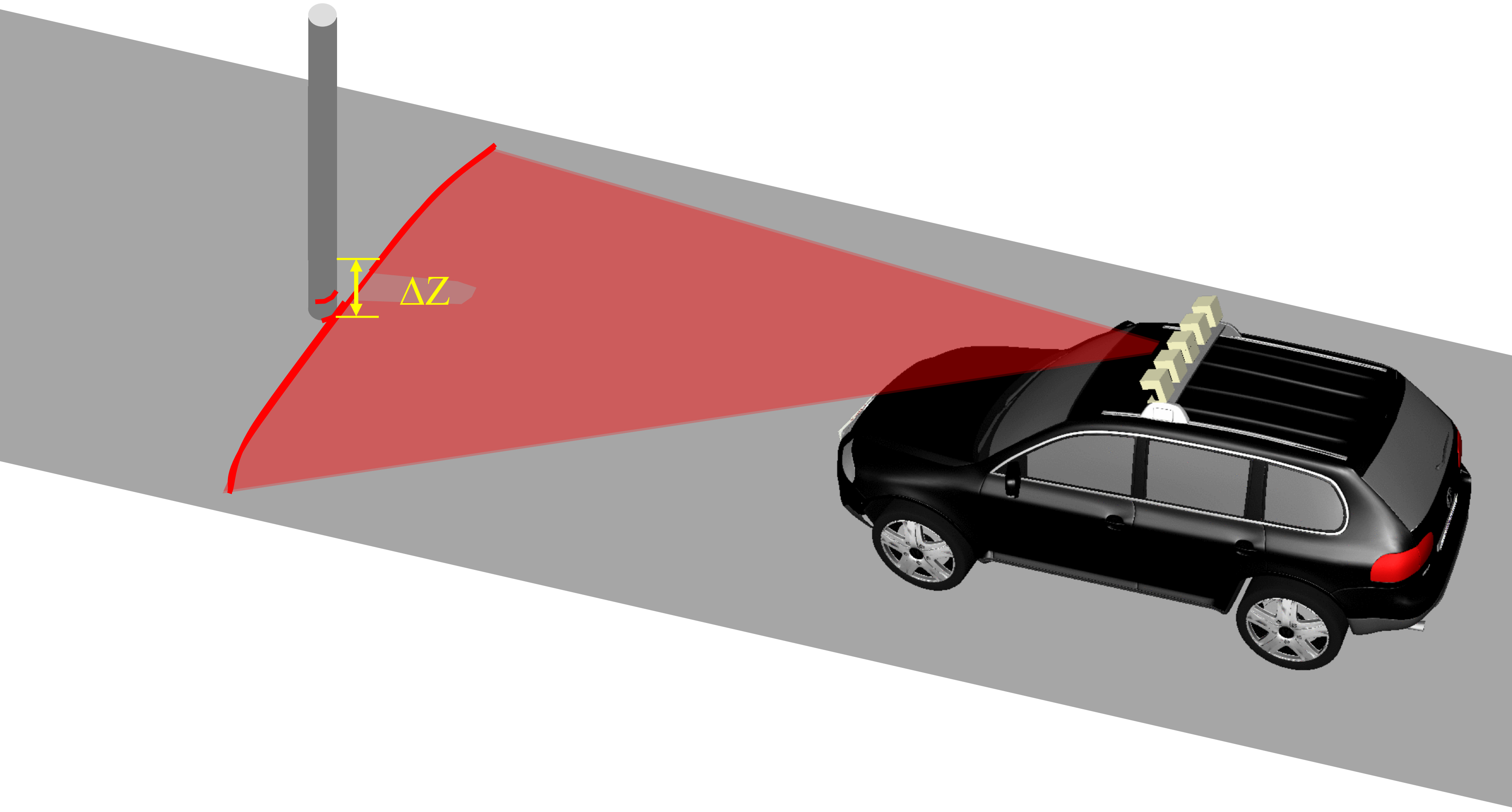


Laser Range Data Integration

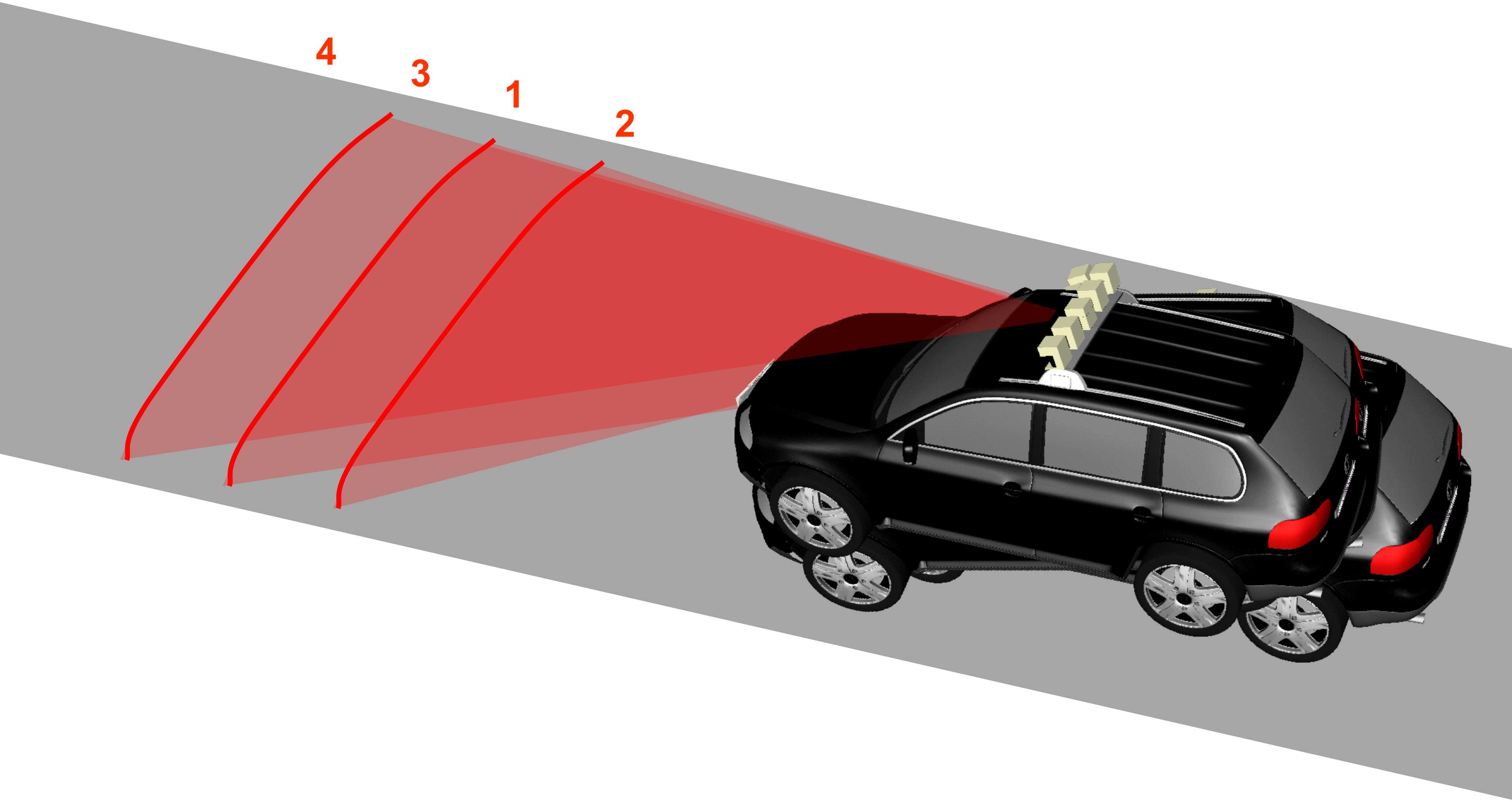
Range Sensor Interpretation



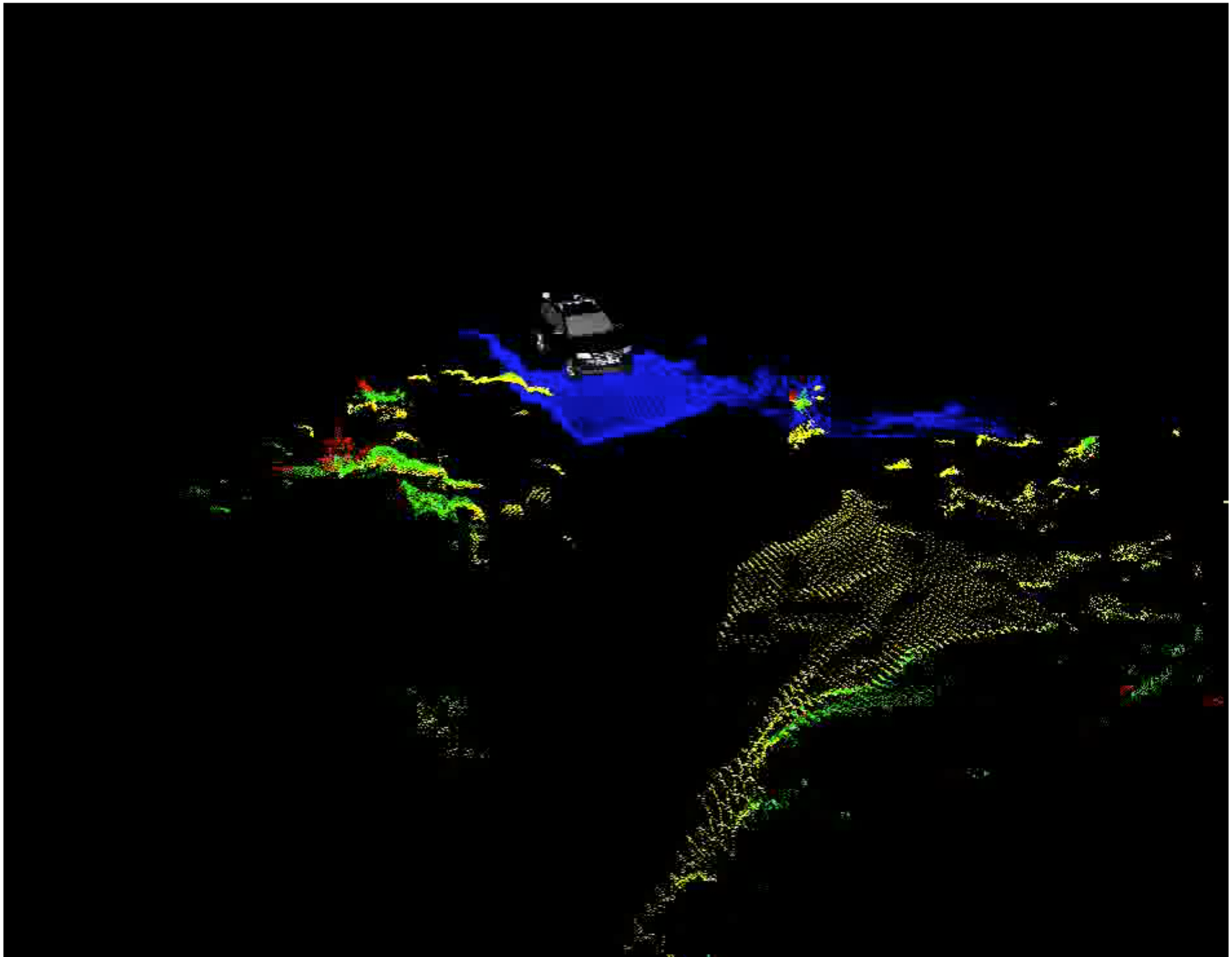
Obstacle Detection



