The Road to Autonomous Vehicles

Ryan Eustice, Vice President of Autonomous Driving

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Outline

- About Toyota Research Institute (TRI)
- Challenges for Self-Driving Vehicles
- TRI Approach to Automation
- Big Questions to Resolve

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About TRI

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TRI Mission

TRI's mission is to use artificial intelligence to improve the quality of human life.

- **Vehicle Safety**
- **Mobility Access**
- **Robotics**
- **Discovery in Materials Science**

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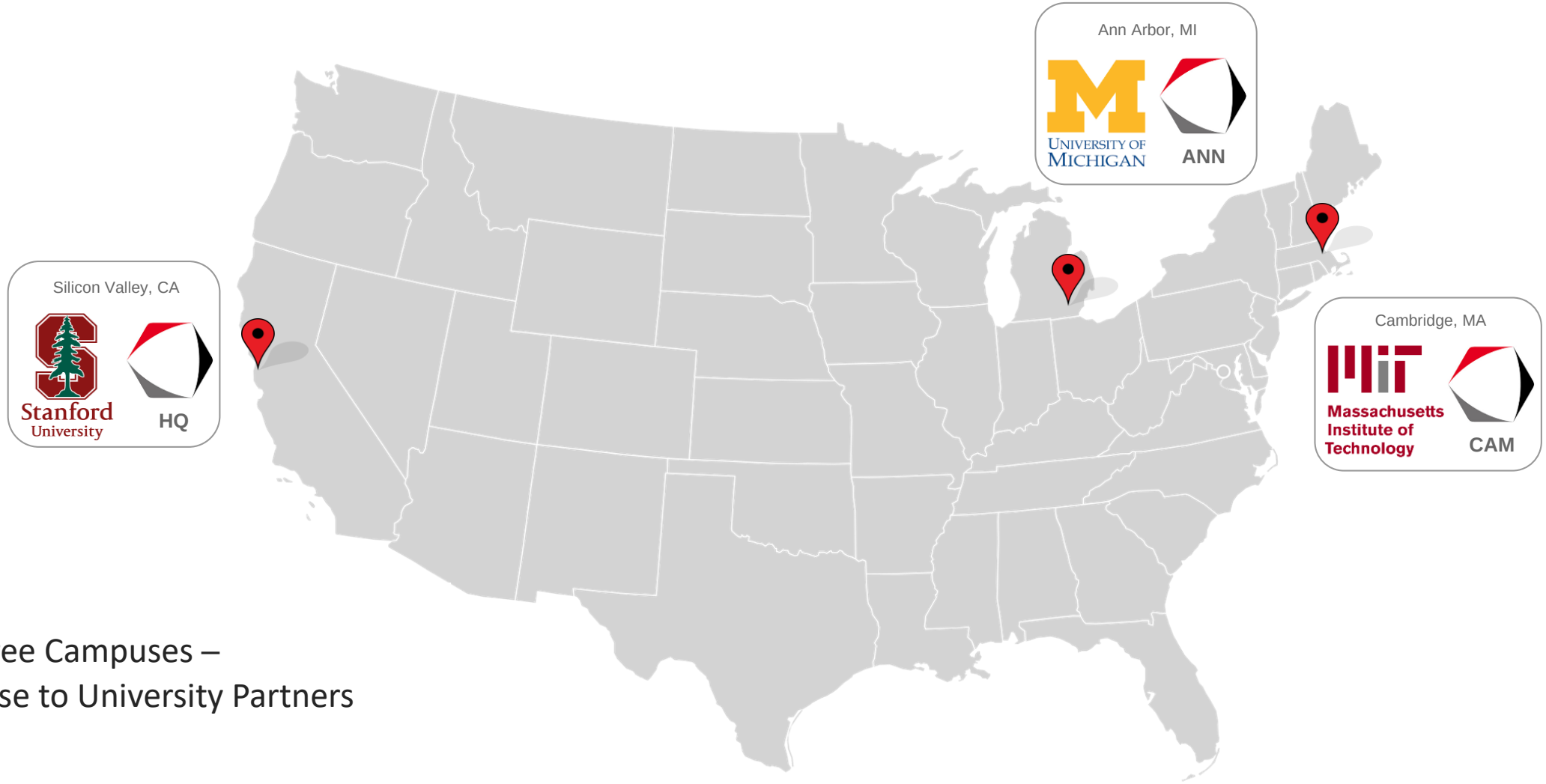
TRI Multi-Campus Strategy



Three Campuses –
Close to University Partners

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Challenges for Self-Driving Vehicles

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Challenges for Self-Driving Vehicles

Adoption Challenges

- Technological
- Economic
- Employment
- Ethical
- Legal
- Security
- Energy and the environment

