

Intelligent Vehicle Systems

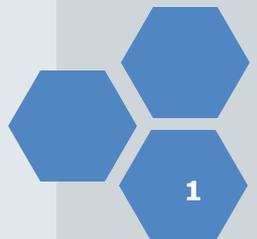
Southwest Research Institute



Autonomy Now: Developing Autonomous and Connected Vehicles

SwRI®

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Executive Director R&D
Intelligent Systems



Presentation Overview

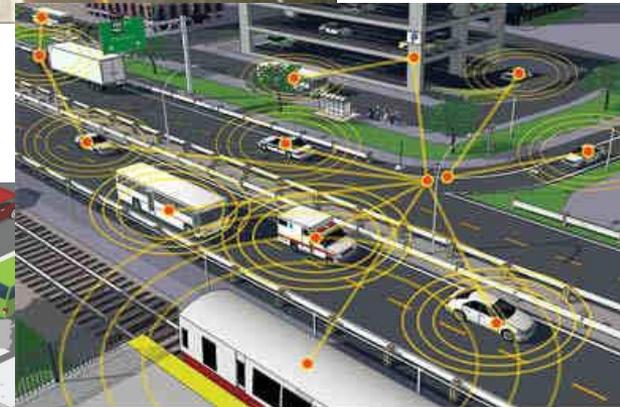
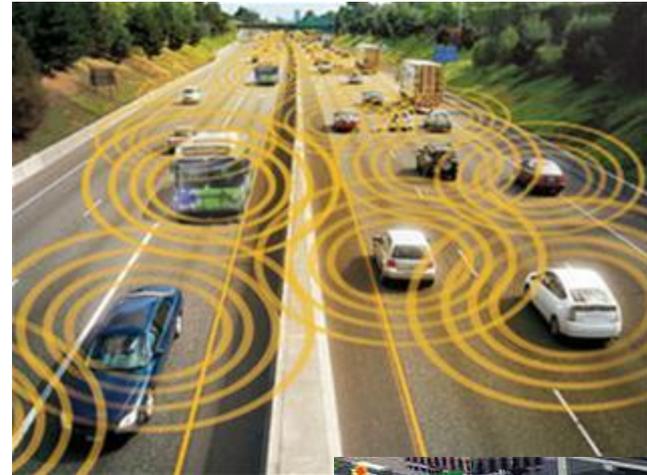
- **Connected Vehicle (CV) technology**
- **Automated Vehicles (AV)**
 - **Examples you don't often see**
 - **State of the practice**



Connected Vehicle Technology

(USDOT Led Nationwide Initiative)

- **V2x:**
 - **Vehicle-to-vehicle**
 - **Vehicle-to-Infrastructure**
 - **Infrastructure-to-Vehicle**
 - **Vehicle-to-_____ (bike, ped, etc.)**



Connected Vehicle Hardware

Illustrative Only – many configurations possible

Roadside Unit



User Interface

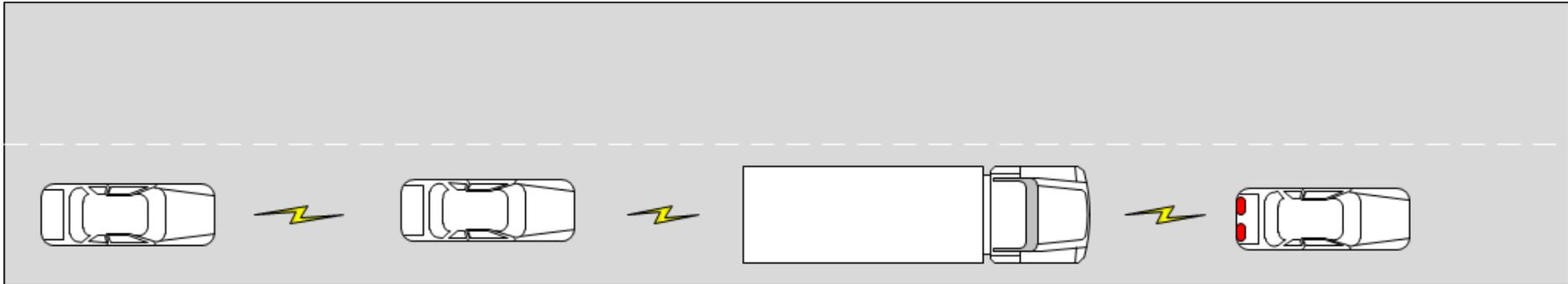


On Board Unit (OBE)



