Next Generation Vehicle Self-Drive Control Concepts and Safety Requirements: A Research Plan

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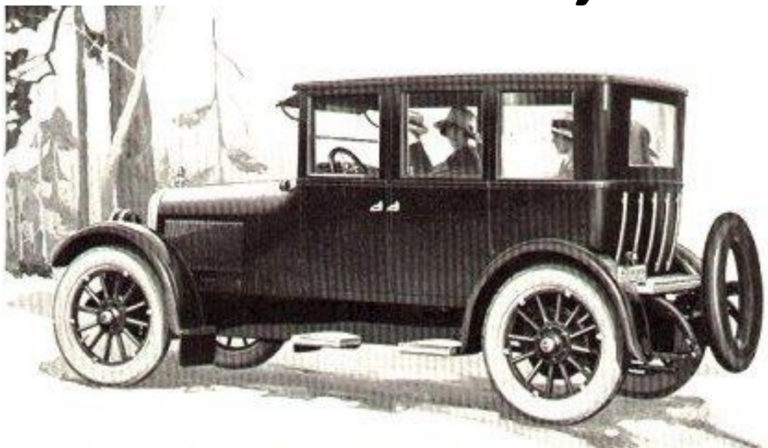
Which Type of Self-Drive Vehicle Control Makes Sense, and Why?

- Autonomous
- Vehicle-to-Vehicle Cooperation
- Road Infrastructure-to-Vehicle Remote Control
- Human control
- Blend of capabilities

KEY ISSUES To RESOLVE:

1. Transition from few to many Self-Drive Vehicles
2. Self-Drive performance and safety standards

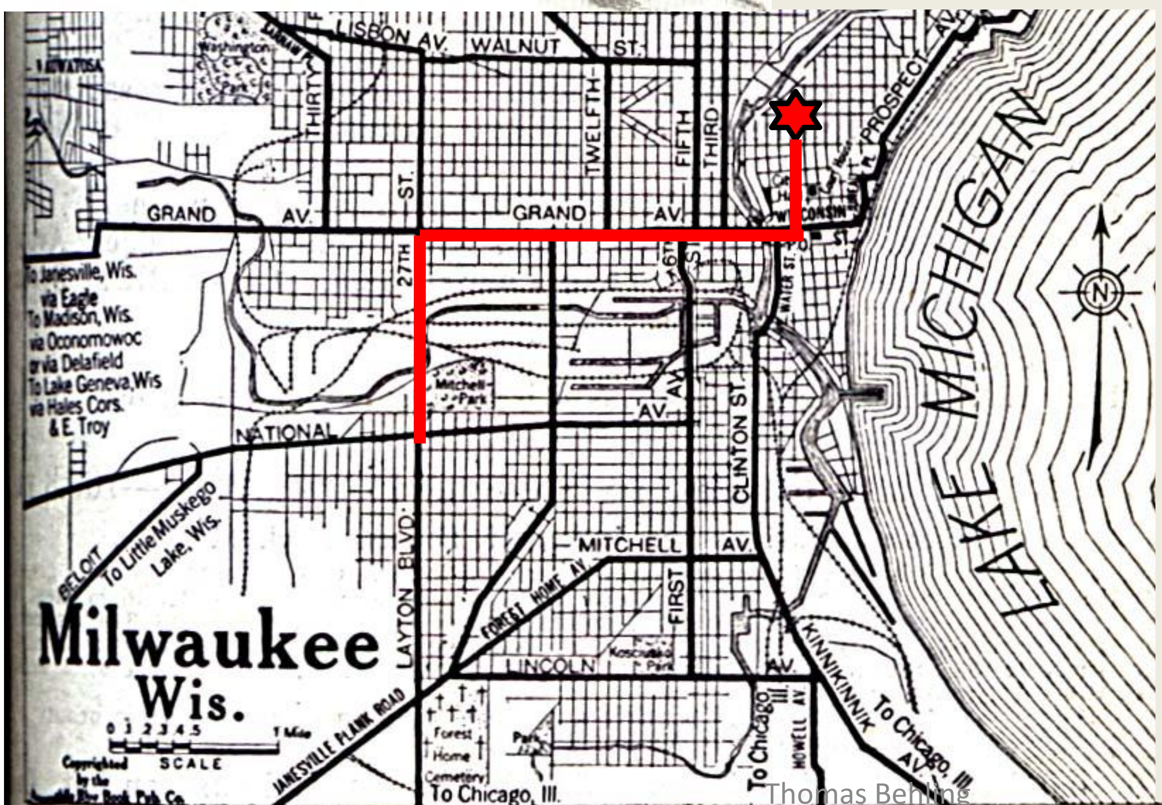
First, A Bit of History



Milwaukee Sentinel

Wednesday, December 8, 1926

PHANTOM AUTO WILL TOUR CITY



"Driverless, it will start its own motor, throw in its clutch, twist its steering wheel, and toot its horn…the "master mind" that will guide the machine will be a radio set in a car behind. "

Recent History

- **1960’s – Ohio State University launches autonomous vehicle project--states roads will be ready in 15 years.**

- **1980’s - DARPA funds Autonomous-Land-Vehicle project using technologies from Carnegie Mellon University (CMU) and University of Michigan. Used laser radar and computer vision--driverless vehicle trailed lead car at 19 mph.**

- **1995 – CMU develops “No Hands Across America” project—a 98.2% autonomous vehicle traversed 3,100 miles. Neural networking used to steer the vehicle, however, throttle and brake were operated by a human via remote control.**

Impact of DARPA Grand Challenges: Impetus for Self-Drive Vehicles

- **Held in 2004, 2005, 2007**
- **2005: Google, Volkswagen, and Stanford Engineers win 132 mile race with "Stanley"**
- **2007: Carnegie Mellon University and General Motors win 60 mile urban race with "Boss"**

Congressional Hearings on Self-Drive Automobiles

June 24, 2014: WASHINGTON - **Transportation and Infrastructure Committee Chairman Bill Shuster (R-PA) welcomed Carnegie Mellon University and its self-drive vehicle for demonstrations**

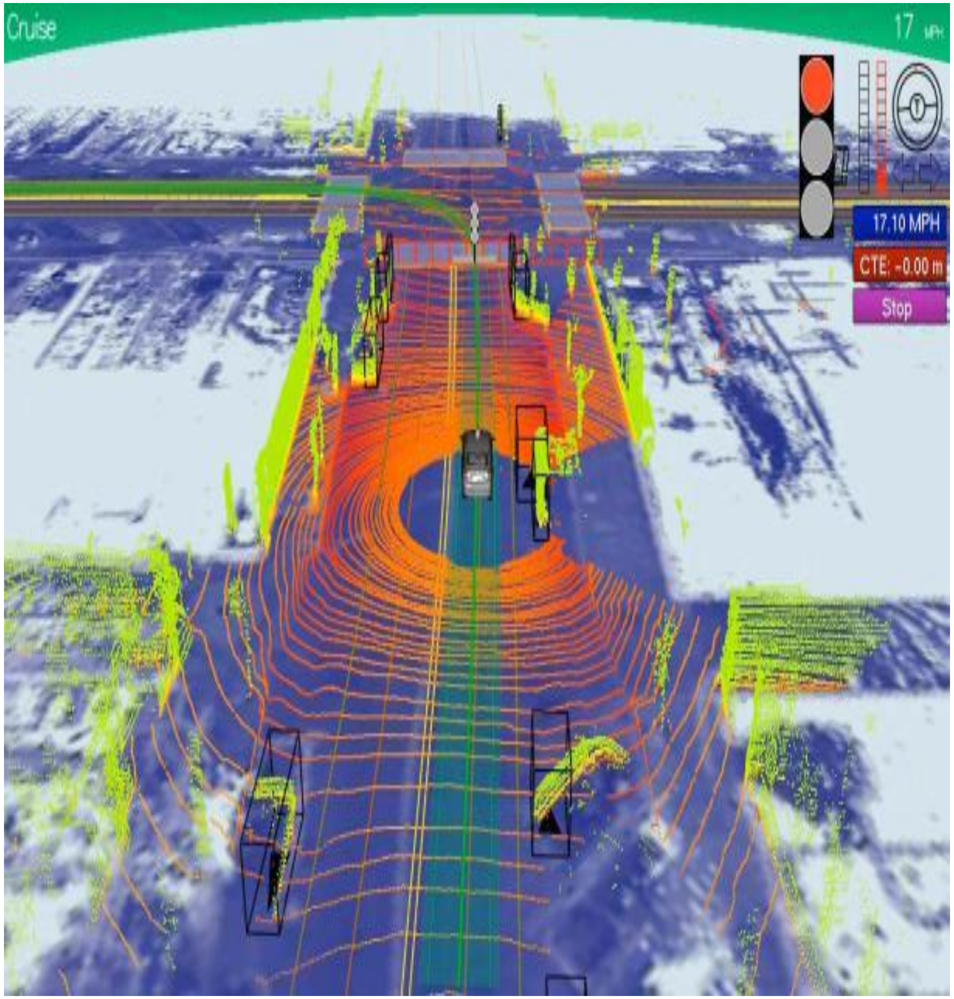
Shuster: "Autonomous vehicles … have significant potential to increase transportation safety and efficiency. The future of transportation is coming quickly, and it's important to provide policymakers with … better understanding of these kinds of innovations."