Technical Challenges

- Maintaining Maps
- Adverse Weather
- Interacting with People
- Better Sensors
- Human Factors

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SAE Levels of Automation

SAE INTERNATIONAL™

J3016

Level 1	One degree of freedom is controlled, e.g., longitudinal Adaptive Cruise Control
Levels 4/5	Human is always a passenger; the only distinction between 4 and 5 is operational domain (i.e., geofenced vs. unrestricted)

0	1	2	3	4	5
NO AUTOMATION	DRIVER ASSISTANCE	PARTIAL AUTOMATION	CONDITIONAL AUTOMATION	HIGH AUTOMATION	FULL AUTOMATION

Level 2	Readiness for hand-off requires constant vigilance from driver that may not be sustainable over time
Level 3	Difficult for vehicle to ensure driver has sufficient warning to re-engage in time for hand-off

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“None of us in the automobile or IT industries are close to achieving true Level 5 autonomy. It will take many years of machine learning and many more miles than anyone has logged of both simulated …and real-world testing to achieve the perfection required for Level 5 autonomy.”

-**Dr. Gill Pratt, TRI CEO**

Consumer Electronics Show, January 2017

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Difficult Situations for Self-Driving

Left turn across traffic

Changes to road surface markings

Traffic cops, crossing guards, police/fire

All weather driving

Courtesy:
J. Leonard, MIT

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Precision Mapping

- Humans don't need precision maps, nor centimeter-scale localization. Why should cars?
- **The problem:** it is extremely difficult to decode roads reliably and in real time with the level of accuracy required
- **The solution:** bake all of this information into a prior map – expect the expected
  - BUT: now, the car needs to know exactly where it is
  - For this localization, centimeters matter