Use Cases – Several of Many

- **Emergency Braking**

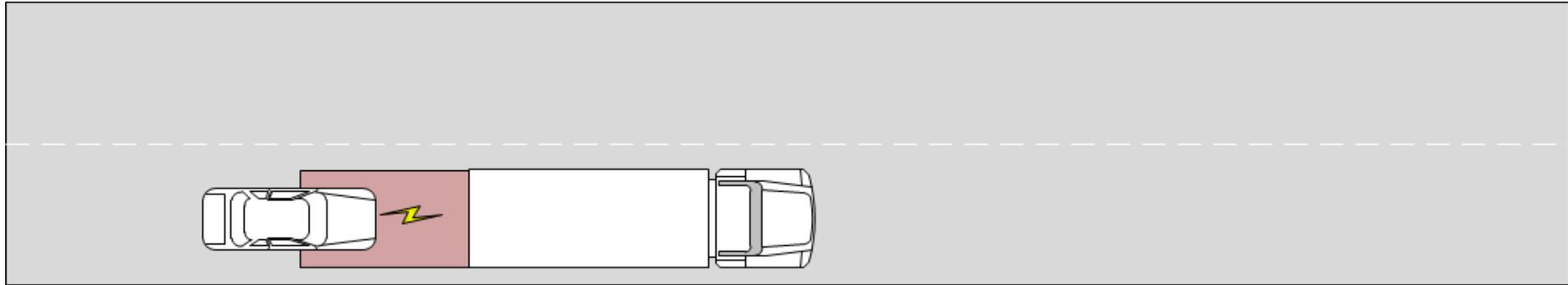


- **Blind Spot Warning**

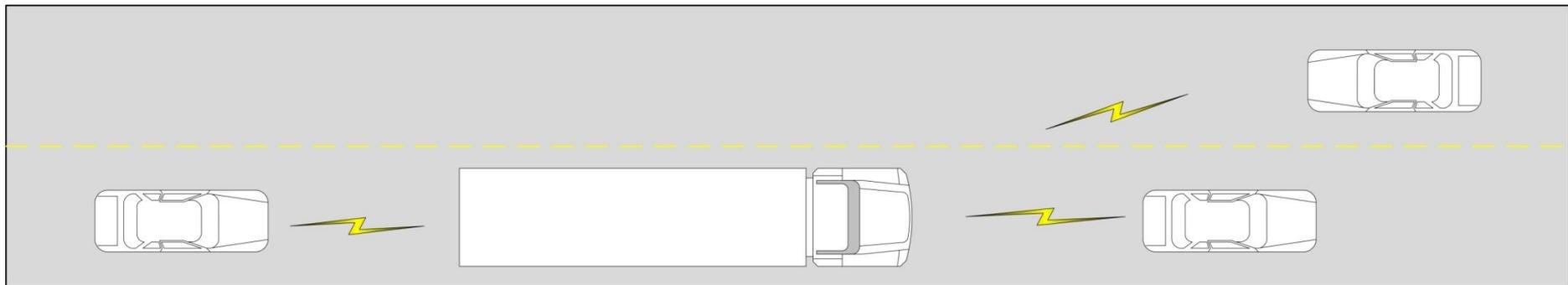


Use Cases – Several of Many

- **Following Distance Warning**

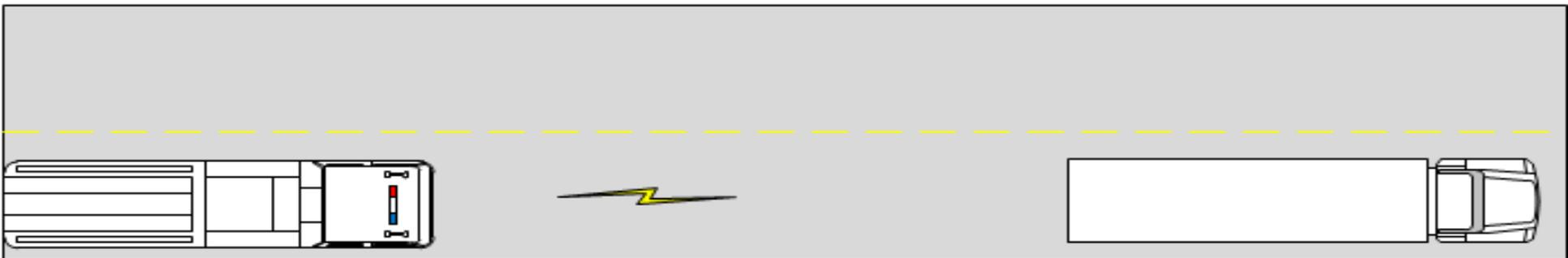
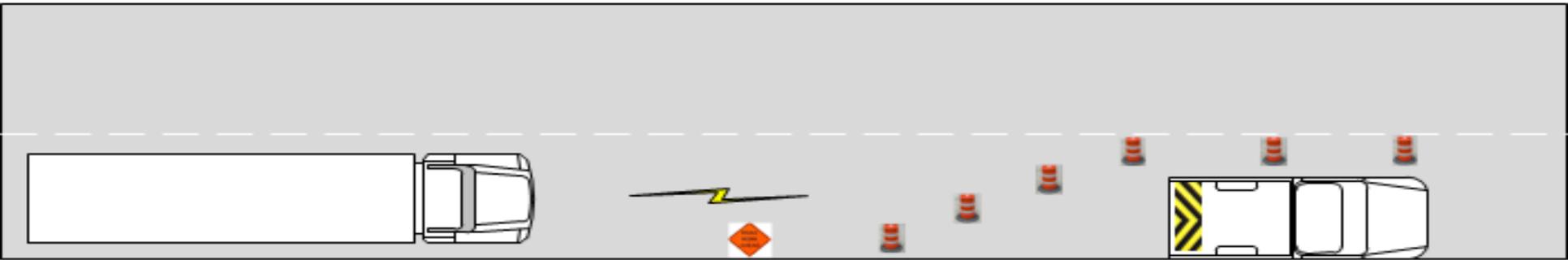
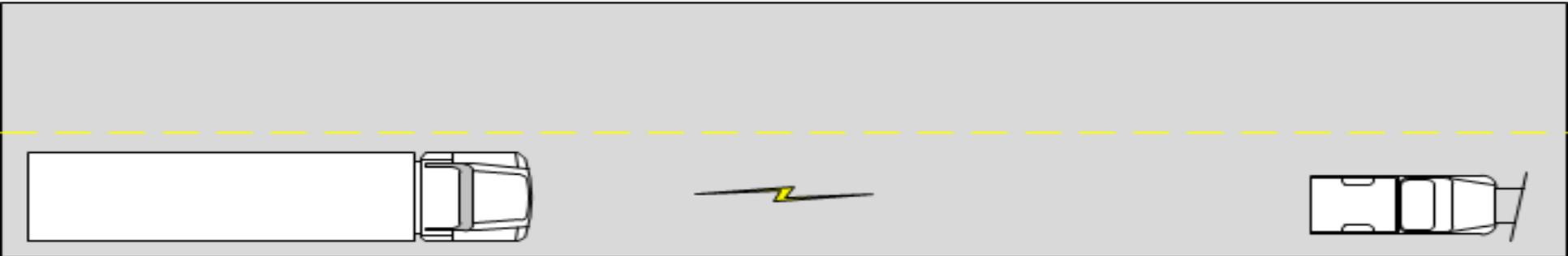