Autonomous Control

- Typical strategy is "sense-plan-act"
- Must deal with environment that includes :
  - Other vehicles on the road, each of which operates dynamically and independently
  - Other road users or on-road obstacles, such as pedestrians, cyclists, wildlife, and debris
  - Weather conditions, from sunny days to severe storms
  - Infrastructure conditions, including construction
  - Rough roads, poorly marked roads, and detours
  - Traffic events, such as congestion or crashes.

How does it work?

- **Google Car Example:**
  - Velodyne 64 beam laser, mounted of roof, generates a 3-D map of environment.
  - 4 radars mounted on the front and rear bumpers to navigate through high speed traffic.
  - Camera located on rear view mirror dedicated to reading traffic lights.
  - GPS



Google Car Concept of Operation

The Google car goes through six steps to make each decision on the road.

1. Locates itself with GPS and special maps embedded with detailed data the roadway. The value of maps was a key insight that emerged from the DARPA challenges. ***Maps are key—they give car a baseline expectation of its environment***

Source *The First Look at How Google's Self-Driving Car Handles City Streets* , Eric Jaffe in *CityLab,* 28 April 2014,

Google Car Concept of Operation, Continued

2. Next the car’s sensors collect data on moving objects.
3. **Data is interpreted as actual objects that might have an impact on the car's route — other cars, pedestrians, cyclists, etc. — and to estimate their size, speed, and trajectory.**
4. **Interpreted data enters a probabilistic prediction model that considers what these objects have been doing and estimates what they will do next.**
5. Car software weighs those predictions against its own speed and trajectory and plans its next move.
6. The final step: turning the wheel, and braking or accelerating

Source *The First Look at How Google's Self-Driving Car Handles City Streets* , Eric Jaffe in *CityLab,* 28 April 2014,

US Department of Transportation Perspectives:

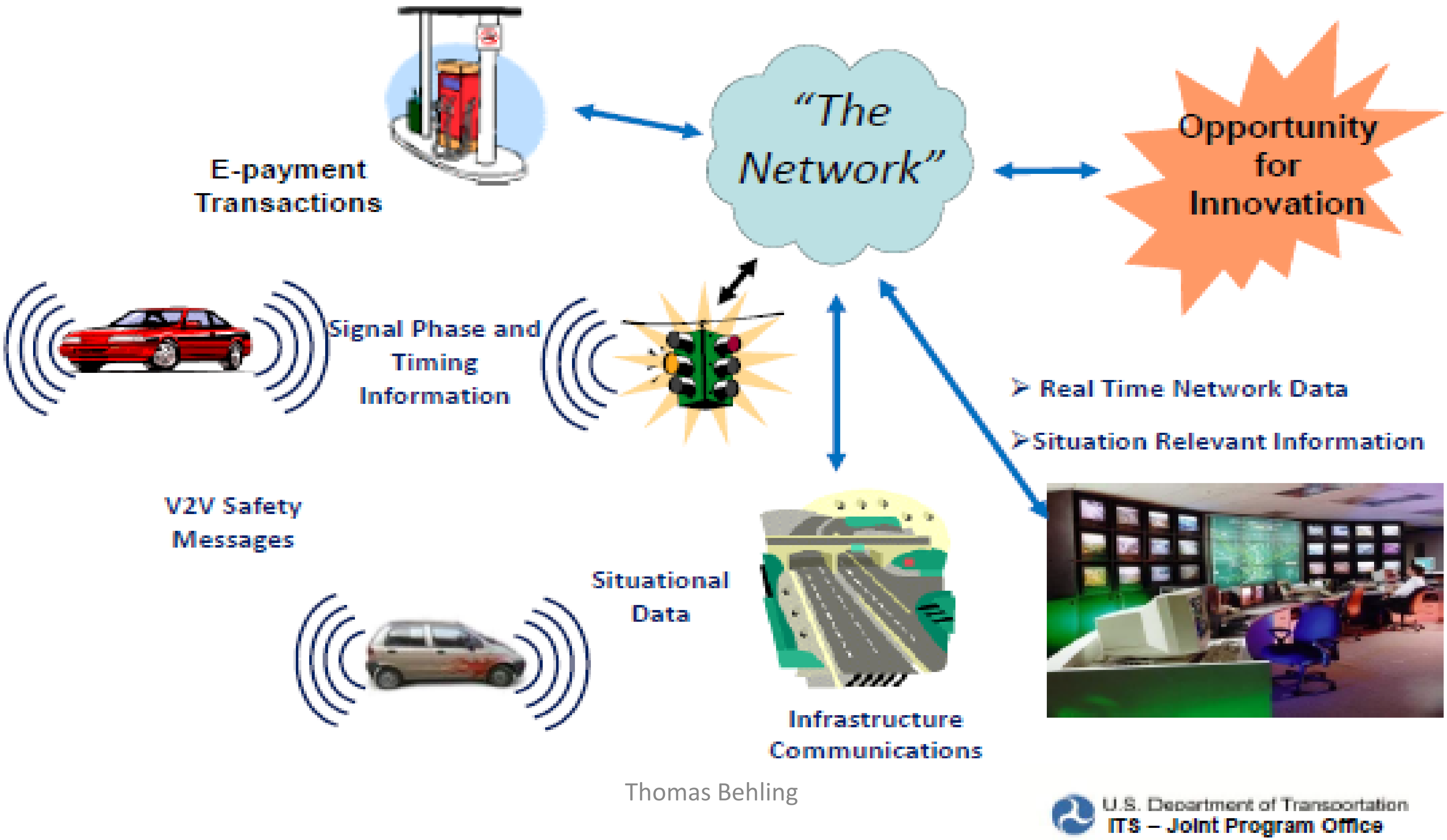
Vehicle to Vehicle and Vehicle to Infrastructure

History of VTV and VTI

- Part of U.S. Department of Transportation's "Intelligent Transportation Systems“ begun 1991
- Early concepts called for dedicated traffic lanes
- October 1999, the FCC allocated 75 megahertz of spectrum (5.850-5.925 GHz) for transportation services to improve highway safety and efficiency (Direct Short Range Communications)
- DSRC systems are being designed to provide short range, wireless link to transfer information between vehicles and roadside systems and other vehicles.

Connected Vehicle Reference Implementation Architecture

Connectivity Between Vehicles and Central Operations Center



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Virginia Connected Vehicle Test Bed in Northern Virginia

Current V2V Status

- August 2012: DOT launched Safety Pilot "model deployment" in Ann Arbor, Michigan
- 3,000 vehicles deployed with V2V technology—demonstrated feasibility
- Issues: security, liability, privacy, communication congestion, consumer acceptance


U.S. Department of Transportation
National Highway Traffic Safety Administration

DOT HS 812 014

NHTSA
www.nhtsa.gov

August 2014

Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application

Examples of Connected Vehicle Applications

Safety Applications

V2V

- Forward Collision Warning
- Emergency Electronic Brake Light
- Blind Spot Warning
- Left Turn Across Path