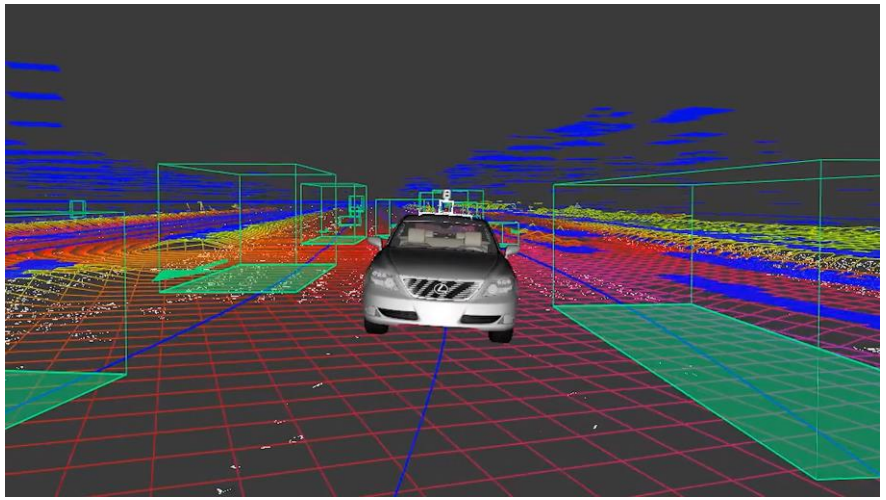

Image Credit: Google Maps

Image Credit: Pinterest

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Traffic Light Detection

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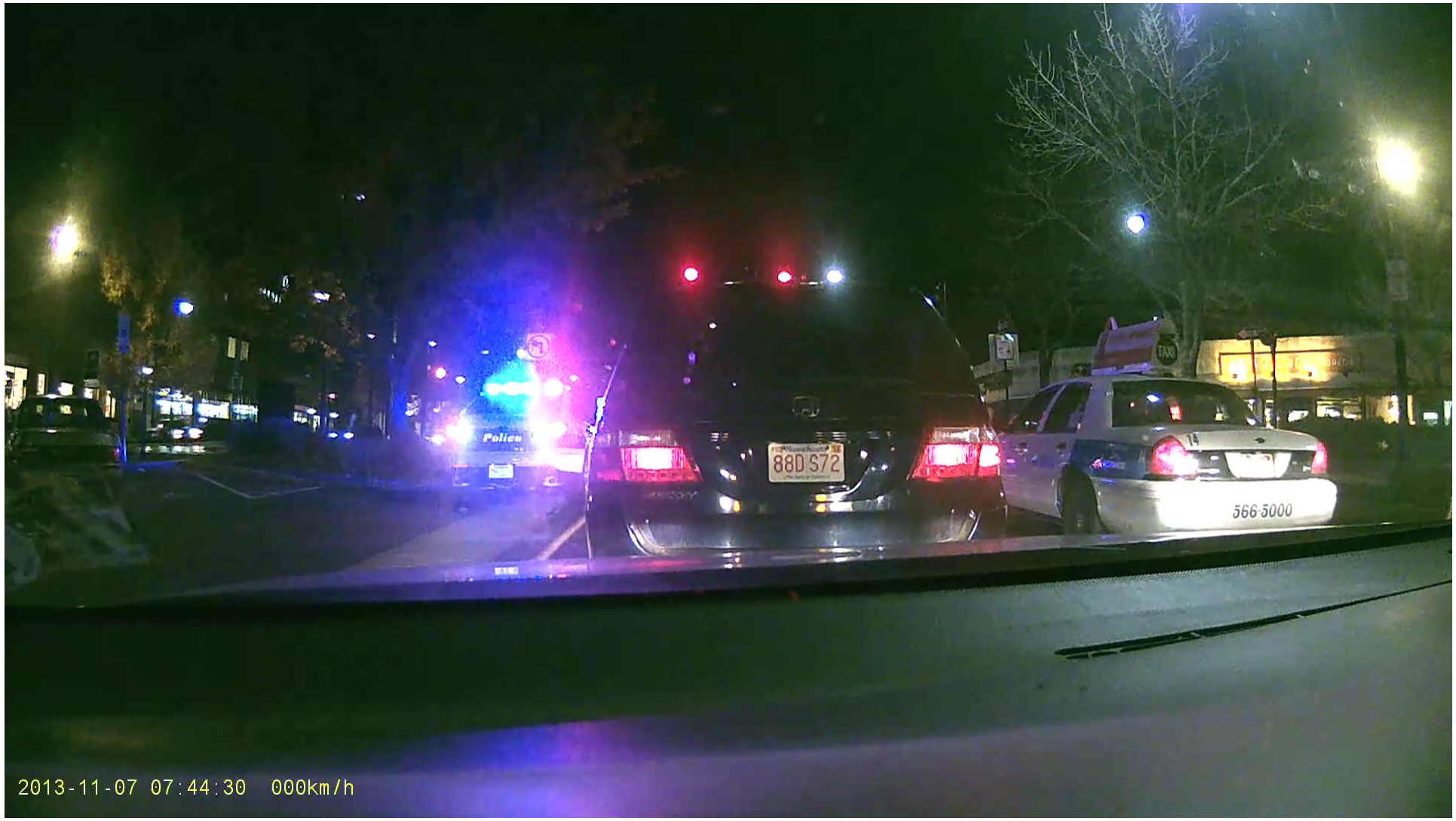
Does Green Always Mean Go?



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The Social Dance of Driving

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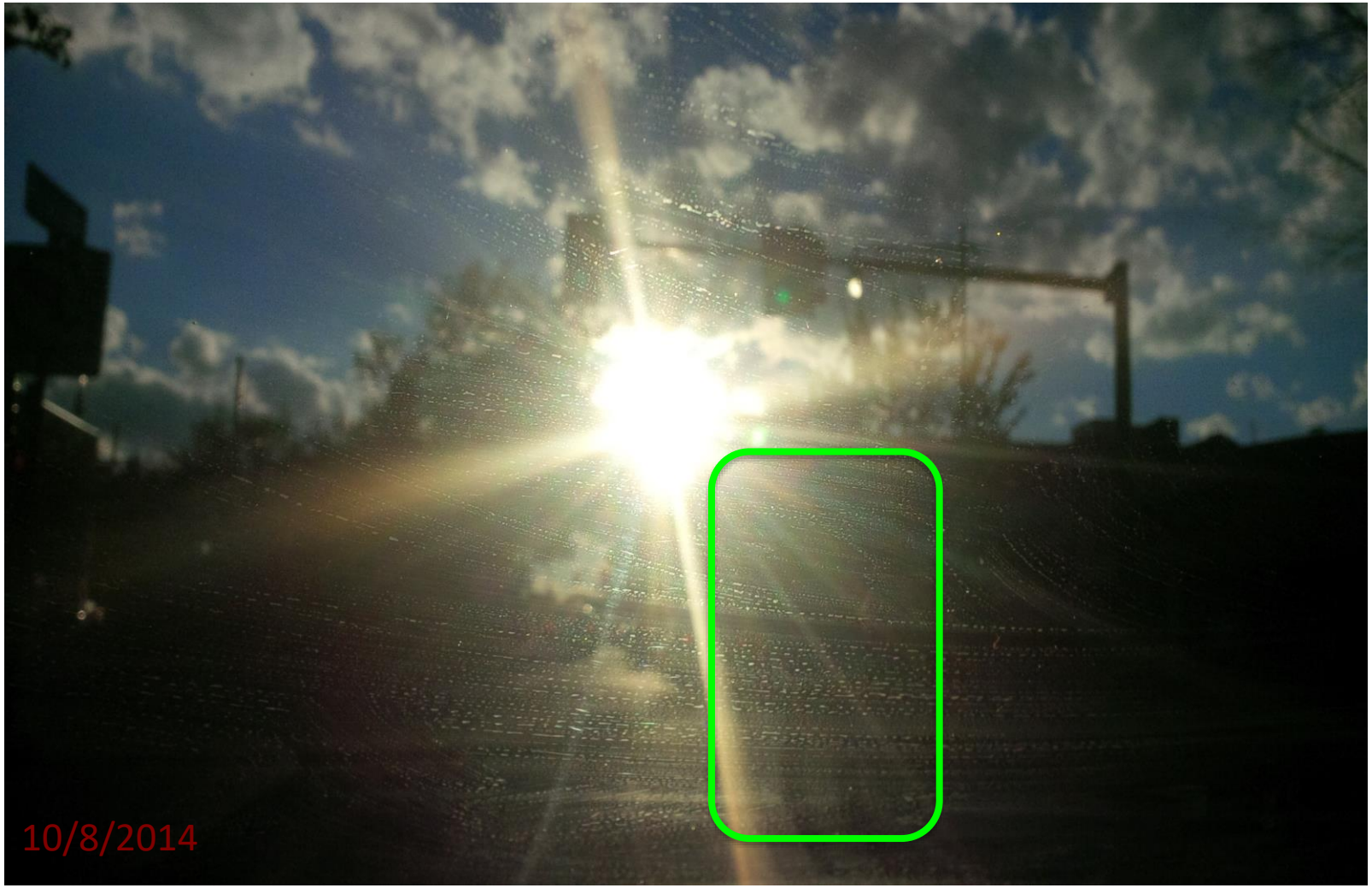
What Do You See in This Picture?