- **Unsafe to Pass:**



Use Cases – Several of Many

- **Emergency Vehicle Alert**



Cooperative Sensor Sharing - example



Cooperative Sensor Sharing System - Patent 7,994,902

Initial SwRI (US) - INRIA (France) Research Conducted in Versailles, France

Warning -> Mitigation -> Avoidance Maneuvers

- **Active Safety Systems that use “connected automation” technology can go beyond Emergency Braking.**
- **Just as CV technology can extend “range” for warning systems, it can do the same for true avoidance maneuvers – enabling an Automated Vehicle to “react” much further in advance of a dangerous scenario.**



Warning = Alert

Mitigation = Impact Reduction

Avoidance = Crash Prevention

Future of Connected Vehicle....

- **Technology has been “researched” and is ready to deploy**
 - **Security credentials and who maintains is a outstanding issue**
- **V2V is “easier” because it does not require infrastructure – clear safety benefits (justifies the cost):**
 - **GM announced that Cadillac's would have the technology in 2017**
 - **Other manufactures making announcements**
- **V2I or I2V is “challenging” because of the infrastructure (and continuing maintenance) costs**
 - **Industry is exploring deployment options – private sector funding will be critical**
- **More and more “real world” demonstrations occurring**

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**

What Makes a Vehicle “Automated” ?

- **What is called an automated / autonomous / unmanned differs by who is discussing and making claims**
 - **Driver able to switch into and out of ‘automated’ mode**
 - **ADAS equipped? (Advanced Driver Assistance Systems)**
 - **No driver at all?**
 - **Some blend of the above...**
- **Examples to discuss:**
 - **Google Vehicle**
 - **PEVs (Personal Electrical Vehicles)**
 - **Agriculture / mining**
 - **Military space (major programs in last 5 years):**
 - **AMAS - Army**
 - **GUSS - Marine Corps / Navy**
 - **SMSS – Army**
 - **SUMET – Marine Corps / Navy**
 - **DSAT – Army**

NHTSA / SAE Driving Levels

Source: SAE

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

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 <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver only	0
1	Driver Assistance	the <i>driving mode</i> -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 <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	Partial Automation	the <i>driving mode</i> -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 <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes	Partially automated	2
Automated driving system ("system") monitors the driving environment								
3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	System	Human driver	Some driving modes	Highly automated	3
4	High Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	System	Some driving modes	Fully automated	3/4
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes		

Semi-Autonomous Driving – available TODAY

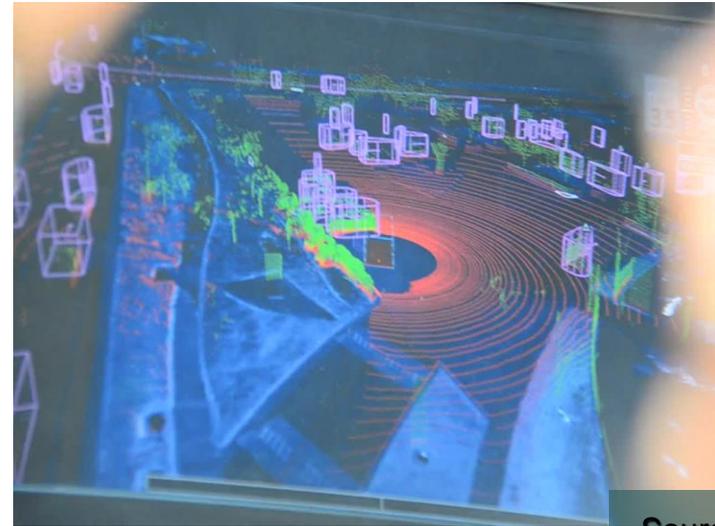
Who is Developing Autonomous Vehicle Capabilities

(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 (VTTI)
 - California PATH, Univ of Parma
 - 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)

State of the Practice (commercial): Google

- **Status:**
 - **Well funded**
 - **Previously only freeway, adding arterial capability**
 - **~1M miles driven**