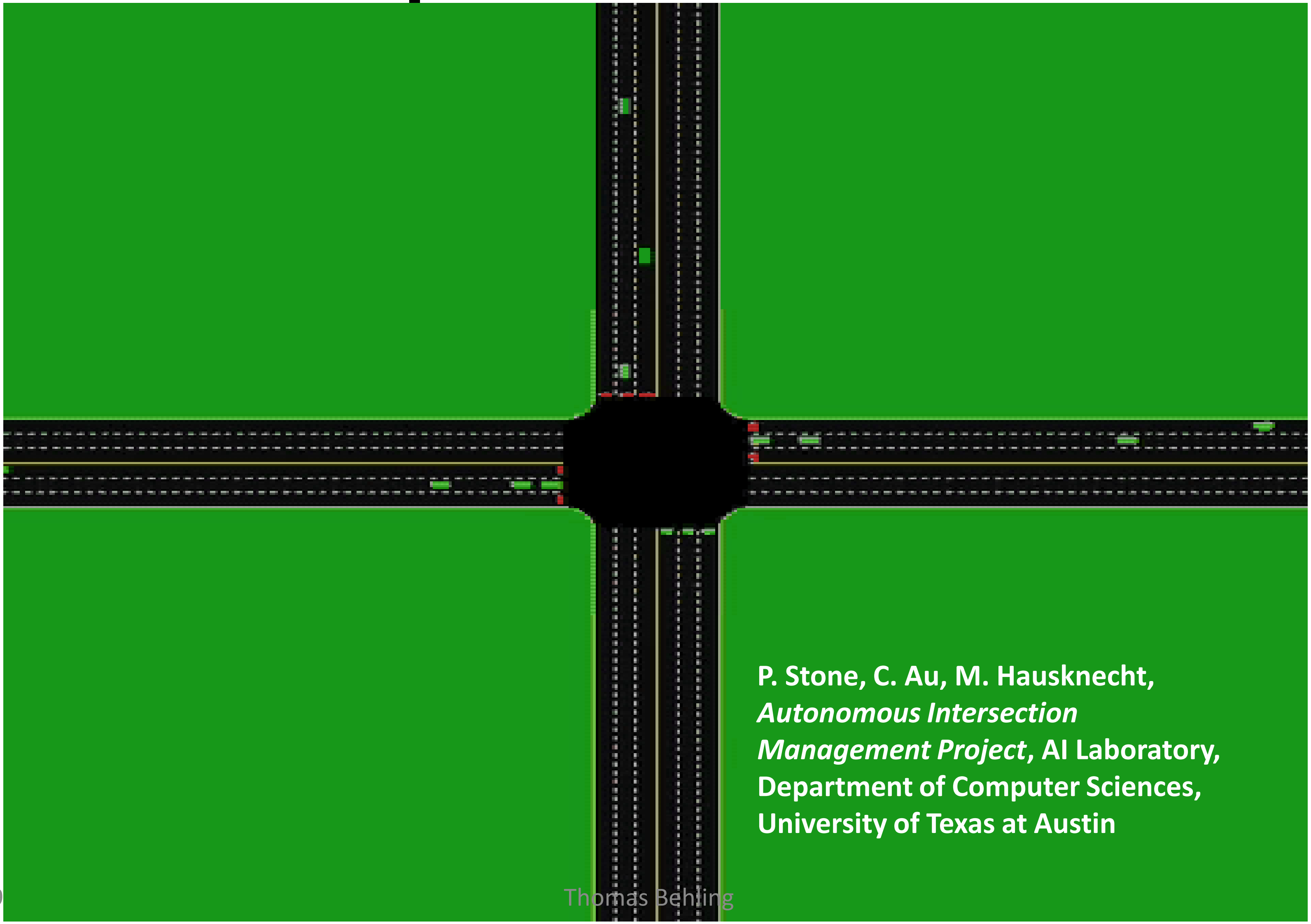
V2I

- Red Light Violation Warning
- Curve Speed Warning
- Stop Sign Violation
- Pedestrian Warning