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Challenges of Guaranteeing Levels 4/5

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TRI Approach to Automation

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TRI Approach to Automation

GOAL: Using Artificial Intelligence, Transform Toyota's Ability to Improve:

Safety

~ 1,250,000 People / Yr. Worldwide
(~ 35,000 in the US)

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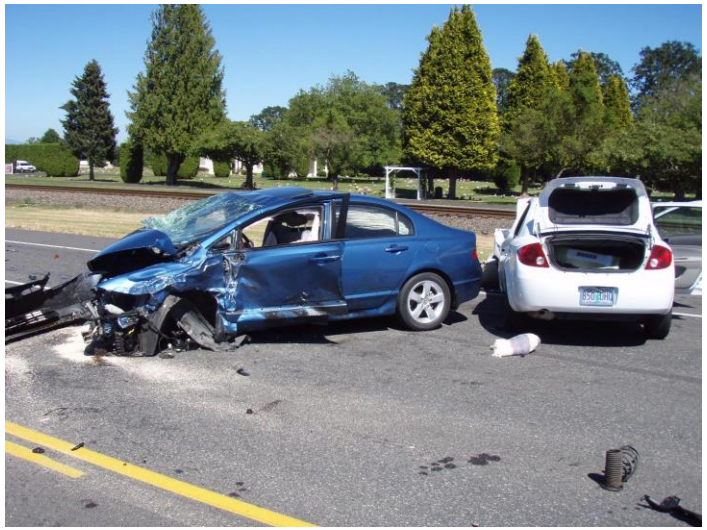
Safety

- USA – 6.1 million crashes per year[1]
  - Over 35,000 fatalities per year (and rising!)
  - 2.3 million injuries
- Worldwide[2]
  - Over 1.25 million deaths per year
  - 50 million injuries
- 93% of accidents have human error as the primary factor[3]
  - Speeding: 21% (by dollar)
  - Drunk: 18%
  - Distracted: 17%



[1] NHTSA, *Traffic Safety Facts, 2014 Crash Data Key Findings* (Nov. 2015)
[2] World Health Organization (WHO), *Global Status Report on Road Safety, 2015*
[3] NHTSA, *The Economic and Societal Impact Of Motor Vehicle Crashes, 2010* (May 2015)

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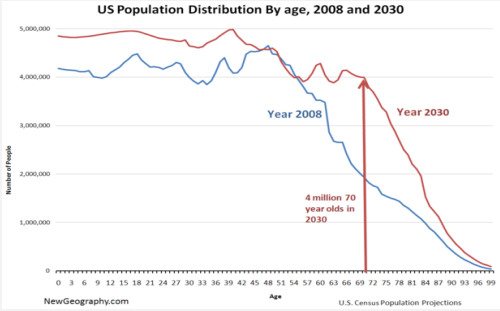

