Update on Progress in US

by

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ITE/ARRB Driverless Vehicle Webinar

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Live on the Internet
• Problem statement
  – Words are important
    • Clear understanding of similarities and differences between “Automated Collision Avoidance”, “Self-driving” and “Driverless”
      – Implications of: “autonomous”, “remotely-operated”,
      – How might we evolve to capture the desired benefits

• Where are we today in the US
  – Traditional manufacturers
  – “start-ups”

• Marketplace
  – Consumers/Personal Use
  – Fleets/Shared Use

• External Forces
  – Private Capital (Venture, etc.), Public Oversight (Federal/State/Local), Special Interests (Non-profits, Foundations, Groups)

• When might we get where?
Problem Statement

• Two objectives
  – **Safety**: Injuring, Killing and Causing way too much property damage in delivering mobility to individuals
• Deaths/yr.: ~ 35K US; ~1.25M World
• Leading cause of death for ages of 5 -> 35
• One of the most dangerous occupations
  – Worse than coal mining
• [NHTSA: Car Crashes cost US $871B/yr (≈ $2,800/person 5/29/14)]($2.8K/person); 1/3 Cash
• Liability expenses 2013 (Transit Buses, US) $500M/yr.
  – $6,300/bus/yr (120 fatalities/yr)
• > 90% involve Human error
• The Bad news (Safety Council’s Press release): Things are getting worse!
Motor-vehicle deaths up 8% in 2015.

With continued lower gasoline prices and an improving economy resulting in an estimated 3.5% increase in motor-vehicle mileage, the number of motor-vehicle deaths in 2015 totaled 38,300, up 8% from 2014. The 2015 estimate is provisional and may be revised when more data are

Txtng while driving is out of control...
Response is Laudable

But... Not Likely to be Effective
Up to today:
Primarily concerned with safety standards associated with Crash Mitigation
(air bags, seat belts, crash worthiness, ...)

ITE/ARRB
Driverless Vehicle Webinar

NHTSA
National Highway Traffic Safety Administration

PAVE
Princeton Autonomous Vehicle Engineering

CARTS
The Center for Automated Road Transportation Safety
Fundamental Automated Crash Avoidance
(Automation overrides the Driver)

http://orfe.princeton.edu/~alaink/SmartDrivingCars/Videos/Subaru%20EyeSight_Commercial60secCrashTest.mp4
Fundamental Automated Crash Avoidance
(Automation overrides the Driver)

https://www.youtube.com/watch?v=yARbNYcjPQM
Fundamental Automated Crash Avoidance
(Automation overrides the Driver)

http://www.youtube.com/watch?v=dWj44GjrSs0
Not Completely New:
Anti-lock Brakes (ABS) & Electronic Stability Control (ESC)

Both: Override driver and “Do the right thing”
Add Intelligent Cruise Control & Automated Lane Centering

Created:  **Self-Driving Car** that can take over the driving task for at least some Driving Scenarios.

The real advance is that this is being done “autonomously” “inside” each individual vehicle in accordance with existing rules of the road and without the imposition of any need or consideration from the road environment or other drivers or vehicles. These systems are driving defensively in certain places under certain circumstances.
#1: Tesla S **AutoPilot** (~$2,500.) See [Video 1](#), and [Video 2](#)
   Very Good Lane Centering, Jam Assist, Driverless Parking, Indication that AutoPilot reduces 50% of crashes

#2: MB Dystronic Plus (~2,800.)
   Poor Lane Centering, Very good Jam Assist and Intelligent Cruise Control

#3: **Volvo S90** (Standard Equipment; [See video](#))
   OK Lane Centering, Very good Jam Assist and Intelligent Cruise Control

#4: **Subaru Eyesight** (~3,000) ([See Video](#))
   Just Lane Departure Warning, Very good Intelligent Cruise Control, Obtained Superior Rating from IIHS

Others: **BMW & Nissan**
   Poor Lane Centering, Very good Jam Assist and Intelligent Cruise Control
Self-Driving Cars Available Today