Source: Google



Source: Google

- **Limitations**
 - **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

- 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



Source: Google

Other companies are developing also – names are proprietary

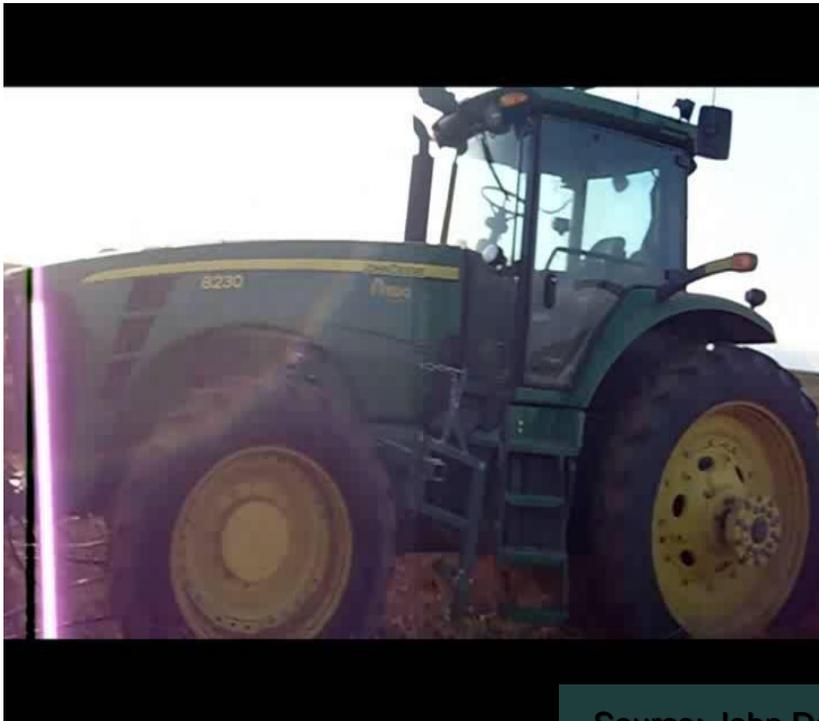


Switch the Focus

- **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”)....**

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

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



Source: John Deere

Source: Komatsu



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

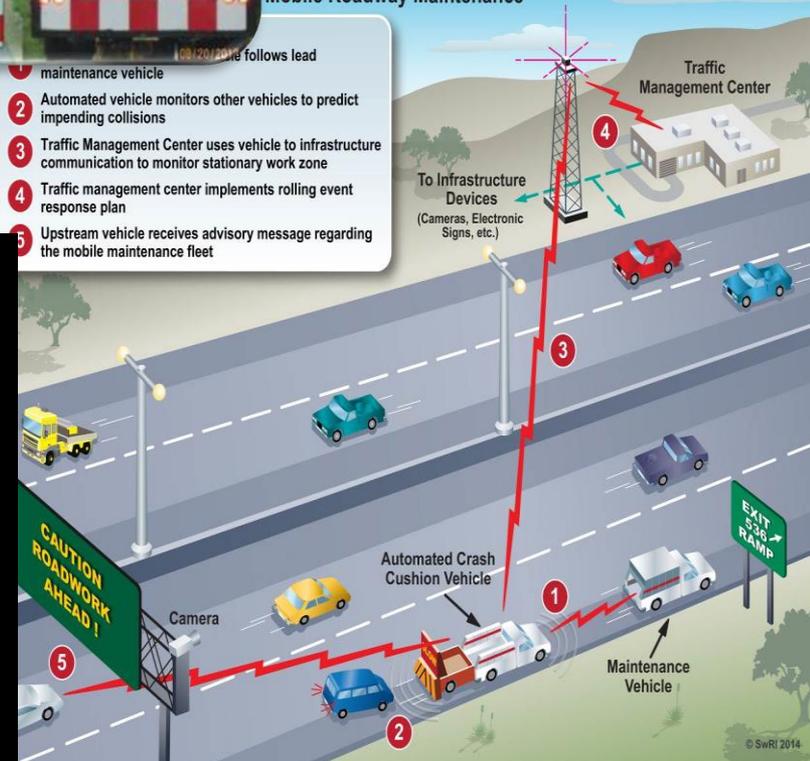
Work Zone Safety: Automated Attenuator Truck

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



Enhancing Work Zone Safety Mobile Roadway Maintenance

- 1 maintenance vehicle follows lead
- 2 Automated vehicle monitors other vehicles to predict impending collisions
- 3 Traffic Management Center uses vehicle to infrastructure communication to monitor stationary work zone
- 4 Traffic management center implements rolling event response plan
- 5 Upstream vehicle receives advisory message regarding the mobile maintenance fleet