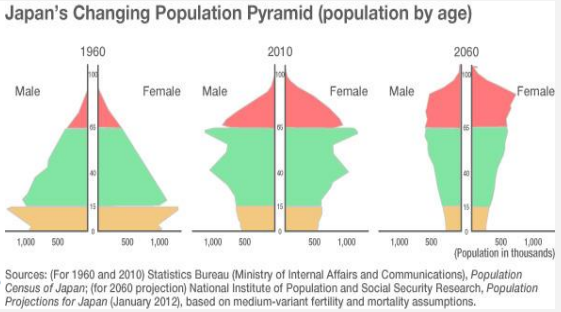

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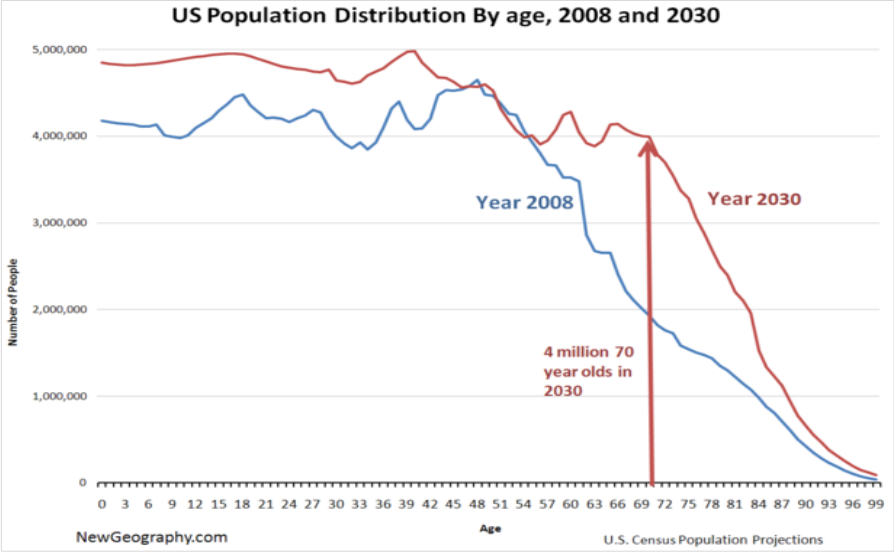
Access

Social Impact

- Aging population (both in the US and worldwide)
- Disabled or impaired



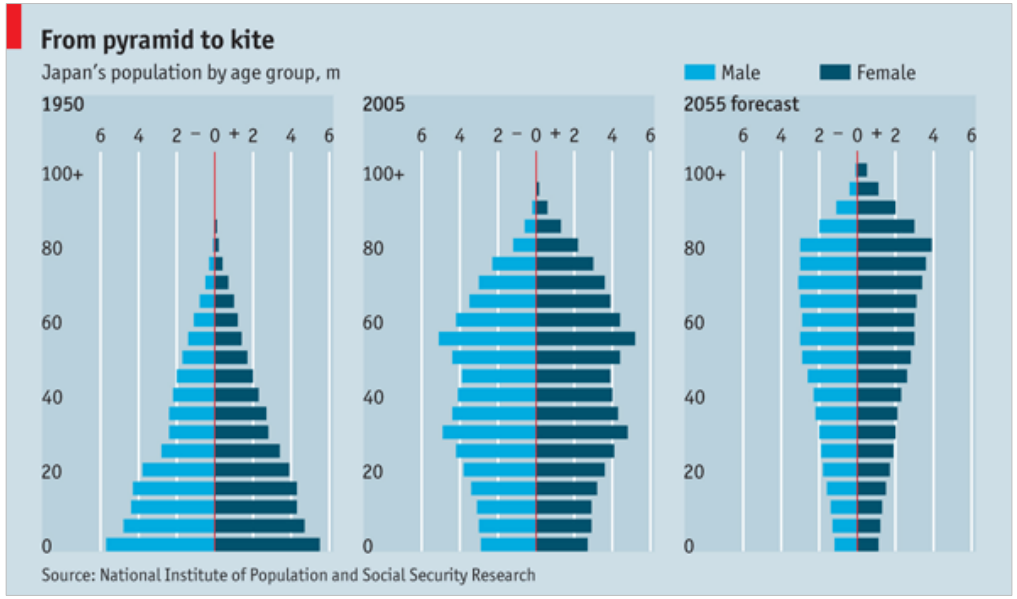


Image Credit: Google

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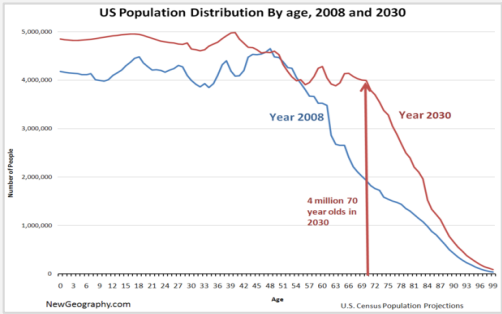