#1: Tesla S AutoPilot (~$2,500.) See Video 1, and Video 2

What it has:

- Sensors: Camera, Radar, Ultrasonics & GPS
- Over-the-air updating of software & downloading of data

What it delivers: (always on)

- Avoids collisions from the front and sides, & lane departures

What it delivers: (on Command @ \{0 < speeds < 130kph\})

- Steer within a lane,
- Change lanes with the simple tap of a turn signal,
- Manage speed by using active, traffic & speed-aware cruise control,
- Parallel park

What it does NOT deliver: (Human Driver MUST do it today)

- Recognize and React to Stop/Yield Objects
- Properly traverse intersections & merges
- Steer well within a lane when lane markings are poor,
- What we don’t know that it should deliver
Problem Statement

• Two objectives

  – Safety: Injuring, Killing and Causing way too much property damage in delivering mobility to individuals

  – Enhanced Mobility: (Better Quality-of-Life)
What if “Tesla’s AutoPilot” was improved to an extent that a driver was unnecessary for the entire trip.

– Really just better software (Cost_{software} \rightarrow 0.00)

– Then....
Problem Statement

• Two objectives
  – **Safety**: Injuring, Killing and Causing way too much property damage in delivering mobility to individuals

  – **Enhanced Mobility**: (Better Quality-of-Life)
    • “On Demand” for All
    • Substantially Cheaper (no driver to pay)
    • Substantially Safer
    • Substantially More Energy Efficient (Fleet Ops w RideSharing)
    • Substantially Lower GHG & Other Pollutants (Ditto)
    • Substantially Less/Elimination of Road Congestion (Ditto)
Fundamental “Driverless” Concept

• Substantially Cheaper Mobility for those that Can’t (or Choose not to) Drive
  – Young (12->15)
  – Too Old
  – Visually Impaired
  – Those under the influence

  – (Today, these folks have access to Taxicabs, Uber, Para-transit that have the same mobility as the personal automobile, but they MUST pay for a driver; whereas everyone else can simply use their time and skill.)
These systems reduce the price of “personal on-demand mobility” by ~ 80%

- Taxi Labor Cost ~80% ; Cost of Automated Tech -> 0

\[ \text{Price}_{\text{new}} = \frac{1}{5} \times \text{Price}_{\text{old}} \]

If information technology enables RideSharing

\[ \text{Price}_{\text{new}} < \frac{1}{10} \times \text{Price}_{\text{old}} \]

- A whole new Mobility opportunity PLUS:

\[ \text{Energy}_{\text{new}} < \frac{1}{2} \times \text{Energy}_{\text{old}} \]

\[ \text{GHG}_{\text{new}} < \frac{1}{2} \times \text{GHG}_{\text{old}} \]

Positive Implications on Congestion
• Broad Definition - **Automated Vehicle:**
  – A *vehicle* that is being actively controlled longitudinally and laterally by non-human actions.
  – Can go [ from \( \{X_a, V_a\} \rightarrow \{X_b, V_b\} \) ] w/o human intervention

• Broad Definition – **Self-Driving Vehicle**
  – An *Automated Vehicle* where \( a \) and/or \( b \) are **NOT** necessarily places where person trips begin and/or end.

• Broad Definition – **Driverless Vehicle**
  – An *Automated Vehicle* where \( a \) AND \( b \) are necessarily places where person trips begin and/or end for every \( \{a,b\} \)
  – Driverless Vehicles **CAN** reposition themselves empty
    – Biggest “Headache for Bike sharing (& car sharing) is empty repositioning (Demand is NOT symmetric)
Everyone Has Ridden in a Driverless Vehicle
Everyone Has Riden in a Driverless Vehicle

• Driverless... Easy to do, If...