Effect of Pitching



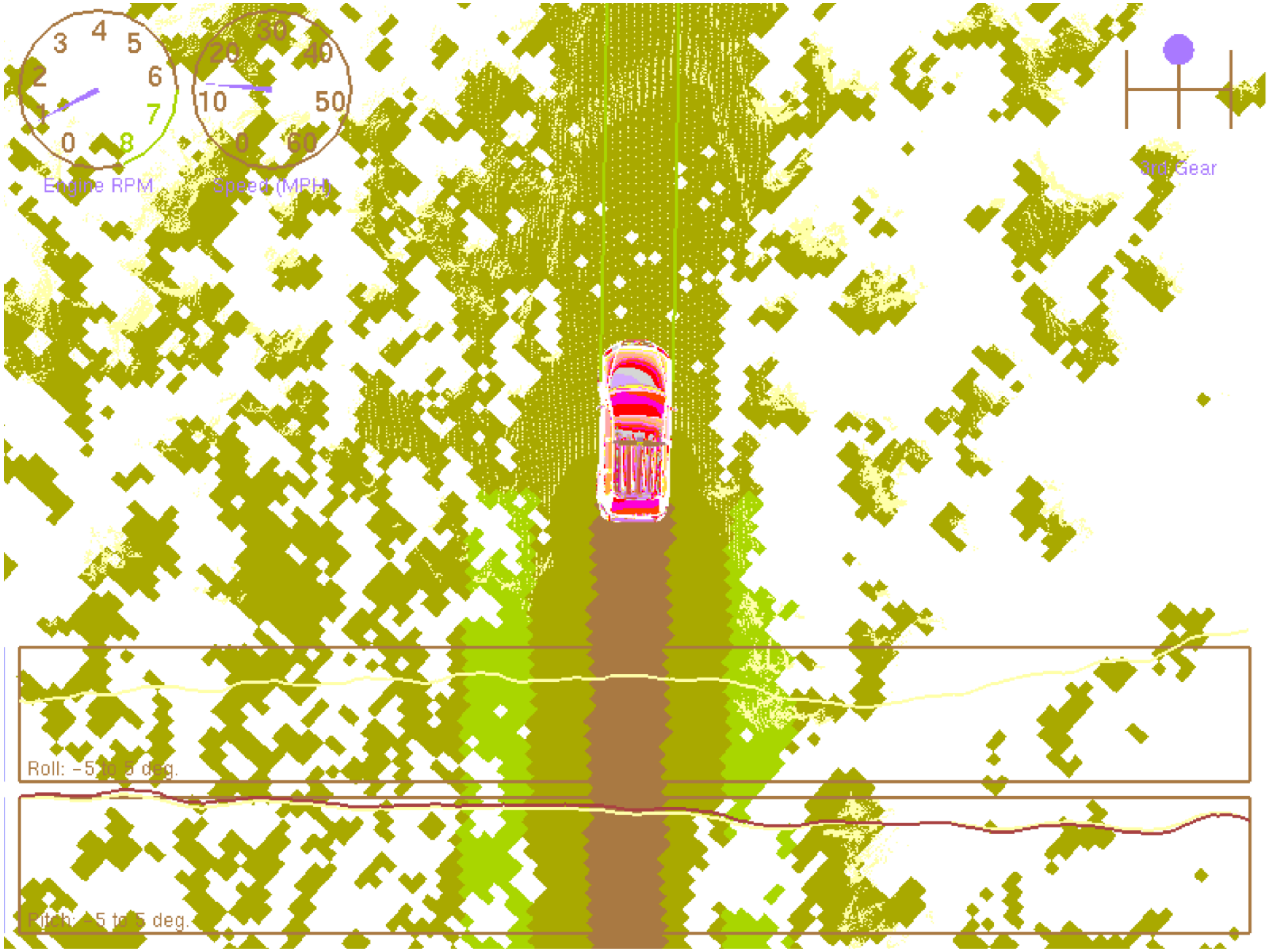
Laser Range Data Integration



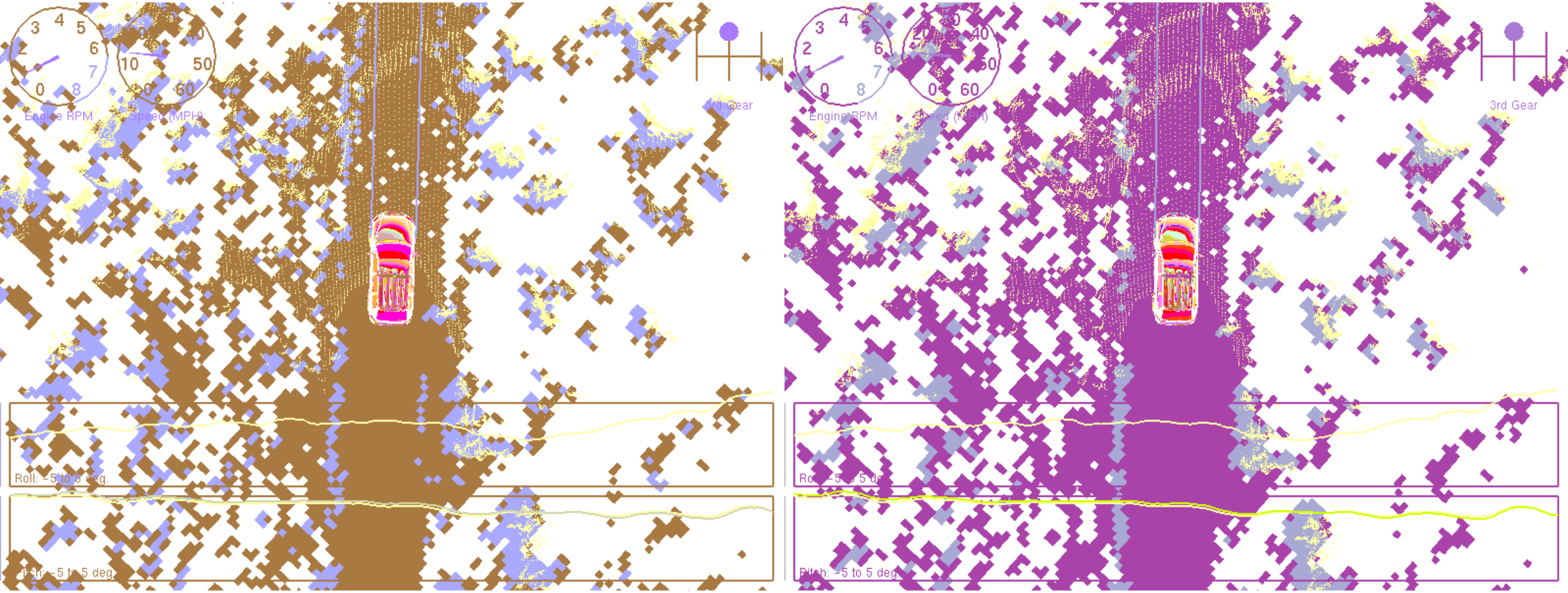
Key Concepts

- Recognition that this wasn't just a hardware problem
