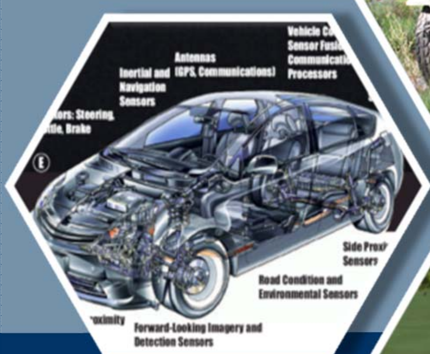
Intelligent Vehicle Systems

Southwest Research Institute



Autonomous Vehicles: State of the Practice

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Automated Vehicle Technology

- **Basic question:**
  - **What is the PURPOSE of a driverless vehicle?**

- **Possible answers:**
  - **Ultimate solution to the driver distraction problem**
  - **Should reduce accidents (although until a significant penetration the overall effect is questionable)**
  - **Should enable a reduction in traffic fatalities**
  - **Make transportation systems much more efficient (more vehicles in the same space)**

- **Sustainability of the technology (at what functional level) – consider driving levels model – expected duration of autonomy:**
  - **5 seconds**
  - **30 seconds to 1 minute**
  - **> 1 hour**

Automated Vehicle Technology Evolution

Self-driving, UGV, Driverless, Autonomous, Automated, etc…

Automated/Autonomous

- First RC vehicles used in 1930s
- FHWA's Automated Highway System in the 1990s, and demo in 1997.
- DARPA Urban Challenge (on-road automated driving) in 2007.
- Demonstration on the streets of Manhattan, NYC at the 2008 World Congress
- U.S. DoD Investment
- Google's Demos/Efforts
- Aggressive Marketing Campaigns leading to announcements by OEMs of their plans for production.

NHTSA Levels of Automation

- No-Automation (Level 0)
- Function-specific Automation (Level 1)
- Combined Function Automation (Level 2)
- Limited Self-Driving Automation (Level 3)
- Full Self-Driving Automation (Level 4)

NHTSA / SAE Driving Levels

- **Descriptive**
- **Minimum levels**
- **Compare to:**
  - o **Germany Federal Highway Research Institute (BASt)**
  - o **NHTSA**

Source: SAE

SAE level	SAE name	SAE narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt level	NHTSA level
Human driver monitors the driving environment								
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver only	0
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	System	Human driver	Human driver	Some driving modes	Partially automated	2
Automated driving system ("system") monitors the driving environment								
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	System	Human driver	Some driving modes	Highly automated	3
4	High Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	System	Some driving modes	Fully automated	3/4
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	All driving modes		

Semi-Autonomous Driving – available TODAY

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Who is Developing Autonomous Vehicle Capabilities
(list may incomplete because information is not openly shared)

- **US OEMs:**
  - GM
  - Ford
  - Tesla
- **European:**
  - Mercedes
  - BMW
  - Audi
  - Volvo
  - Renault
  - Scania (trucks)
  - Jaguar Landrover
  - Deihl
  - RUAG
  - Rheinmetall Defence
- **Japan:**
  - Nissan
  - Honda
  - Toyota
  - Hino
  - Isuzu
- **Tier 1 Suppliers:**
  - Bosch
  - Continental
  - Delphi
- **US non-OEMs:**
  - Lockheed Martin
  - Southwest Research Institute (SwRI)
  - Smaller Defense Contractors:
    - TORC, GDRS, ASI, etc.
  - University Research
    - CMU, Stanford. Virginia Tech
    - California PATH, VTTI
  - Google
- **Government (non DoD)**
  - US:
    - Human Factors for Vehicle Highway Automation
    - USDOT Automation Program
  - European Union:
    - CitiMobil and CyberCars
    - Safe Road Trains for the Environment (SARTE)
  - Energy ITS Project (Japan)

Autonomy Examples

- **Commercial Space:**
  - **Google / Auto OEMs**
  - **PEVs (Personal Electrical Vehicles)**
  - **Agricultural**
  - **Mining**

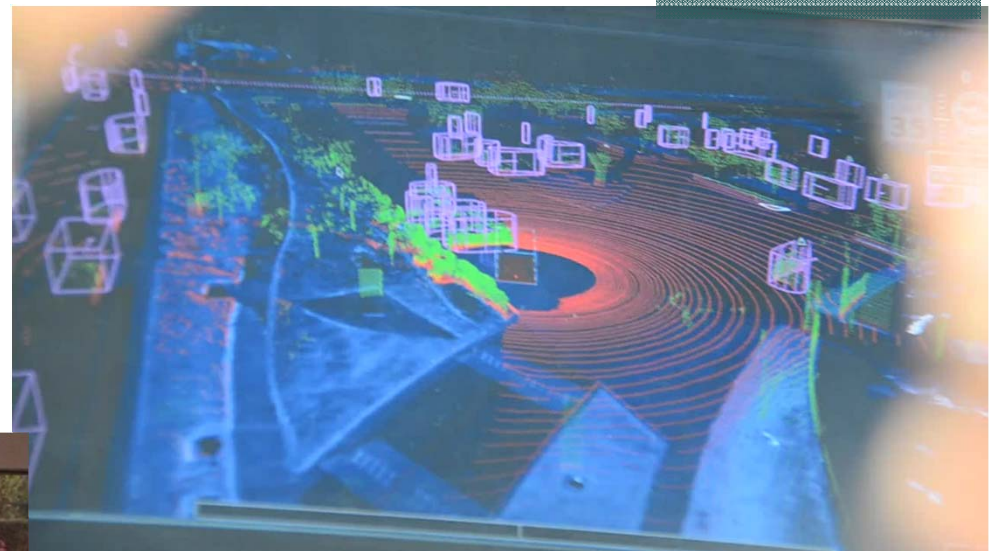
- **Military space (major programs in last 5 years):**
  - **AMAS - Army**
  - **GUSS - Marine Corps / Navy**
  - **SMSS – Army**
  - **SUMET – Marine Corps / Navy**
  - **DSAT – Army**