We can properly constrain/condition the “roadway”

Make it exclusive/eliminate conflicts (railroads, elevator shafts, exclusive grade-separated guideway)

All today’s driverless examples are constrained to their exclusive guideway

What we are trying to do is to make Automated Vehicles (Including Driverless) that simply use today’s conventional road, “As-Is”, without disrupting the conventional users of those roadways
Everyone Has Ridden in a Driverless Vehicle

• CAUTION

We have yet to “drive” the 1st Foot with an empty driverless vehicle without anyone in (or closely monitoring) the vehicle on a conventional public roadway operating otherwise normally.

(a driverless vehicle has yet to drive down “Nassau Street in Princeton” or “El Segundo Blvd in Mountainview” or the “New Jersey Turnpike” during Mid-day or even Mid-night!)
Everyone Has Ridden in a Driverless Vehicle

- **CAUTION... So...**

  We can either: Improve “Tesla AutoPilot”... so that it operates essentially on “all” roads in “all” conditions

  (The more roads and the more conditions the more customer “Mobility-on-Demand” trips that can be served, the more the customer will “depend” on the Driverless “autonomousTaxi (aTaxi)” Service.)

  Or, slow down enough and choose roads that are naturally constrained to begin offering Mobility-on-Demand with low-speed aTaxis in those areas and grow from there.
Automated Driving

• Today (Self-Driving) ... It is all about SAFETY!

• Ultimately (Driverless) ... It is all about Enhanced Mobility
  • “On Demand” for All
  • Substantially Cheaper
  • Substantially Safer
  • Substantially More Energy Efficient
  • Substantially Lower GHG & Other Pollutants
  • Substantially Less/Elimination of Road Congestion
Today’s Low-speed “Driverless” Vehicles

- **Easy Mile**
- **2GetThere**
- **robosoft**
- **Catapult**
- **Meridian Shuttle**
- **Google** Self-driving car
“Today’s” Low-speed “Driverless” Demonstrations

- **CityMobil2**
“Today’s” Low-speed “Driverless” Demonstrations

- **CityMobil2**

- **British “Upcoming” Demonstrations**
  - Greenwich, Bristol, Milton Keynes

- **US “Upcoming” Demonstrations**
  - Autin, TX ??, Mountain View, CA ?, Some Florida Gated Community??
  - 42\textsuperscript{nd} Street NYC ???
What About......
“Today’s” Low-speed “Driverless” Demonstrations

- CityMobil2

- British “Upcoming” Demonstrations
  - Greenwich, Bristol, Milton Keynes

- US “Upcoming” Demonstrations
  - Austin, TX ??, Mountain View, CA ?, Some Florida Gated Community??
  - 42nd Street NYC ???, Moffett Field/Ames Research Center ???, Princeton ???

- Canadian “Upcoming” Demonstrations
  - Toronto??
Tomorrow’s aTaxis

• Driverless vehicles that are capable of mixed use operation on essentially every street, road and highway.
  – Not likely to evolve from any low speed driverless except Google’s
  – Not likely to evolve from any conventional manufacturer except Tesla
    • While Daimler and others could... The business model...Fleet sales, shared-use, shared-ride is too disruptive.
  – Needs a new vision to disrupt the $10T/yr world mobility market.
    • Google: Advertising opportunities fund the whole transformation
    • Apple: Has cash and needs a new market
    • Amazon: aDelivery... labor free “last mile logistics”
    • Uber: Solves their biggest headache: Uber Drivers.
    • New Guy??... Faraday Future also ??? Others????
Forces For & Against

• One only needs to get the Automated Vehicles technology to “work” on a “single” vehicle to initiate viral adoption!
  – Definition of “work”:
    
    Cost of the Technology

    <

    Net Present Value \{ Expected Liability Savings \text{delivered by that technology} \}

• Since the technology
  – Does NOT require any infrastructure costs
  – Involves mostly “Moore’s Law Elements
• The inequality will be achieved and
  – Insurance will fuel the viral adoption.
For:

- Extremely positive **Value Proposition**
  - *From* Real Safety,
  - *Through* Comfort & Convenience
  - *To* Simply making $$$ delivering Mobility as a Service (MaaS)
- Ability to **get started** with very little investment
- Insurance can profit handsomely...
• For:
  – Extremely positive Value Proposition
    • *From* Real Safety,
    • *Through* Comfort & Convenience
    • *To* Simply making $$$ delivering Mobility as a Service (MaaS)
  – Ability to **get started** with very little investment
  – Insurance can profit handsomely...