Mobility and Evacuation Applications

- Intelligent Network Flow Optimization
- Emergency Communication, Staging and Evacuation
- Variable Speed Limits for Traffic in Bad Weather
- Motorist Advisories and Warnings
- Information and Routing Support for Evacuation and Emergency Responders

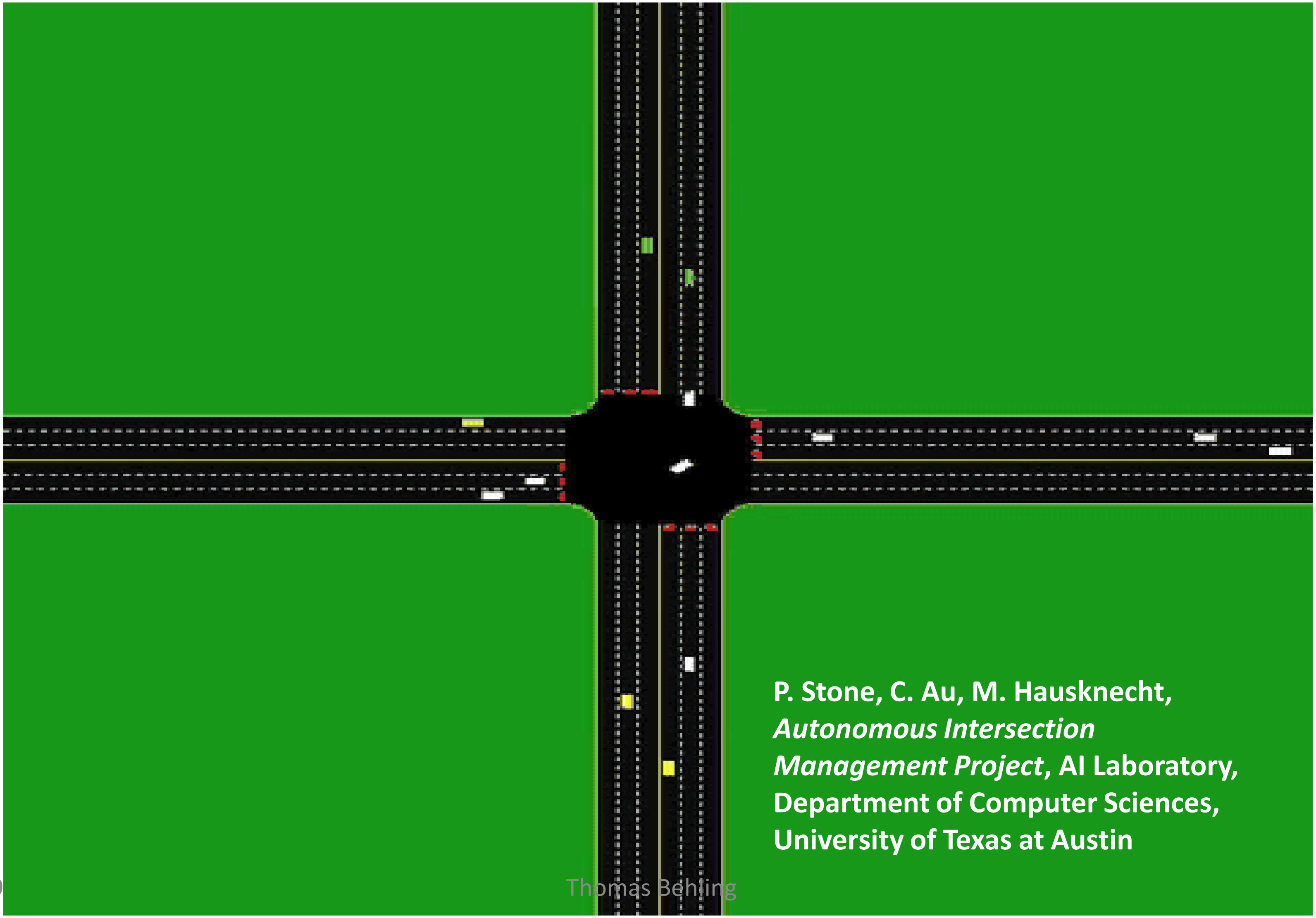
VTI Intersection Management: Example with No Assists