  - **Long term success: blending Connected Vehicle and Automated Vehicle:**
    - **Cooperative Vehicles**
    - **Cooperative Automation**

State of the Practice (commercial): Google

- **Pros**
  - **Well funded**
  - **Previously only freeway, adding arterial capability**

Source: Google



Source: Google

Cons

- **Expensive sensor suite**
- **Must pre-drive route**
- **Requires high precision map database**
- **For the U.S. - only 3,200 km of the 6.4M kms of highway “mapped”**

Google: Newest Announcement - PEVs

- In May 2014 Google has revealed a prototype of its latest driverless car:
  - No steering wheel
  - No braking or acceleration pedals
  - A stop and go button.
- Platform developed from scratch – not based on existing chassis:
  - No need to accommodate a driver
  - Two passengers
  - Maximum speed of 25 miles per hour
- Google says the car's most important feature is its safety:
  - Sensors that remove blind spots
  - "…can detect objects out to a distance of more than two football fields in all directions…" (note: unknown sensor technology).
- Visually appealing

- Development timeframe:
  - ~100 prototypes
  - Testing in summer of 2014
  - Available for purchase by 2020

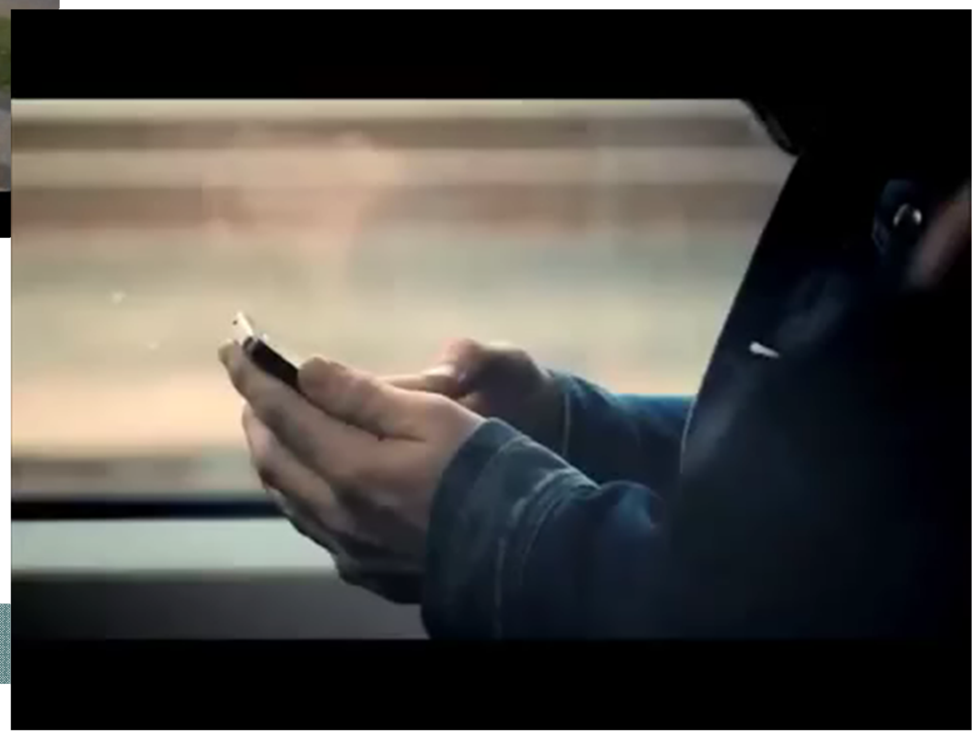
Other companies are developing also – names are proprietary