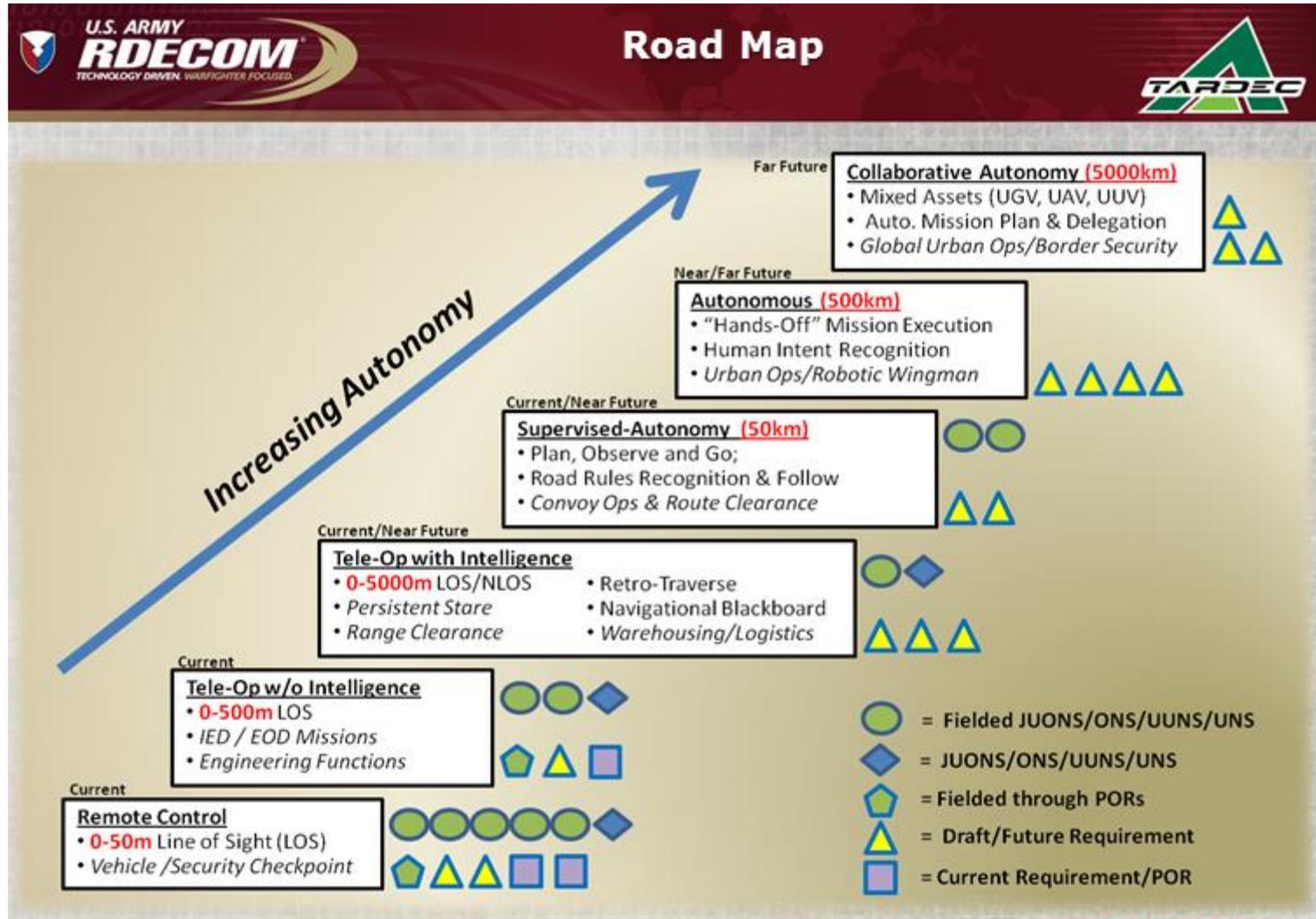


Automated Attenuator Truck

Integrating Connected Vehicle (CV) & Automated Vehicle (AV) Technology

TARDEC Roadmap

TARDEC is the R&D Center for the Army



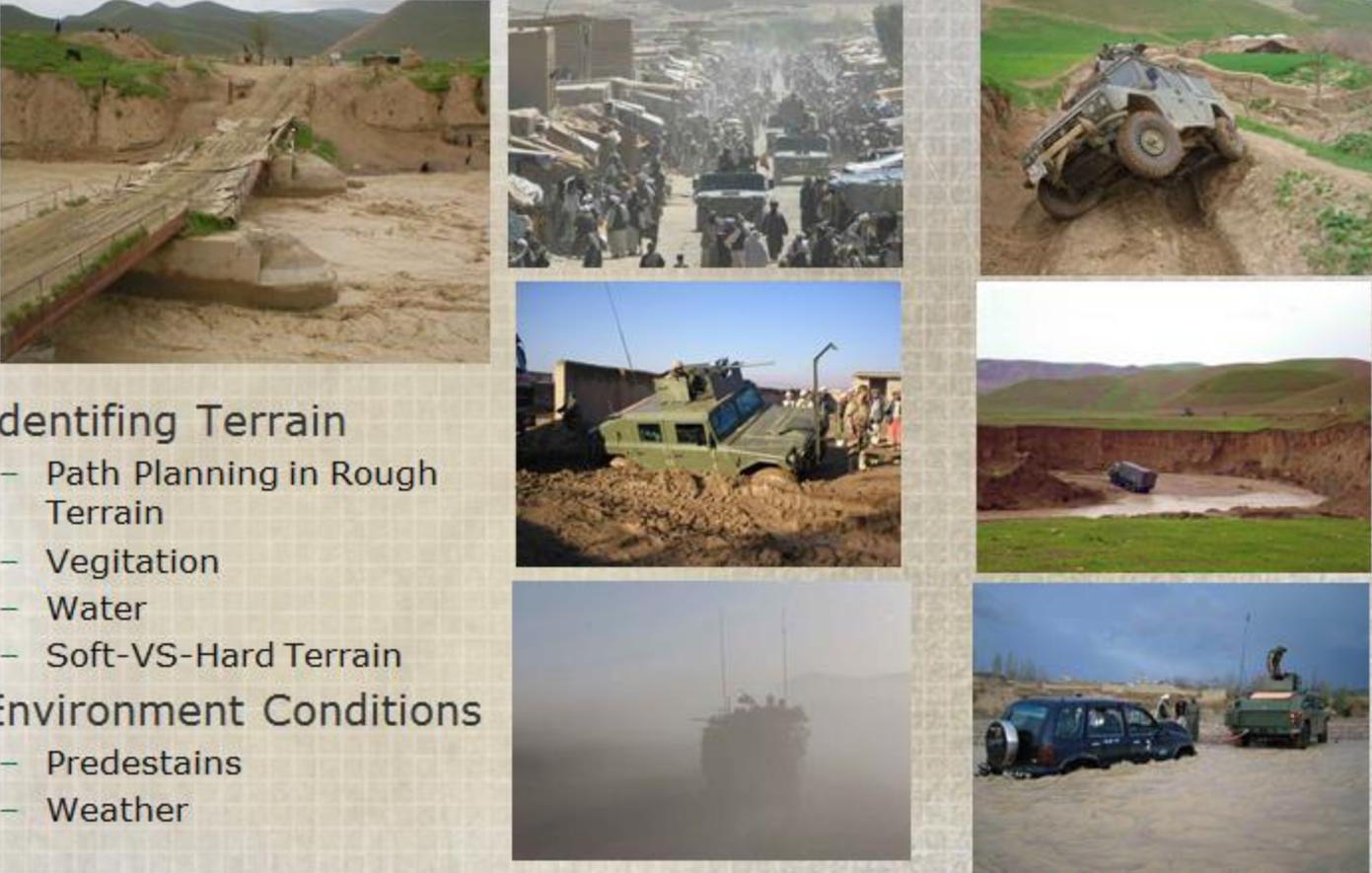
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