  - Modular architecture was necessary for improvement.
- More robust navigation
  - Multi-sensor approach to localization
  - Machine learning to remove false positives

Training Stanley (Human Driving)



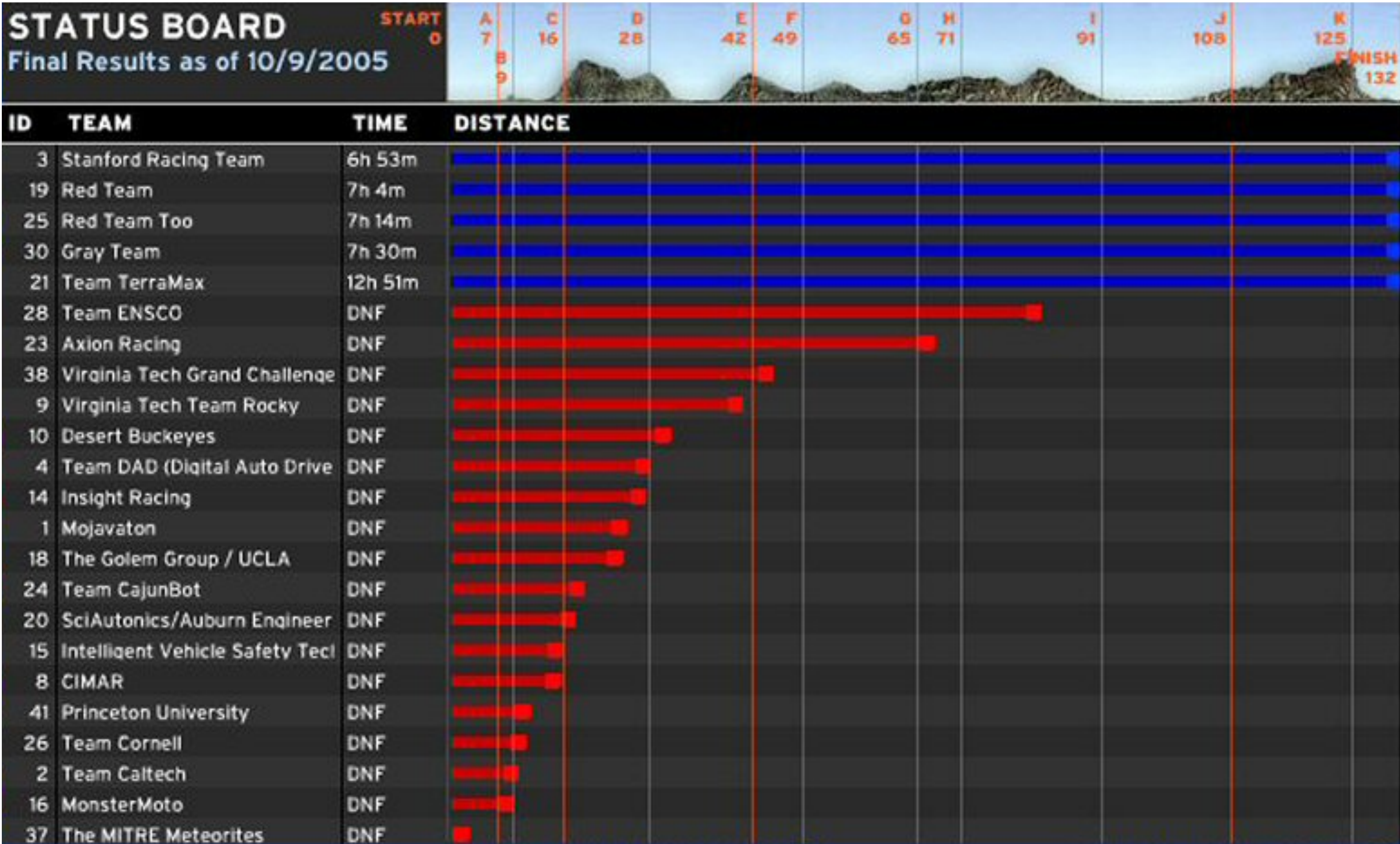
Stanley….After Learning



Without Learning: 12.6% false positives

With Learning: 0.02% false positives

Final Result: Five Robots finished!