OEMs

Mercedes

Source: Mercedes

Volvo



Source: Volvo

State of the Practice (agricultural/mining): John Deere / Komatsu

- **Deere**
  - **Agriculture**
  - **Constrained environment**

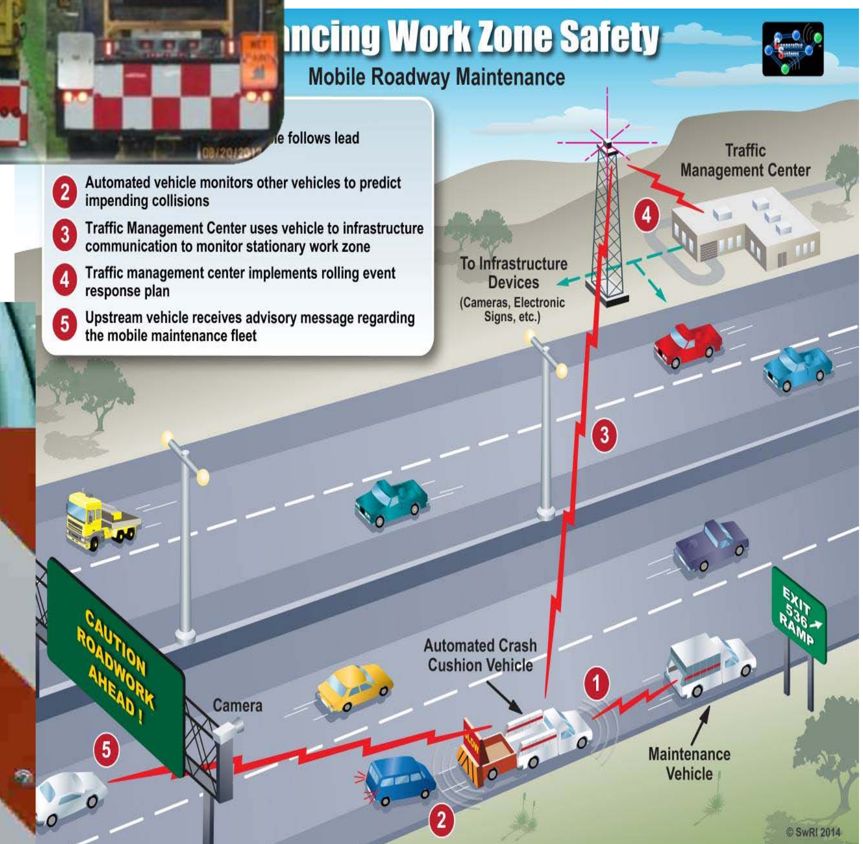
Source: John Deere

Source: Komatsu

- **Komatsu**
  - **Fixed route**
  - **Very dirty conditions**

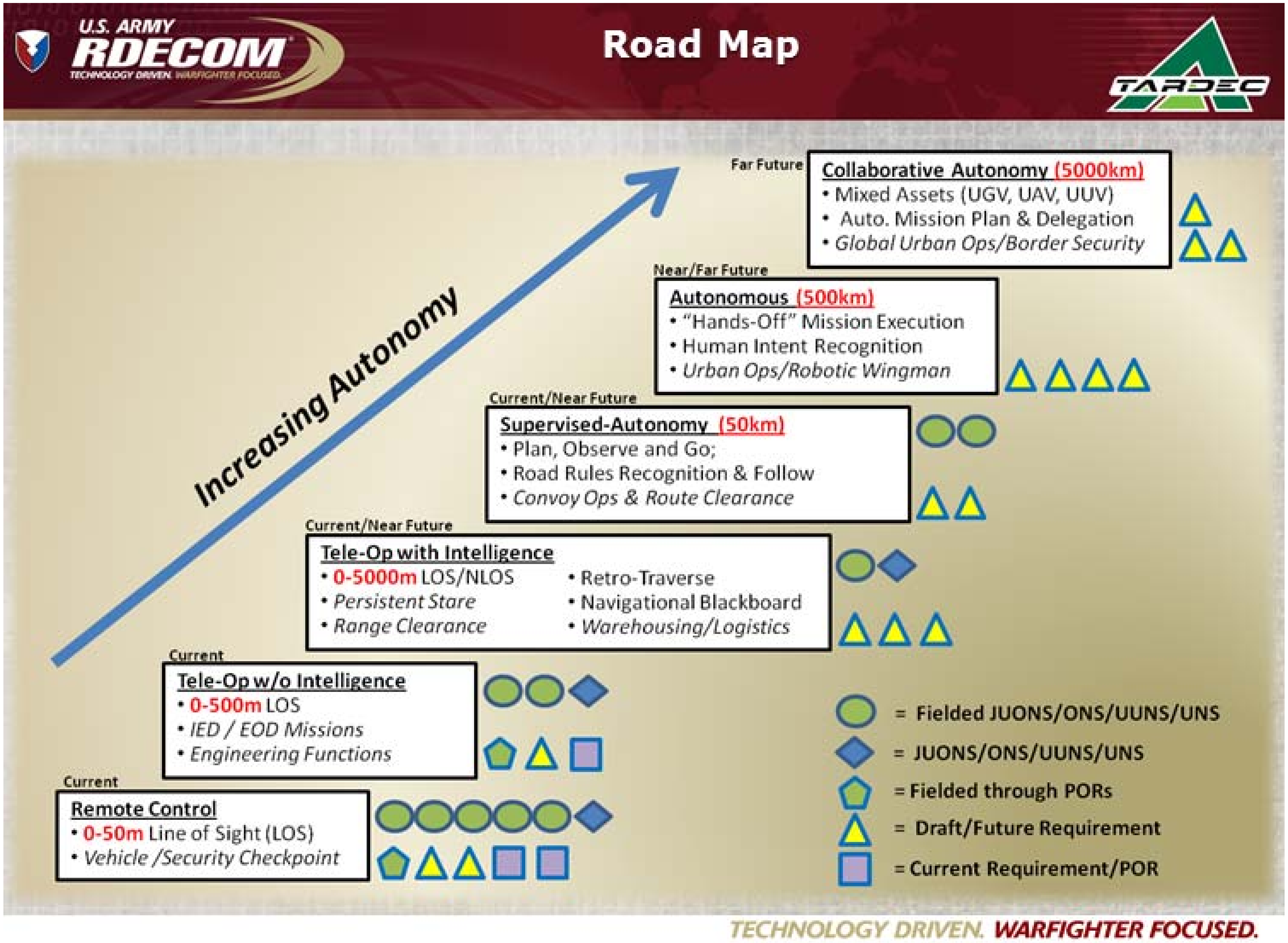
Work Zone Safety: Automated Attenuator Truck

- **Pilot Texas DOT Project**
  - o **Moving work convoys:**
    - **Linear spacing**
    - **Lateral offsets**
  - o **Static: reposition with hand signals**



TARDEC Roadmap

TARDEC is the R&D Center for the Army



On-Road and Off-road are Very Different…

GUSS (Ground Unmanned Support Surrogate)

- Reducing exposure to unsafe environments and to lethal enemy actions.
- Lighten soldier's loads by carrying supplies.
- Automate external re-supply.
- Reduce time in-between missions by not having to return to their base to retrieve and return items.