P. Stone, C. Au, M. Hausknecht, *Autonomous Intersection Management Project*, AI Laboratory, Department of Computer Sciences, University of Texas at Austin

LINK

With VTI Management: Crossings Reserved via Intersection Manager



LINK

Transition Issue: Vehicles Are Differently Equipped

- **Cars "A" and "B" approach intersection**
- **You are passenger in Car A, which is self-drive**
- **What is the protocol for Car B?**

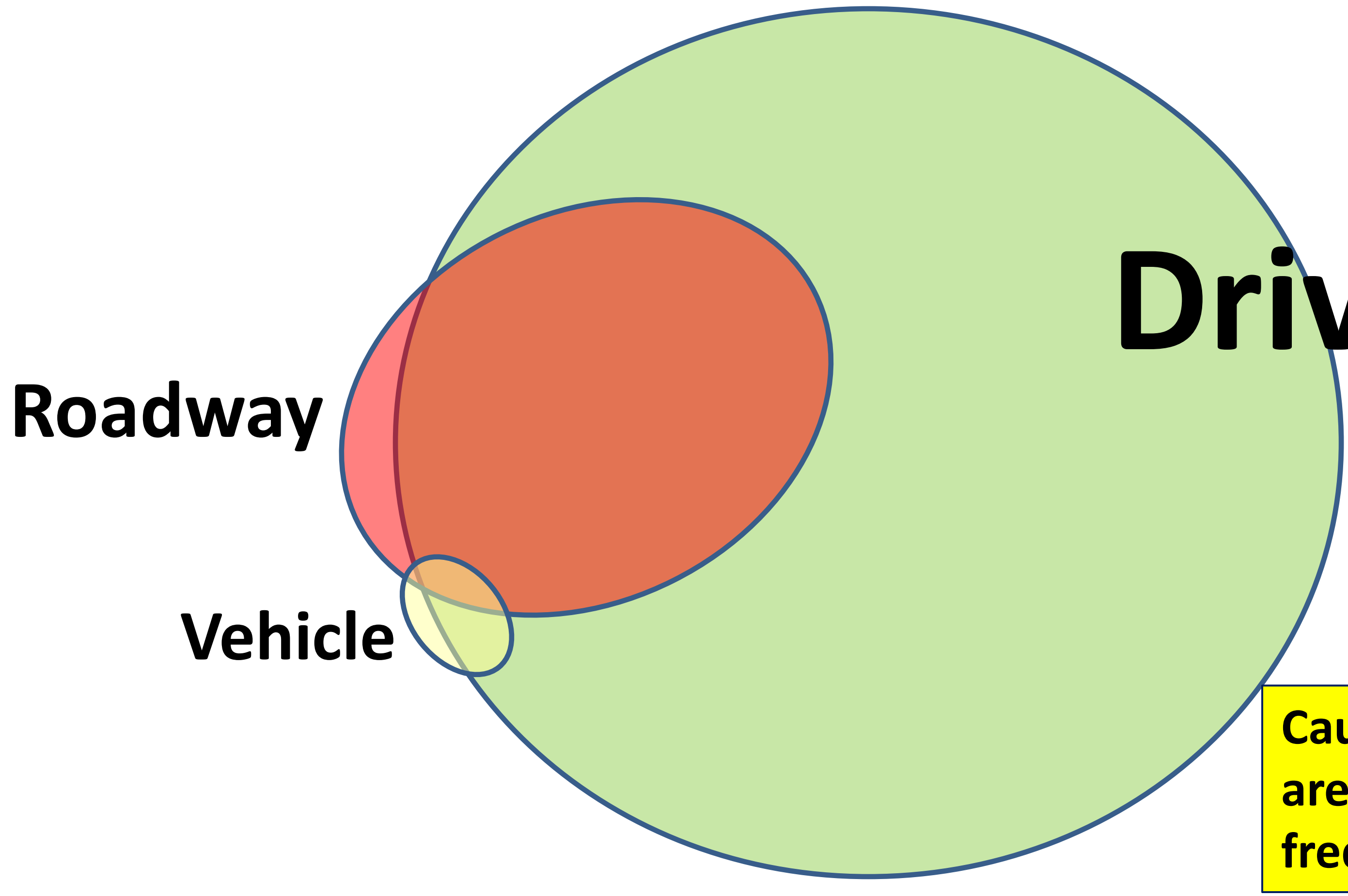
Car B Status	Car B systems OK	Car B has system fault
Driver in Car	Standard traffic rules	Standard traffic rules with alert
Driverless	Driverless traffic rules	Special conditions