ID	TEAM	TIME
3	Stanford Racing Team	6h 53m
19	Red Team	7h 4m
25	Red Team Too	7h 14m
30	Gray Team	7h 30m
21	Team TerraMax	12h 51m
28	Team ENSCO	DNF
23	Axion Racing	DNF
38	Virginia Tech Grand Challenge	DNF
9	Virginia Tech Team Rocky	DNF
10	Desert Buckeyes	DNF
4	Team DAD (Digital Auto Drive	DNF
14	Insight Racing	DNF
1	Mojavaton	DNF
18	The Golem Group / UCLA	DNF
24	Team CajunBot	DNF
20	SciAutonics/Auburn Engineer	DNF
15	Intelligent Vehicle Safety Tecl	DNF
8	CIMAR	DNF
41	Princeton University	DNF
26	Team Cornell	DNF
2	Team Caltech	DNF
16	MonsterMoto	DNF
37	The MITRE Meteorites	DNF

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DARPA Urban Challenge

- 6 hours to complete 60 mile urban course
- New challenges:
  - Avoid other drivers, pedestrians, cyclists
  - Obey signs and traffic laws
  - Course unknown before day of race
  - Parking and u-turns

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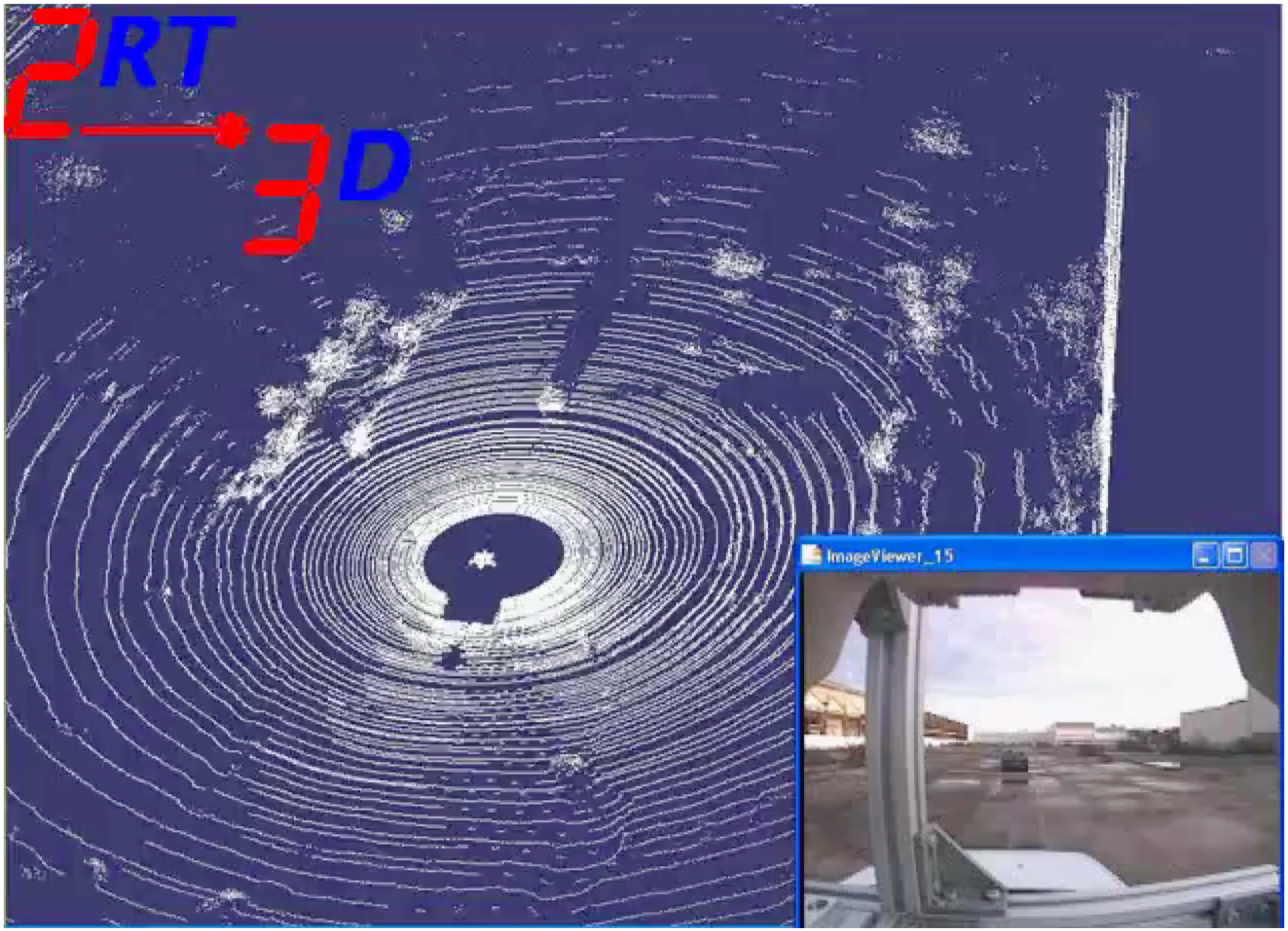
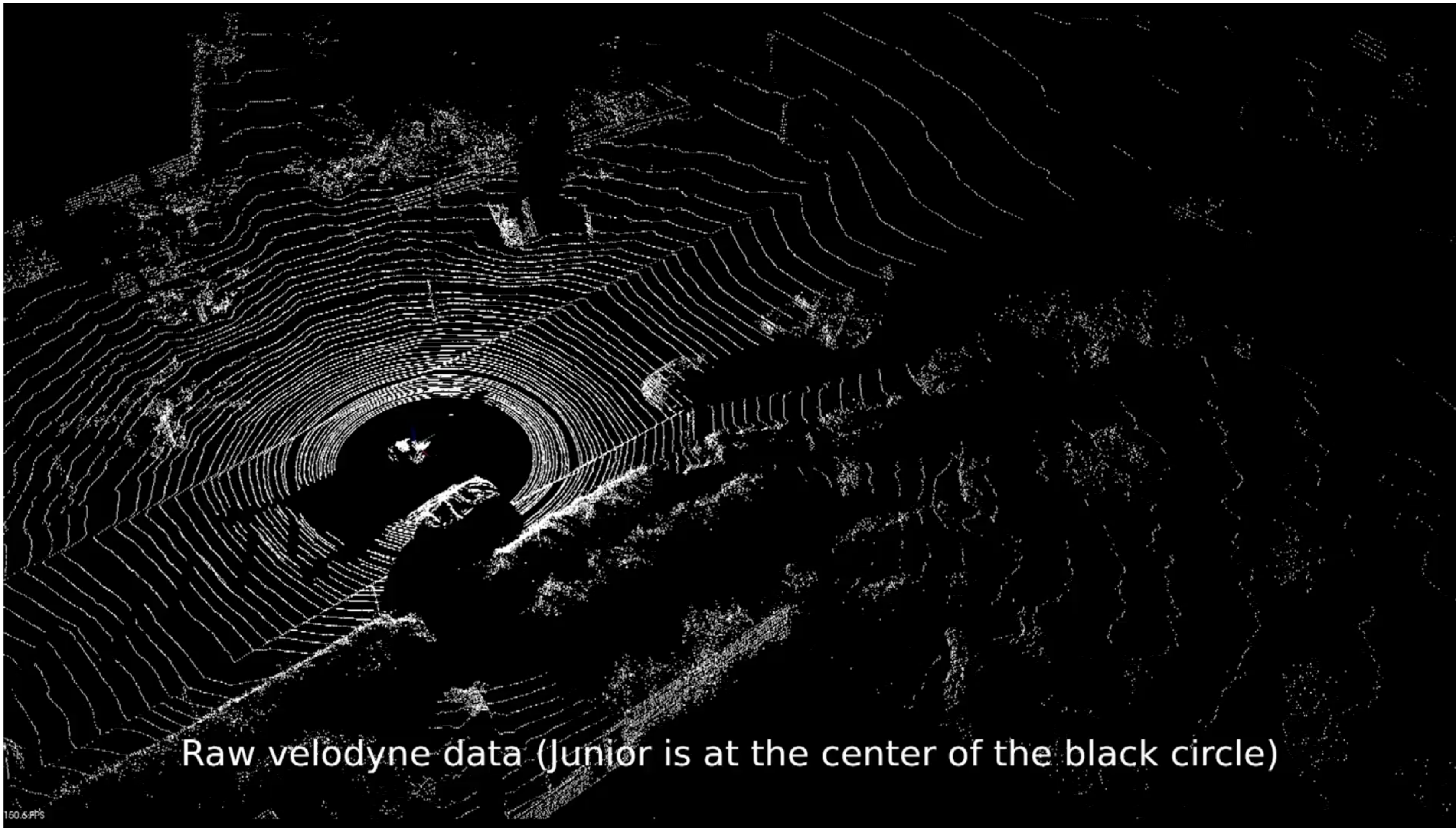
Google Self-Driving Car