Lockheed Martin K-MAX

- **Marine Corps program**
- **Capable of delivering a full 6,000 lb of cargo at sea level and more than 4,000 lb at an altitude of 15,000 feet.**
- **First mission in Afghanistan on December 17, 2011.**
- **Still being used.**

State of the Practice (military): AMAS (LM)

- **Autonomous Mobility Appliqué System (AMAS)**
- **Portable Autonomy:**
  - **A-kit (autonomy)**
  - **B-kit (vehicle interface)**
  - **C-kit (payload)**

Source: Lockheed Martin

State of the Practice (military):

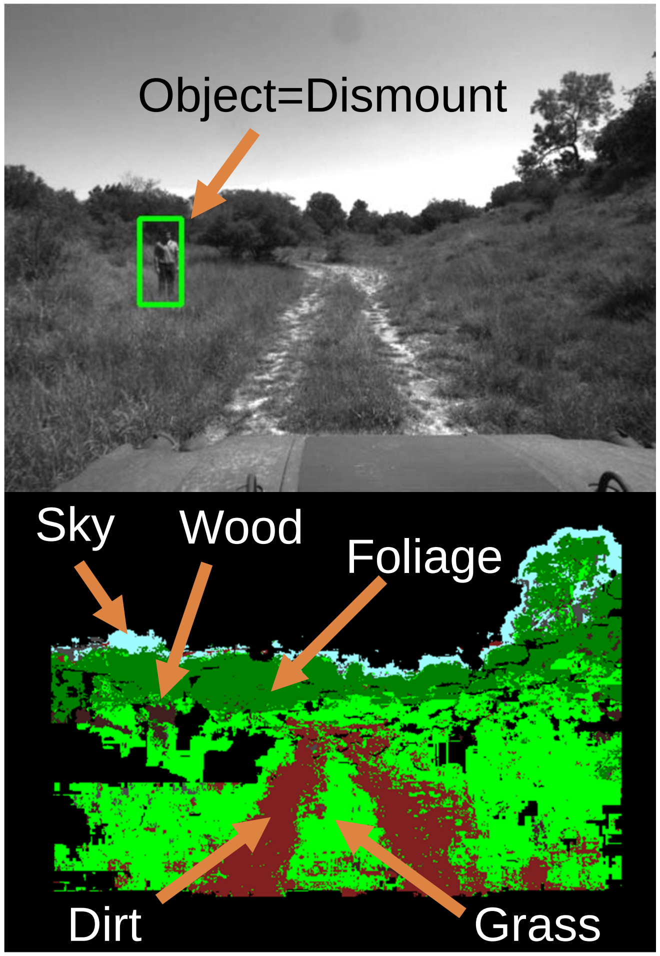
(mules and support tools)

- **Squad Mission Support System (SSMS)**
  - **Active sensor technology**
  - **Carry loads over difficult terrain**