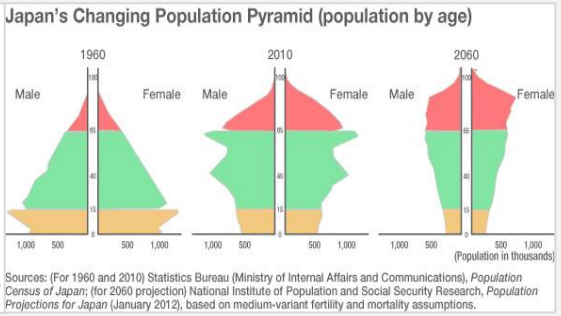

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Quality of Life

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Quality of Life

In-Home Robotics

Image Credit: Intuition Robotics

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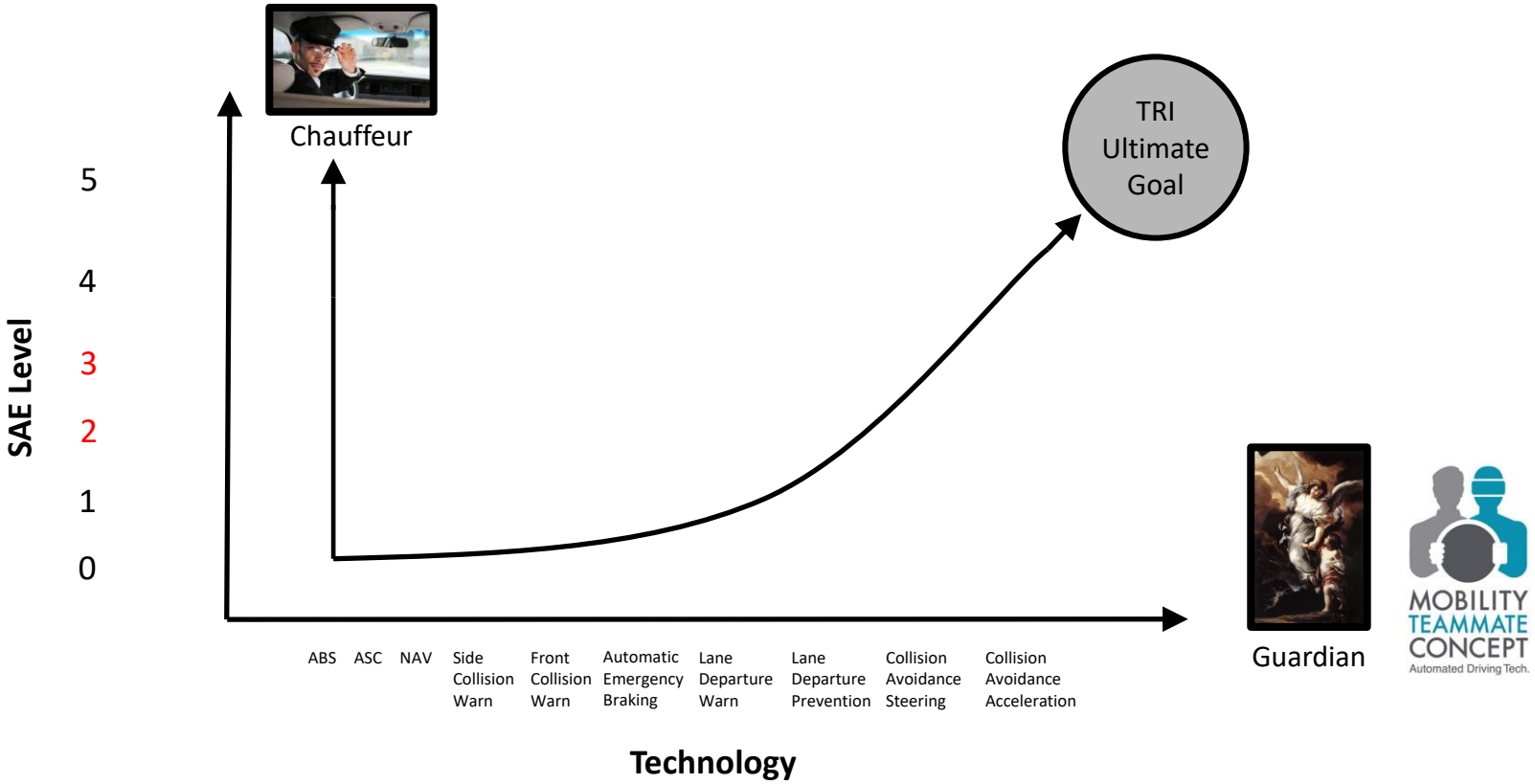
TRI Approach to Automation: One System, Two Applications