Scenario 2

Scenario N

Some Observations on Safety Standards

Self-Drive Could Reduce Vehicle Accidents, Especially Driver Induced



Causes of accidents—area corresponds to frequency of occurrence

K. Rumar, 1985, cited by Harry Lum and Jerry A. Reagan in "Interactive Highway Safety Design Model: Accident Predictive Module, Public Roads Magazine (Winter 1995) .

But Self-Drive Control Systems Must Deal with the Unexpected

- **Control must be robust for individual vehicle and for cooperating vehicles**
- **Single Vehicle example: if a ball were to roll into the path of a vehicle, a driver would expect that a child could follow. Car based sensors and algorithms need to anticipate this event**
- **Many other examples**

Real Example From Home: Pedestrian Crosses Against Traffic

Real Example From Home: Pedestrian Pauses in Median Strip

Patterns of Behavior Vary According to Location, Time of Day, Day of Week, Etc

Self-Drive Vehicles Will Face Higher Safety Standards

- **Self-Drive can reduce human-caused crashes, especially fatalities**
- **But today's overall crash rates are already low**
- **In US, one crash (non-fatal) per 500,000 vehicle miles traveled (VMT)**
- **Google car has logged 700,000 accident-free miles (as of April 2014)**
- **Goal: much better than one crash per MVMT**

In US, 3 Trillion Vehicle Miles Traveled per year results in nearly 6 Million accidents. Compiled from US National Highway Traffic Safety Administration reports (Nov and Dec 2013)

How to Assess Control Concepts and Develop Transition Plan

Start with customer/driver needs, e.g.,:

- Reduce time driver is engaged in commuting (car acts like a train, giving driver time for other tasks)
- Add new functionality: operate car autonomously to pick up and deliver passengers
- Reduction in fatal and non-fatal crashes

Issues to be Worked

- How to measure effectiveness of control concepts?
- Can *performance* be improved by <u>using patterns of driver behavior at detailed level</u>?

Some First Steps

1. Assess utility of existing traffic models and data sets for applicability to key driver needs discussed above, e.g., do the models work only for freeway traffic? Can they handle dense urban traffic with pedestrians?
2. **Prepare plan for data gathering and model development**
   - **Break down exemplar needs into journey segments**
   - **Enhance existing data sets with data on traffic patterns in city neighborhoods gathered via automated means**
3. **Build data set of traffic behavior on an intersection-by-intersection and journey-segment basis, keyed to detailed maps**

LINK TO VEHICLE VIDEO

Vehicle Movement Automatically Registered by Time, Location, Direction, Speed

Some First Steps

4. Use driver/pedestrian behavior data to create taxonomy and scripts for specific patterns of self-drive/driver and self-drive/pedestrian interactions (e.g., urban traffic behavior at intersections with traffic lights and heavy rain).
5. Develop standard set of reference scenarios based on combinations of scripts to assess vehicle interactions, V2V and I2V communication needs, safety, reliability, and resilience under adverse conditions
6. Assess effectiveness of vehicle control systems (self-drive with/without V2V or I2V coordination) for different on-road mixes of self-drive/driver vehicles
7. Develop crash rate data for reference scenarios for different mixes of human and self-drive vehicles

Final Thought: A Key Enabler for Transitioning to Self-Drive Vehicles

- Highly detailed, local maps of roadways are a key component of self-drive capabilities.
- In same manner, detailed scripts of driver and pedestrian behavior must be developed and keyed to specific locations.
- This gives self-drive car “expectation” of both the road environment and the likely actions of other moving objects