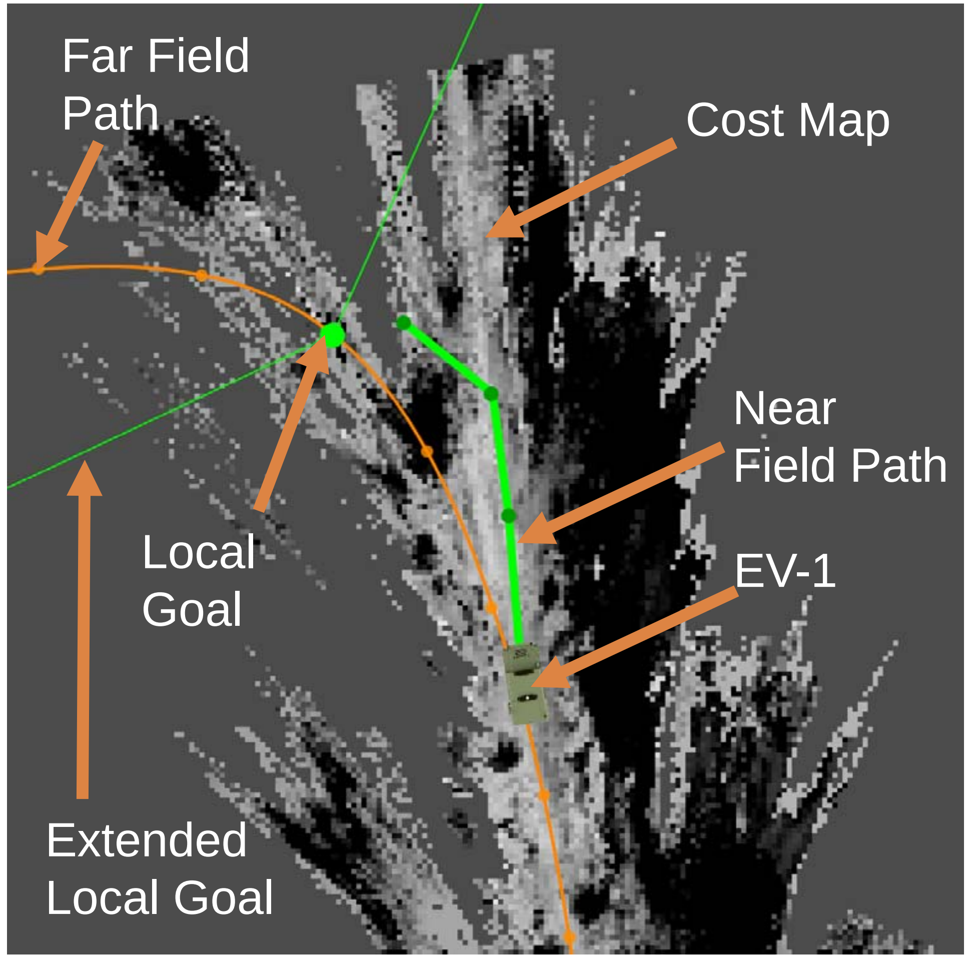
Source: Lockheed Martin

State of the Practice (military)
Oshkosh TerraMax

SUMET EO-Only Perception and Autonomy Path Planning

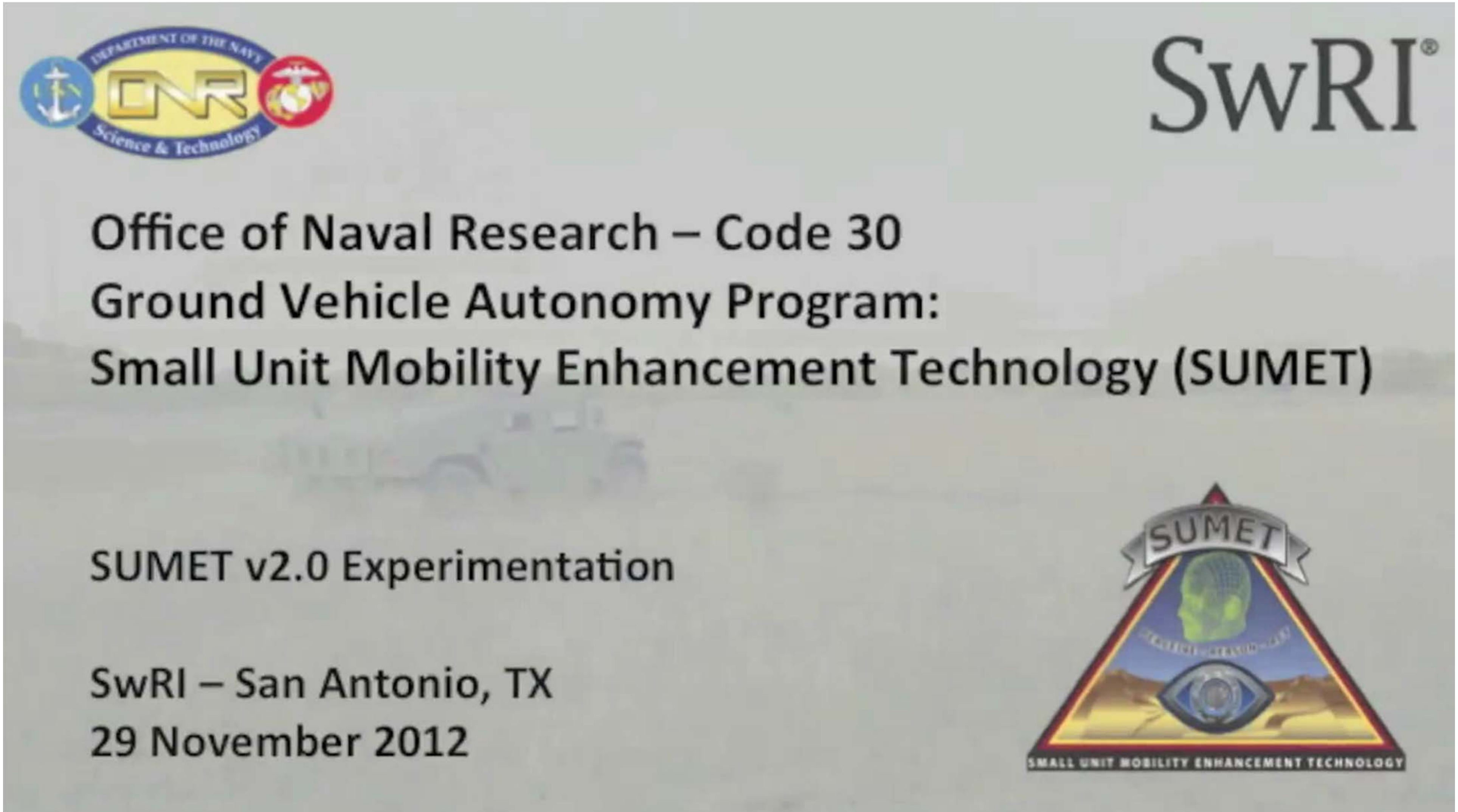


Material Classification

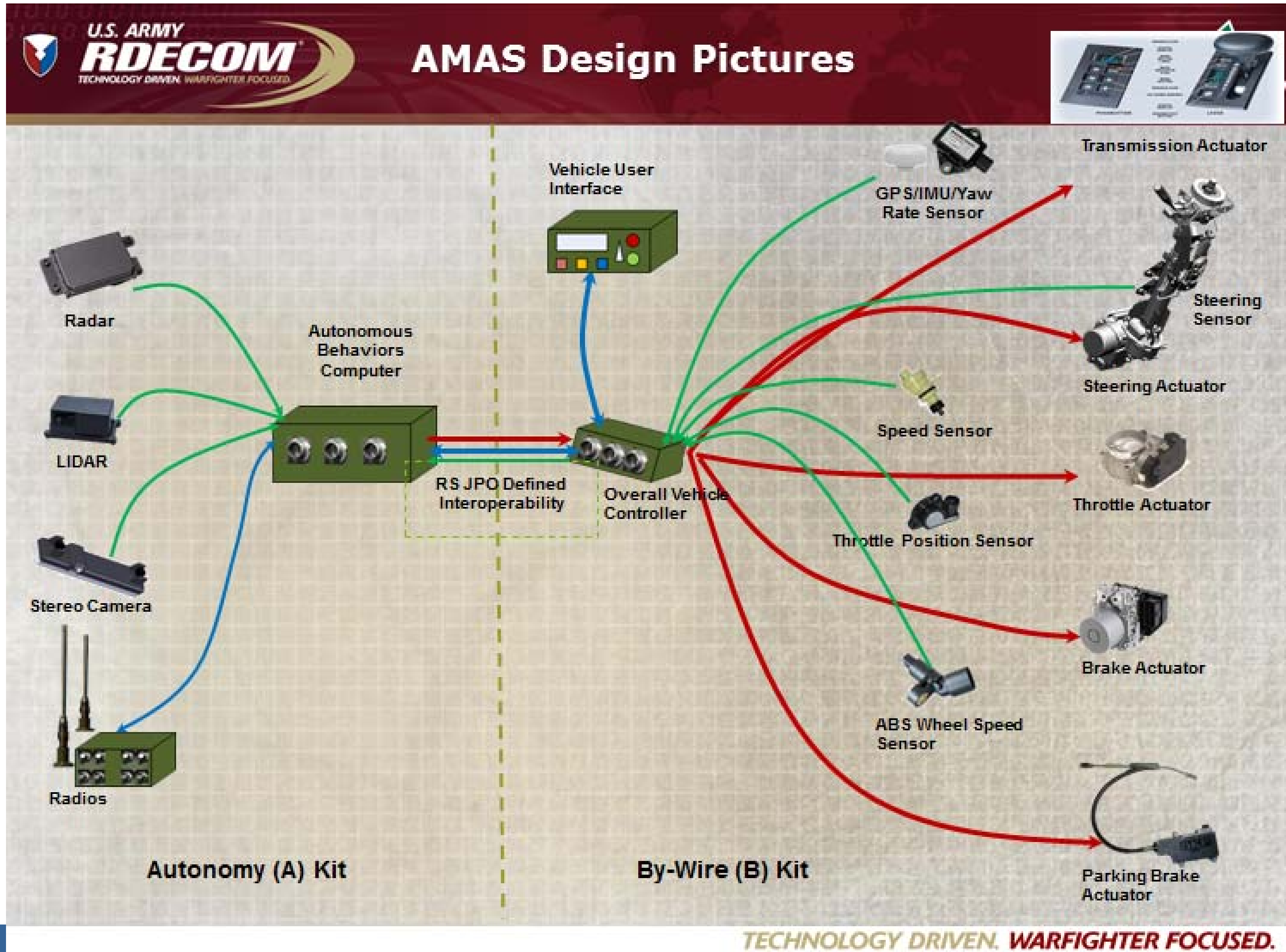


Cost Map and Path Planners

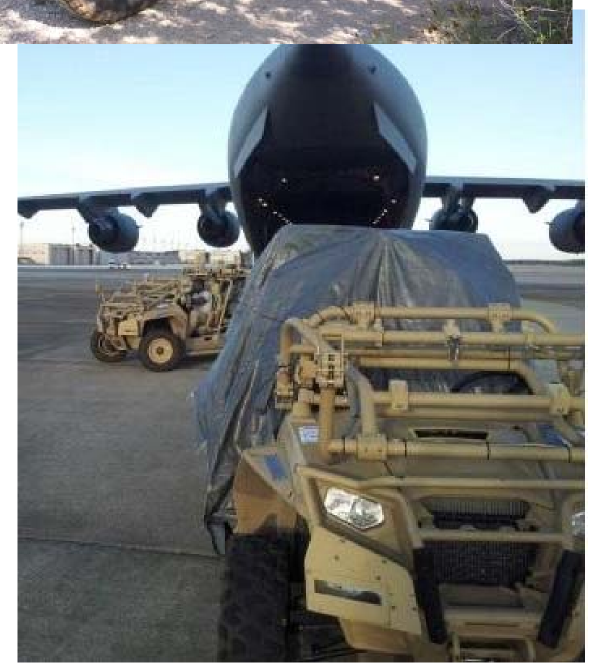
Sample Unmanned Demo Video: Marine Corps SUMET Program

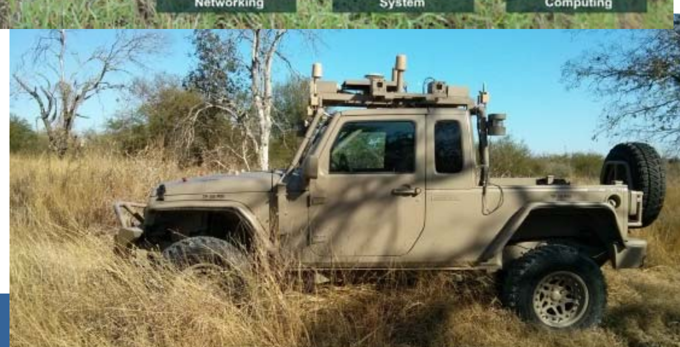


AMAS (Autonomous Mobility Applique System) Retrofitting Existing Fleet



Army: DSAT (Dismounted Solider Autonomy Tools) ATEC Tested and Deployed System





Capability Video

State of the Practice (defense): RUAG

Source: RUAG

- **Material classification**
- **Snow and ice environments**
- **“New” environment to the system**

Where will we see Autonomy First ?