On-Road and Off-road are Very Different...

U.S. ARMY RDECOM
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Challenging Terrain and Environment Conditions

TARDEC



- Identifying Terrain
 - Path Planning in Rough Terrain
 - Vegetation
 - Water
 - Soft-VS-Hard Terrain
- Environment Conditions
 - Predestains
 - Weather

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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.**
- **Deployment ended summer 2014**



State of the Practice (military):

(mules and support tools)

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



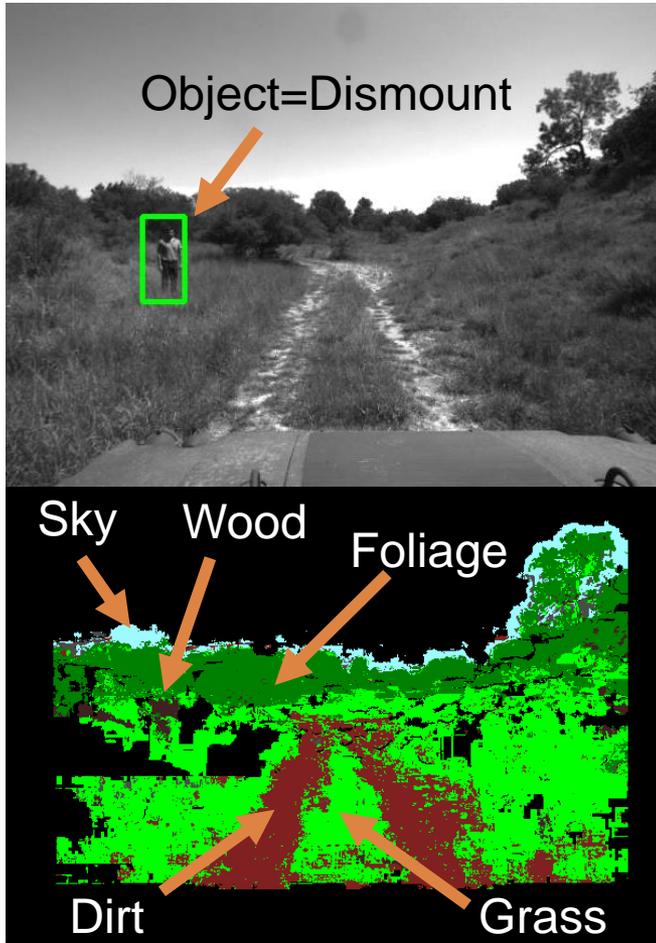
Source: Lockheed Martin