Velodyne LiDAR



2RT3D (August 26, 2009)

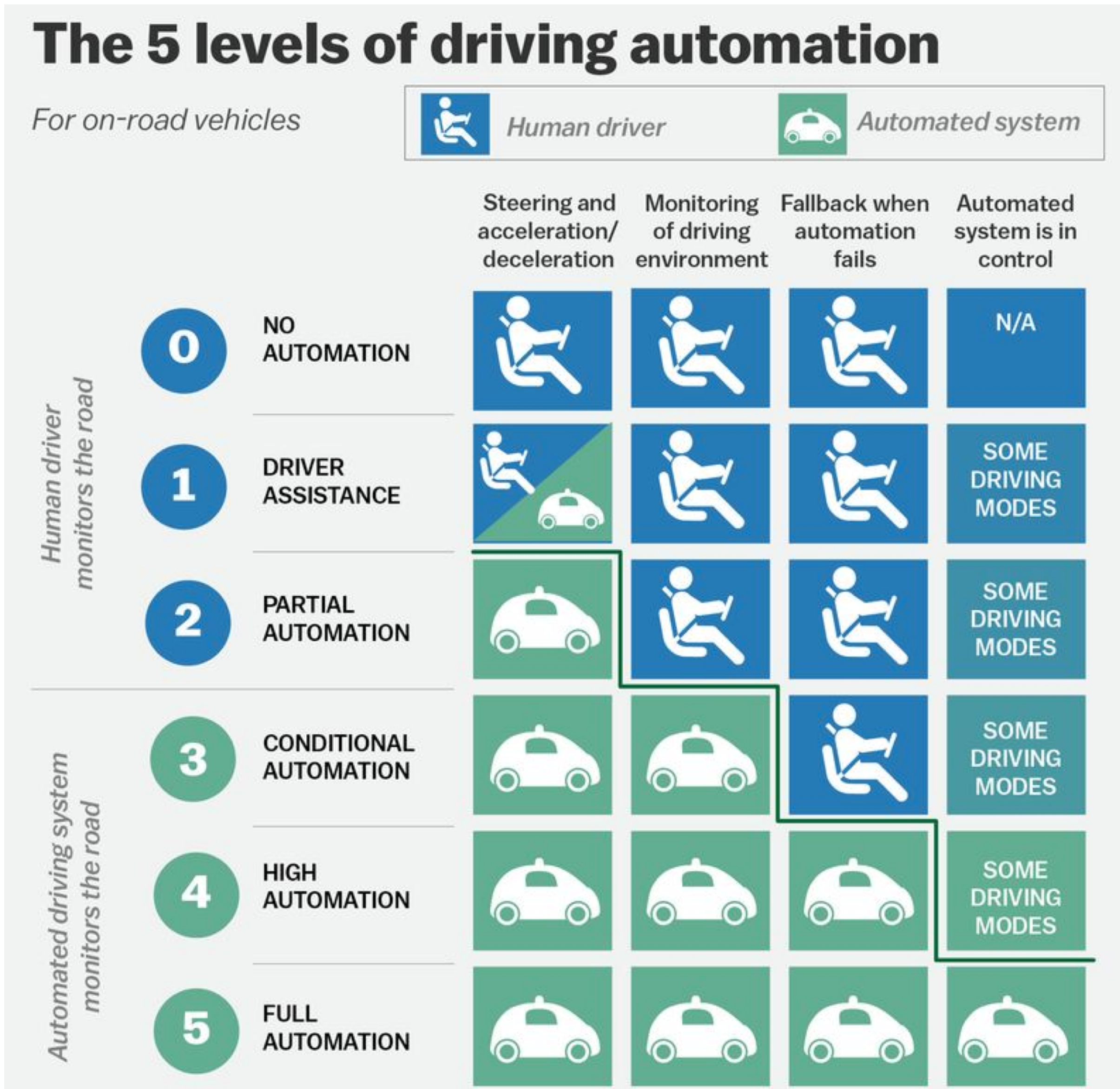
Velodyne LiDAR



Brice Rebsamen (August 27, 2013)