- **Lots of press and widely spread articles about on-road projects….**
- **Domains other than passenger vehicles have experienced success:**
  - **Agriculture**
  - **Mining**
  - **Military**
- **Common thread in these areas include:**
  - **Constrained environments**
  - **Can accept some level of "collateral damage" (with no legal implications)**
- **However, we keep hearing "they will be here in 2017 (or 2020")….**

Automated Vehicles Forecast (AVS14)

Data courtesy of AVS14 (held in California, July 2014)

- **What do the industry professionals think (as opposed the media looking for an interesting story or a self-serving company promotion):**

- **At industry event in California in July 2014 some polling was done:**
  - **~250 responses, 80% MS+ degree**
  - **64% EE/ME/CS/HF, 24% CE**
  - **31% Univ/Research Inst, 24% Auto Ind, 17% Govt**
  - **80% US, 44% CA and MI**

- **Results were insightful….**

Automated Vehicles Forecast (AVS14)

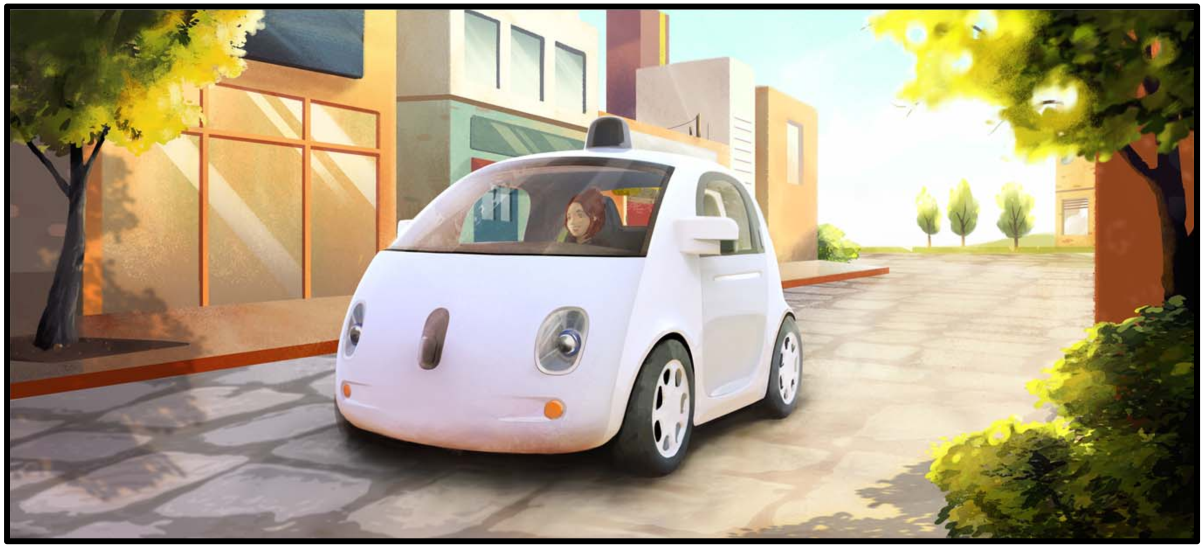
Data courtesy of AVS14 (held in California, July 2014)

- **Top 3 barriers:**
  1. **Legal**
  2. **Regulations**
  3. **Cost**
- **Equal number rated Technology highest and lowest**
- **Level of safety compared to today**
  - **56%: as-safe to 2x**
  - **36%: 10x to perfect safety**
- **73%: Society will accept some automation-caused accidents**
- **46%/54%: Level 3 practical/not practical (driver expected to respond)**
- **67%: V2V *essential* for Level 5**

Automated Vehicles Forecast (AVS14)

Data courtesy of AVS14 (held in California, July 2014)

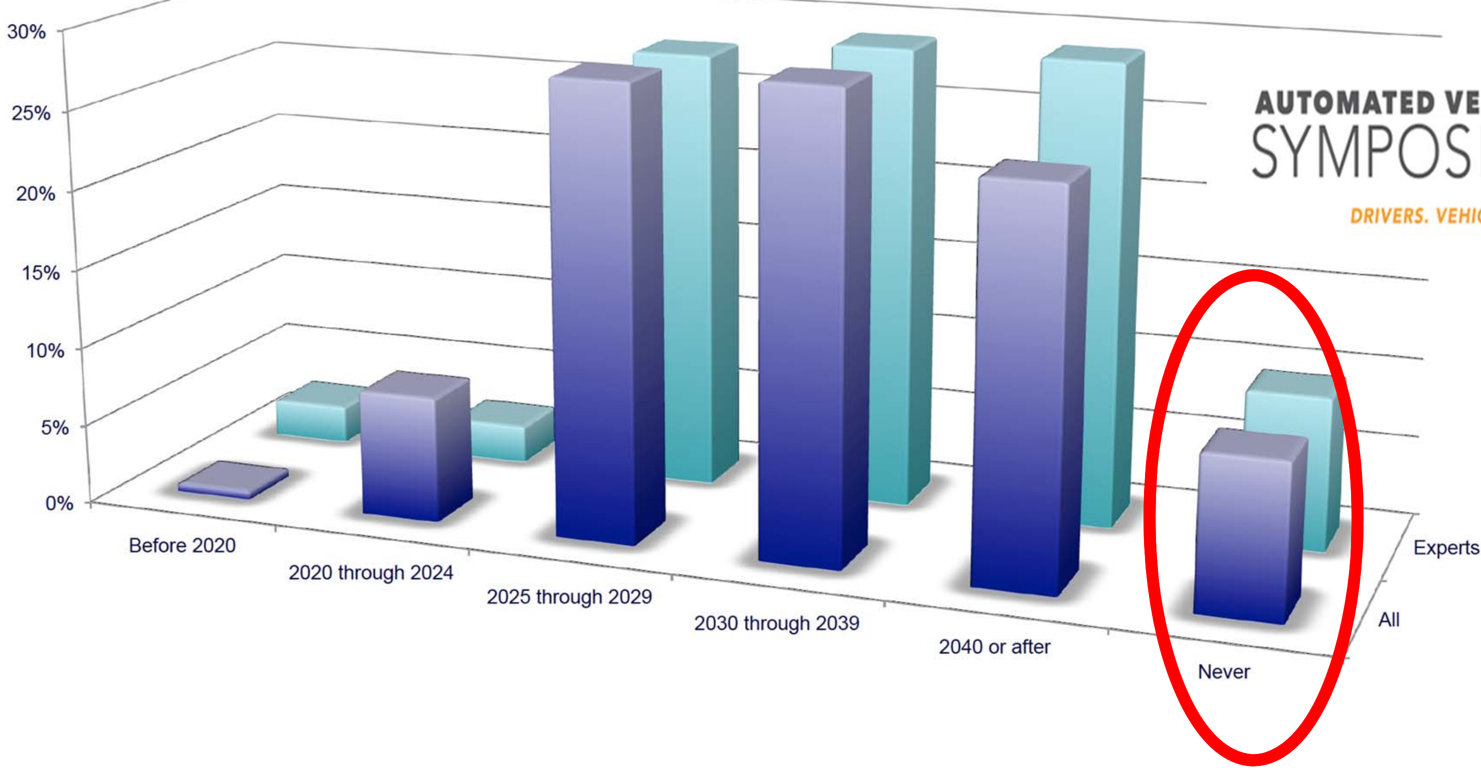
When do you expect to be able to trust a fully automated taxi to take <u>YOUR</u> elementary school-age child or grandchild to their school (with no licensed driver onboard)?