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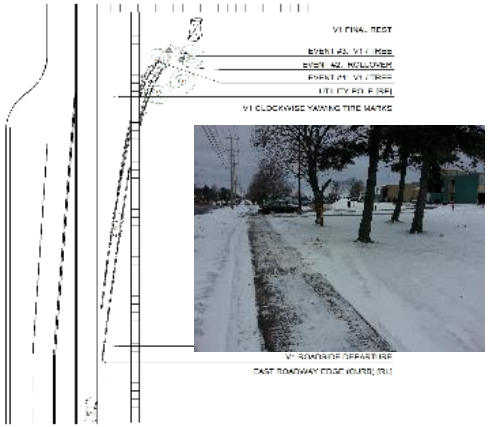
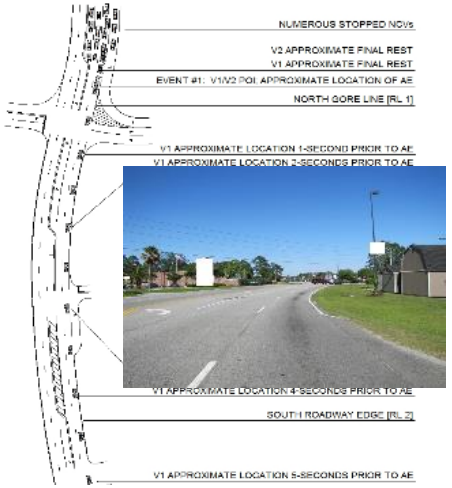
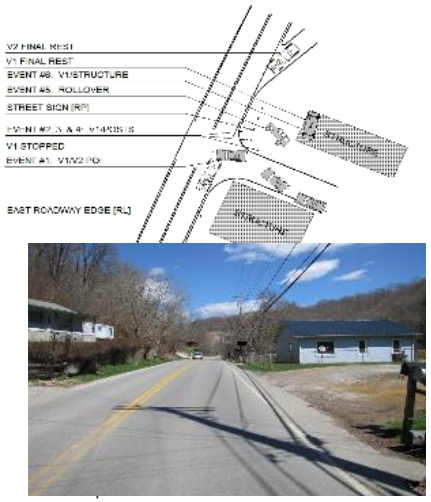
Guardian Strategy — Build an Uncrashable Car

“Flip” the handoff problem – Human always in control

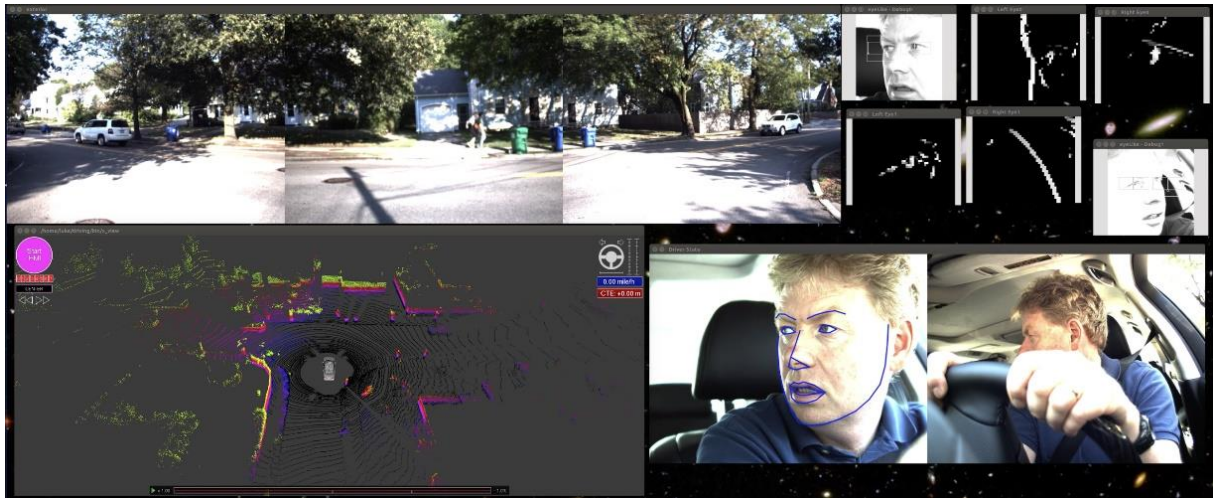
- Don’t leave the road
- Don’t hit anything
- Don’t get hit
- Understand driver intent