• Against:
  – Disrupts the traditional business model
    • 100 year-old macho “Mad Men” persona of driving and hauling stuff.
• Caught completely napping (if not completely comatose).
  – US DoT: Stuck on Connected by ITS trying to sell gizmos and infrastructure when all this needs is good and consistent paint and readable signs.
    • It's all about independent autonomous vehicles and NOT the infrastructure nor centralized “Big Brother” operations.
      – Because it ran out of money DoT decided to get into the “Big Brother” business managing & orchestrating what everyone should do. This technology said.. “forget about it” The infrastructure is just fine as it is and we don’t need (nor want) management & orchestration.
  – NHTSA: Stuck in “Crash Mitigation Business”
  – State DoTs, DMVs & Locals: Completely overwhelmed and underfunded with day-to-day responsibility of Conventional System
  – Transit Agencies: Hopelessly bankrupt, trying to stay alive
• Legal system: Who know???
  – One can argue that current system is focused on tricking and playing games with us to do the right thing.
    • Speed limits are joke. Traffic “laws” are totally disregarded because they have been set with a wink under the assumption that we are going to violate them
    • Way too much of our legal system is focused on traffic laws
    • It is a vicious taxing system on the poor that get one of the random traffic tickets. Since they can’t pay it then get arrested later for an “outstanding warrant” (if they are lucky because in some cases the vicious cycle degenerates into a tragedy... All because of a random traffic ticket.
  – A few states have weighed in
  – We should seriously consider calling this a new MODE
    • give it its own incentives and oversight without trying to shoehorn it into the human mode
• For now we should just wait and not do anything to either promote, slow down or direct the evolution.
  – It has enough on the promotion side
    • It doesn’t need public money
    • The public could assume the early risk. Even if the worse thing happen, the liability exposure is absolutely minimal. At most a few people would die.
      – We are accepting the killing of a 100 a day with the existing system.
  – It doesn’t need any investment in the infrastructure

  – Just let the market forces get it off the ground and watch & learn.
Elevator Analogy of an aTaxi Stand
Temporal Aggregation
Departure Delay: DD = 300 Seconds
An aTaxiTrip
{oYpixel, oXpixel, TrainArrivalTime, dYpixel, dXpixel, Exected: dTime}
“Last Mile” Impact on NJ Transit Rail

Table 1: Train Network

<table>
<thead>
<tr>
<th>Train Statistics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Train Trips</td>
<td>1,513,339</td>
</tr>
<tr>
<td>Train Passenger Miles</td>
<td>24.37 million mi.</td>
</tr>
<tr>
<td>Average Train Trip Length</td>
<td>16.12 mi.</td>
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</tbody>
</table>

(Today: 281,576, +537%!)
### Results

#### New Jersey - True Average Vehicle Occupancy

<table>
<thead>
<tr>
<th>CD = 0</th>
<th>CD = 1</th>
<th>CD = 2</th>
<th>CD = 3</th>
<th>CD = 4</th>
<th>CD = 5</th>
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<tbody>
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<td>1.00</td>
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<td>1.06</td>
<td>1.06</td>
<td>1.06</td>
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</tr>
<tr>
<td>DD = 5</td>
<td>1.10</td>
<td>1.92</td>
<td>2.45</td>
<td>2.76</td>
<td>2.93</td>
</tr>
</tbody>
</table>

#### NJ State True AVO 3D Plot
Fundamentals of aTaxis

\[ \$_{\text{new}} = \frac{\$_{\text{now}}}{5} \]

\[ \$_{\text{Capital}} = \text{ZERO!} \]

\[ \$_{\text{new}} = \frac{\$_{\text{now}}}{\text{AVO}} \]

\[ \times \]
Discussion!

Thank You

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www.SmartDrivingCar.com