What do the Experts (collectively) Say?

Data courtesy of AVS14 (held in California, July 2014)

Q16: When do you expect to be able to trust a fully automated taxi to take your elementary-school-age child or grandchild to their school (with no licensed driver onboard)?



AUTOMATED VEHICLES SYMPOSIUM 2014

DRIVERS. VEHICLES. INFRASTRUCTURE.

Economic Driver: What Would People Pay…

- **Surveys or economists suggest (~$3,000):**

Public opinion surveys [edit]

According to a survey of 17,400 vehicle owners conducted by J.D. Power and Associates[when?], 37 percent of all survey responders initially said they would be interested in purchasing a fully autonomous car. However, that figure dropped to 20 percent once they learned the technology would cost an additional $3,000. With an additional cost of $3,000, 25% of the male vehicle buyers were willing to pay for a fully autonomous vehicle, while only 14 percent of women wanted the feature.[73] According to a 2011 online survey of 2,006 consumers in the US and the UK conducted by Accenture, 49 percent of all survey responders said they would be comfortable using a "driverless car".[74]

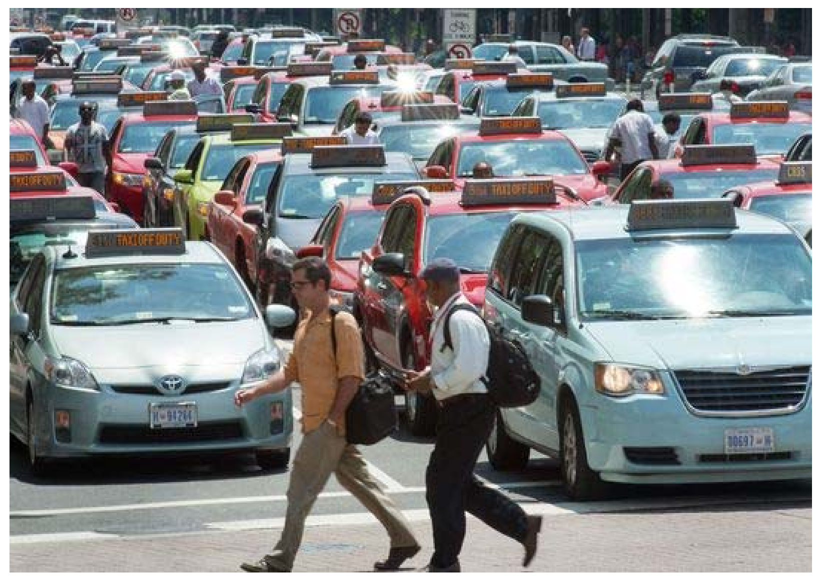
  - ***Sources:***
    - ***Economist Technology Quarterly* (2012) Look, No Hands. September 1 issue: 17-19.http://www.economist.com/node/21560989**
    - **J.D. Powers: http://www.jdpower.com/content/press-release/xOOFcYK/2013-u-s-automotive-emerging-technologies-study.htm**

- **Today's cost of hardware on 'operational vehicles':**
  - **$110K to $280K**
  - **Mass production should help lower this number but how much?**

Punchline: Perception/Behaviors are Challenging

- **"Deer in the headlights"**

- **"Realistic" driving**
  - **June 2014 in DC**
  - **Taxi "strike"**
  - **How to "nose" into traffic**



Looking out to the Horizon: What is Next?,

- **Next 3 to 20 years:**
  - **Don’t expect to see automated vehicles regularly used on public roads**
  - **Military operations can accept collateral damage**
  - **Closed operations (such as mining, agriculture) have less unpredictability:**
    - **No teenage / crazy drivers**
    - **Limited obstacles**
    - **Very well known environment (that does not change much)**
    - **Possible areas:**
      - **Ports / freight yards**
      - **Retirement communities**
  - **Potential game changed: dedicated transit or truck or “technology lanes**

- **Need “connected” to get “automated”**

- **Holy grails:**
  - **Perception (sensors) / Behaviors**
  - **Cost**
  - **“Use of technology”: generational (millennials may be more accepting)**

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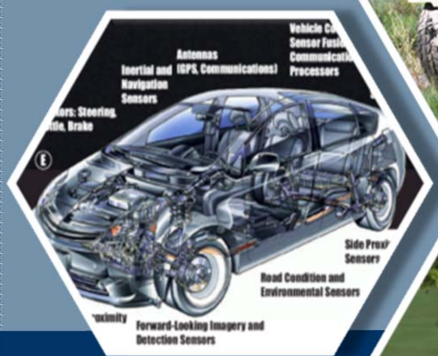

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Thank You

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