Autonomous Vehicles Today

Policy and Regulation



Enhanced Driver Support and Autonomy

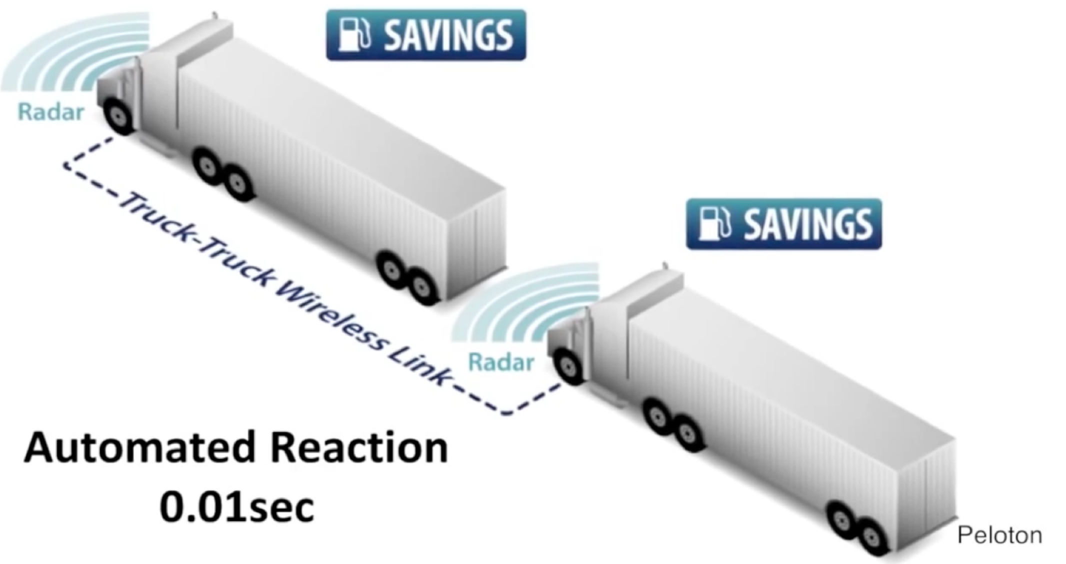
Even Better Sensing

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Job Loss


FT 2025
FUTURE TRUCK


PROUDLY BREWED.
SELF-DRIVEN.
Budweiser
OTTO
OTTO

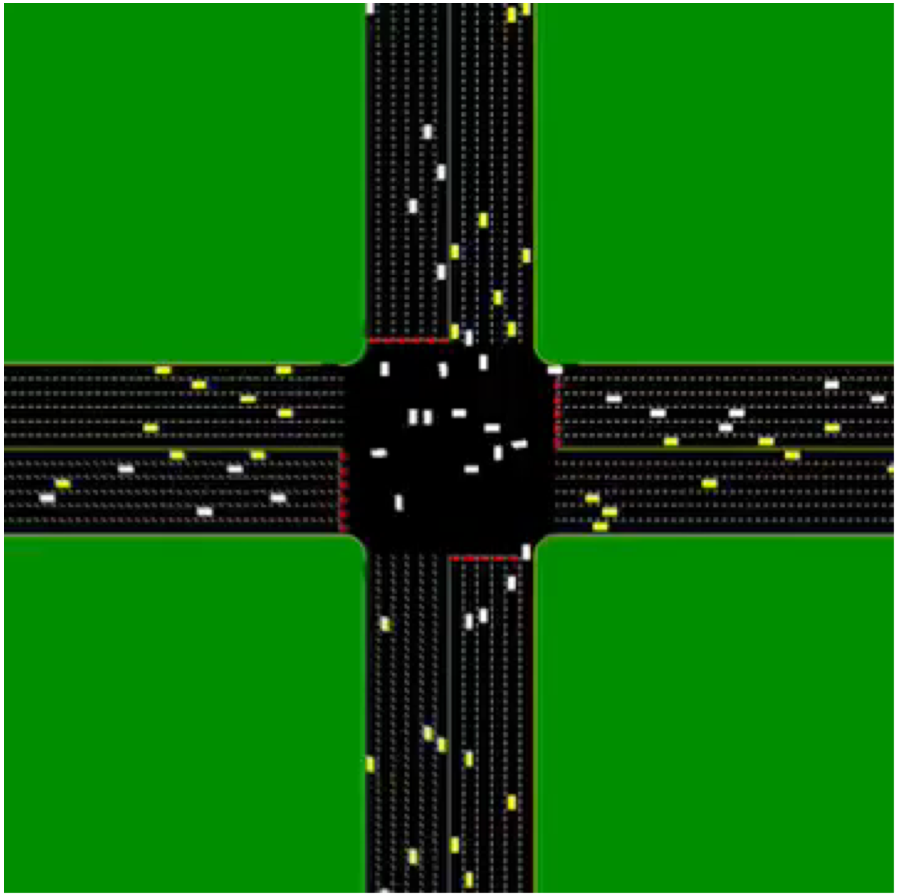

SAVINGS
Radar
Truck-Truck Wireless Link
SAVINGS
Radar
Automated Reaction
0.01sec
Peloton

Beyond the Technology

Traffic and Congestion

- Traffic Accidents (USA)
  - 42,636 dead (2004)
  - 2,788,000 injured (2004)
  - Leading cause of death, age 3-33
- Commuting (USA)
  - 1.25 hours per day and working person

Can self-driving cars reduce accidents, limit pollution, eliminate road rage, and simplify community?



Autonomous intersection management
6 lanes, bi-directional traffic
Simulation by Peter Stone

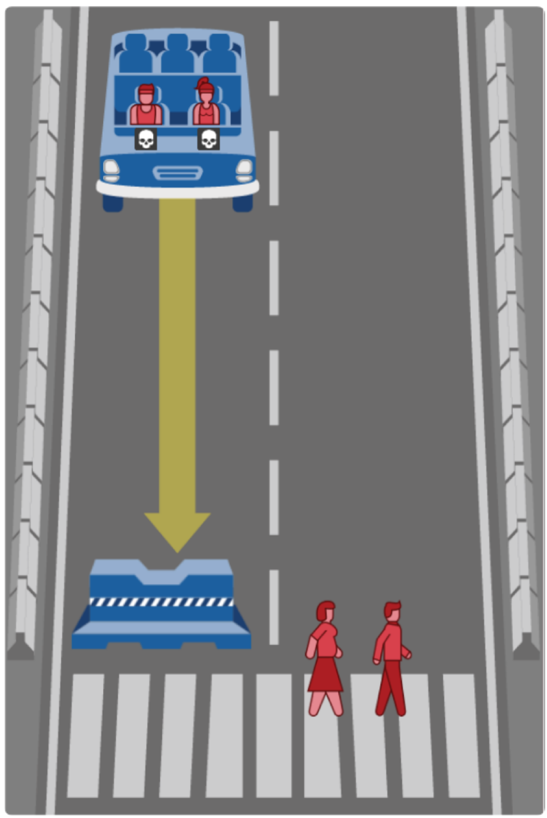
Decision Making: Trolley Problems

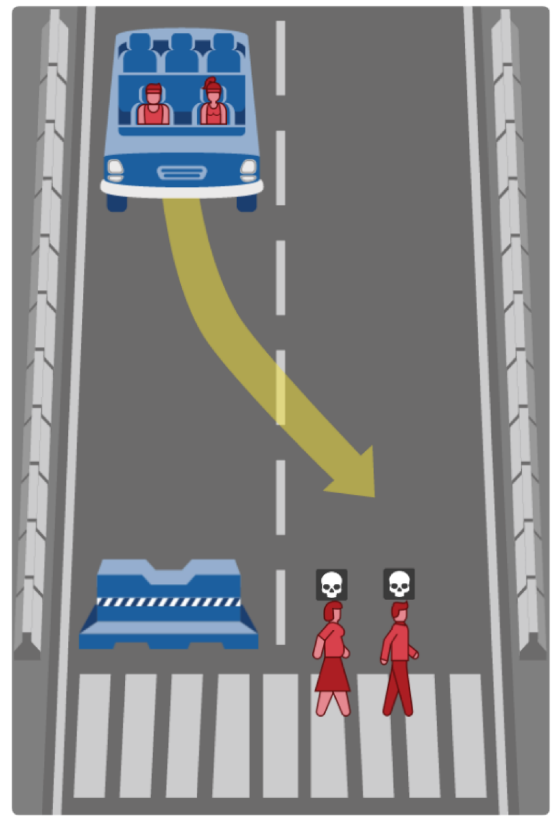
What should the self-driving car do?

1 / 13

In this case, the self-driving car with sudden brake failure will continue ahead and crash into a concrete barrier. This will result in ...
Dead:

- 1 female athlete
- 1 male athlete





In this case, the self-driving car with sudden brake failure will swerve and drive through a pedestrian crossing in the other lane. This will result in ...
Dead:

- 1 large woman
- 1 man

http://moralmachine.mit.edu/

Topics to Discuss

- What does “safe” mean in this context?
  – How do we certify something as being safe?
- What impact will this technology have?

-- Infrastructure	-- Liability and insurance
-- Urban / suburban divide	-- Eldercare
-- Employment	-- Accessibility

- How does this change if we consider planes? Trains? Boats?
- Will the US be willing to give up driving?
- Can technology refuse to allow human control?

Administrivia

- Problem Set 7 out now on Canvas
- Next week
  - Robotics
  - Kinematics, dynamics, and control