State of the Practice (military) Oshkosh TerraMax

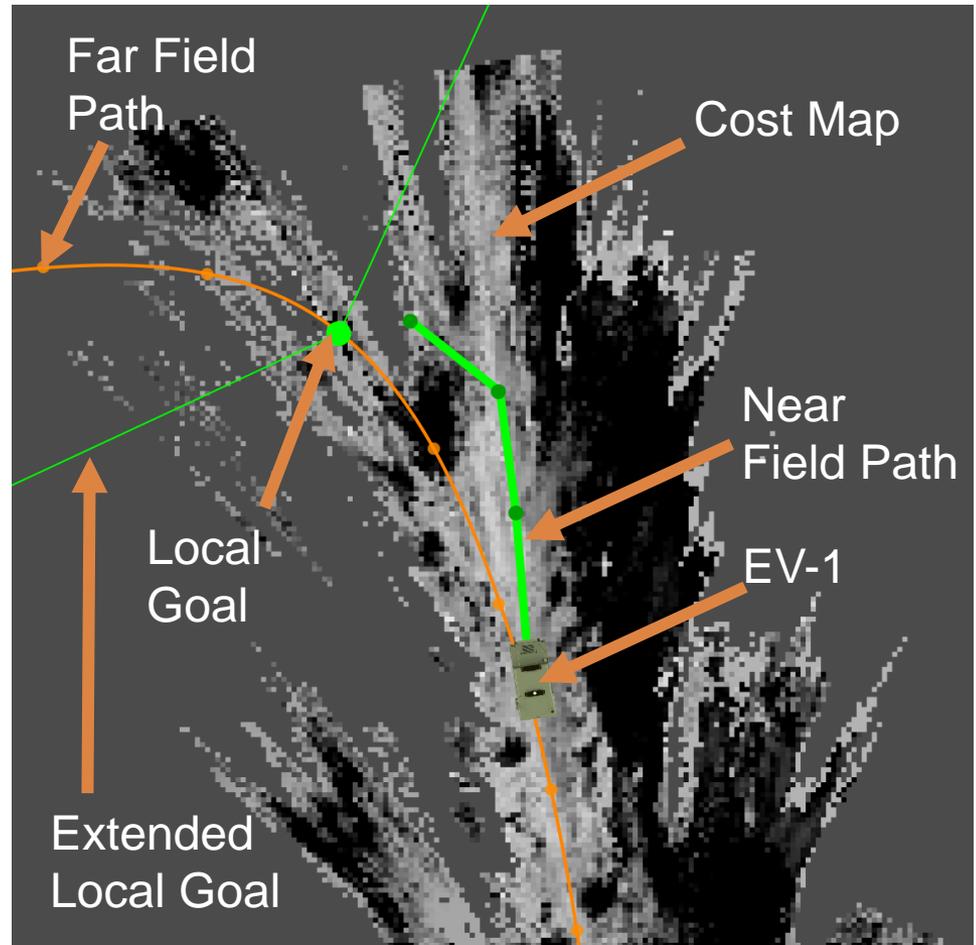
Source: Oshkosh

The logo for TerraMax, featuring the word "TERRAMAX" in a bold, black, serif font. The letters are closely spaced, and a small trademark symbol (TM) is located at the end of the word.

SUMET EO-Only Perception and Autonomy Path Planning



Material Classification



Cost Map and Path Planners

Sample Unmanned Demo Video: Marine Corps SUMET Program

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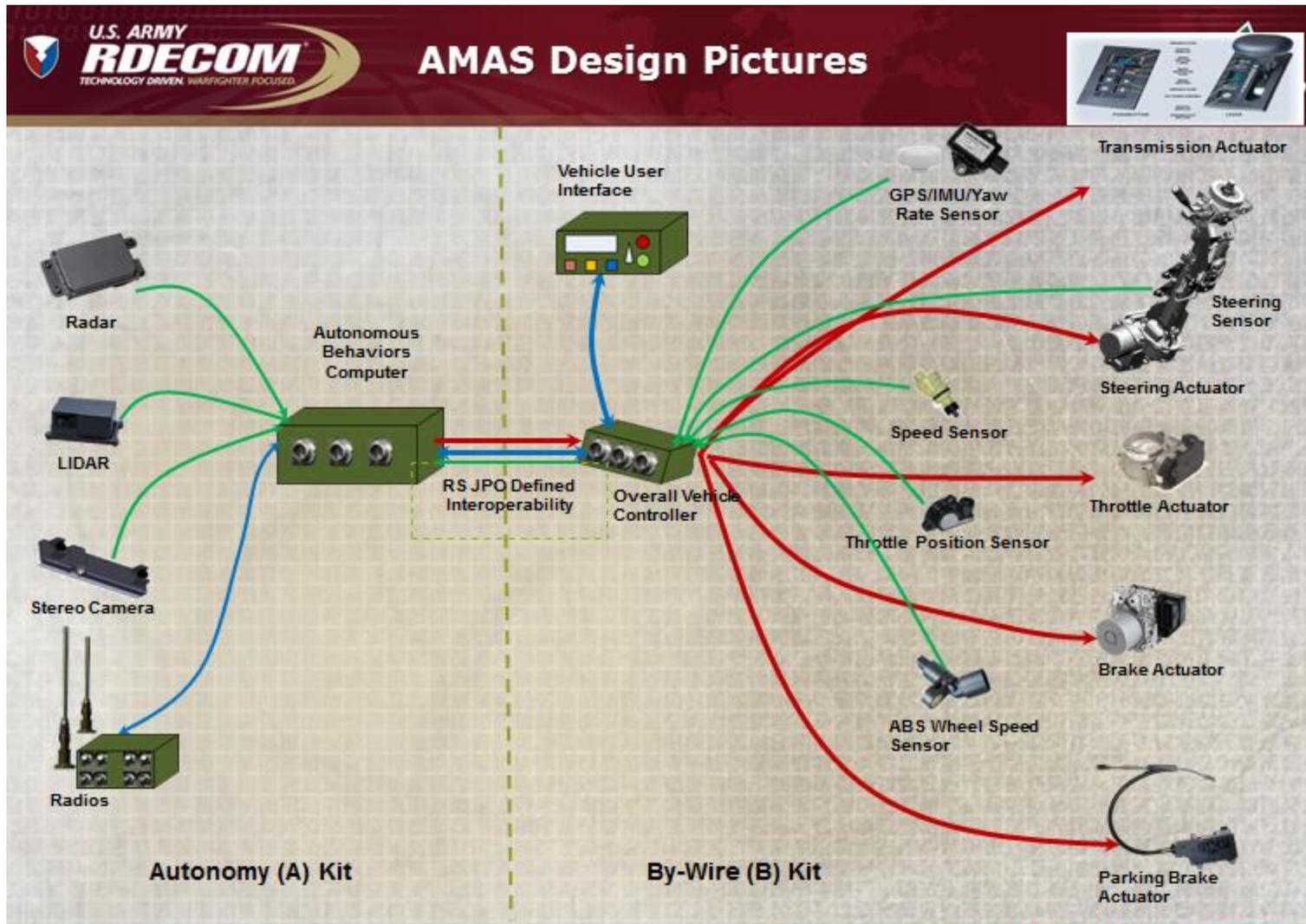
Office of Naval Research – Code 30
Ground Vehicle Autonomy Program:
Small Unit Mobility Enhancement Technology (SUMET)