- Inform
- Warn
- Intervene



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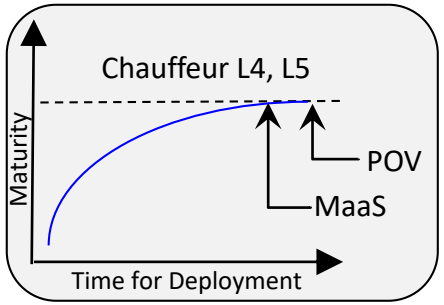
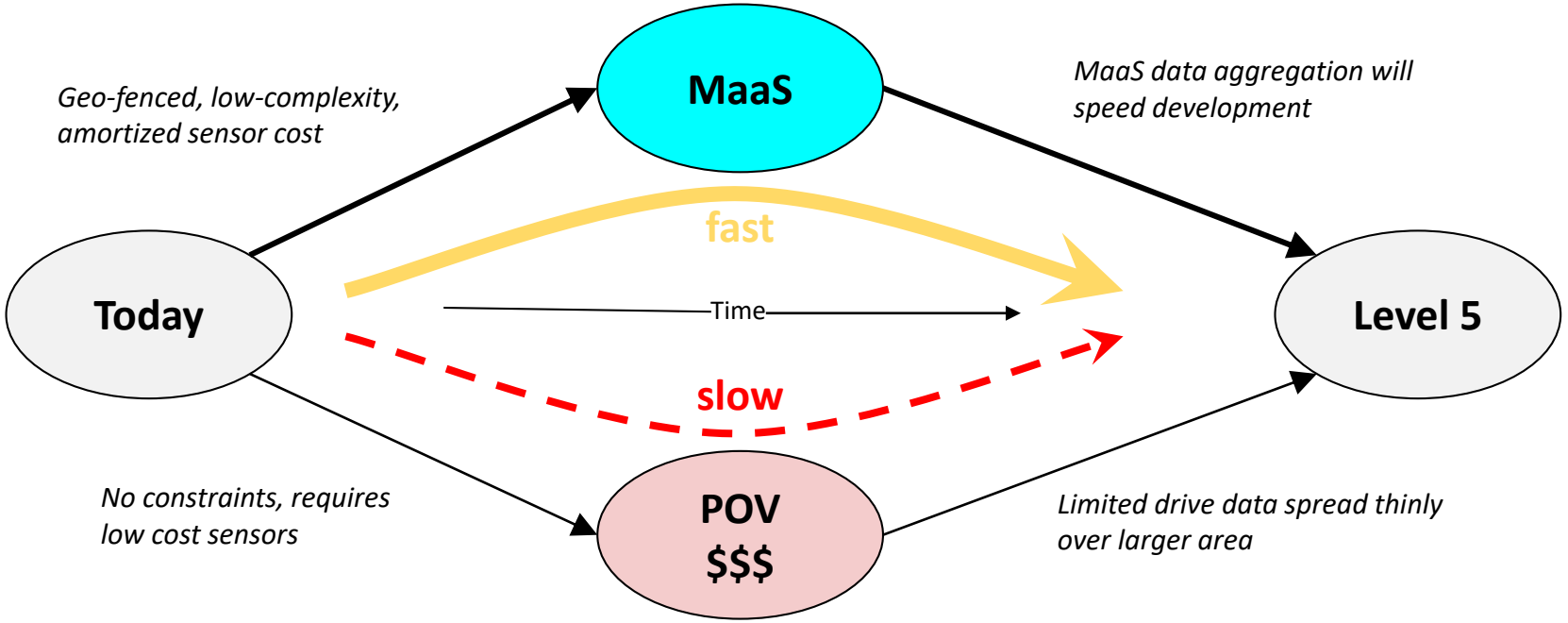
Chauffeur Strategy – Mobility as a Service (MaaS)



- Mobility as a Service (MaaS) may offer best application for bringing Level 4 to market faster
- Chauffeur for personally-owned vehicles (POV) requires solving the long asymptote for anywhere L4/L5 capability



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Big Questions Going Forward




- What are the technical challenges?
  - Maintaining Maps
  - Adverse Weather
  - Interacting with People
  - Robust Computer Vision (towards PD=1.0, PFA = 0.0)
- For Level 2 and Level 3 approaches, can humans be trusted to take control when necessary?
- For Level 4 and Level 5 approaches, can near-perfect false-positive and false-negatives be obtained in a wide variety of demanding settings?
- Can we deploy autonomous vehicle technology sooner?

Human must pay attention, but autonomy will jump in to prevent accidents

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Summary

- The potential for automated vehicles is great
- But, the idea has been a bit overhyped in the media and public's mind – current technology not yet ready for nationwide, all-weather driving
- Human factors, along with rigorous testing and validation, will play a critical role in how this technology is safely brought to market

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