SUMET v2.0 Experimentation

SwRI – San Antonio, TX
29 November 2012



AMAS (Autonomous Mobility Applique System) Retrofitting Existing Fleet



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

CAD



Capabilities Advancement Demonstration

Source: Lockheed Martin

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



Capability Video



Dismounted Soldier Autonomy Tools (DSAT)

U.S. Army TARDEC
Ground Vehicle Robotics

Operational Mode Experiment
July 2013



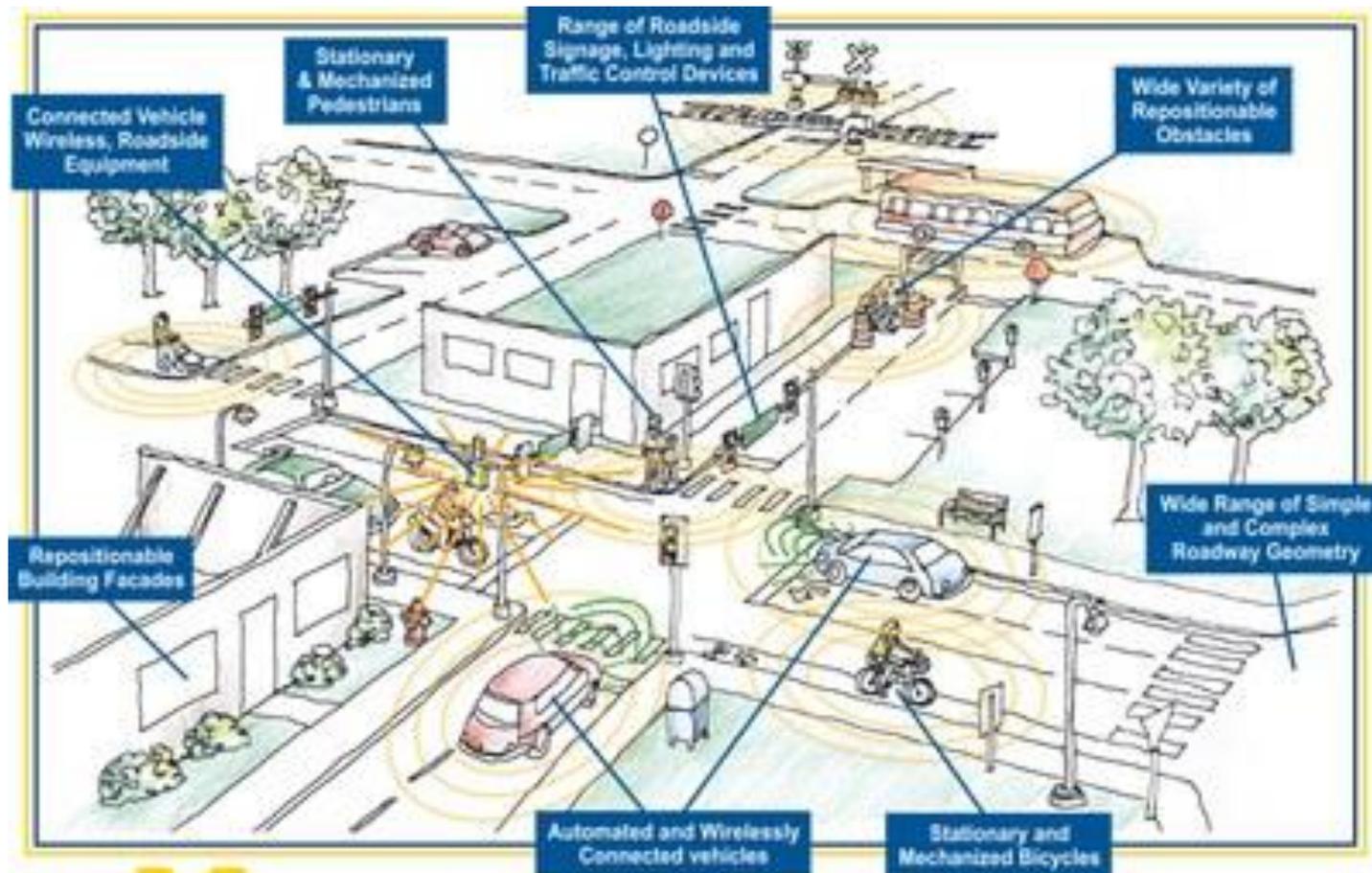
State of the Practice (defense): RUAG

Source: RUAG

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



How to Test AV Technology: UMTRI: Mobility Transformation Facility



Mobility Transformation Facility

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)

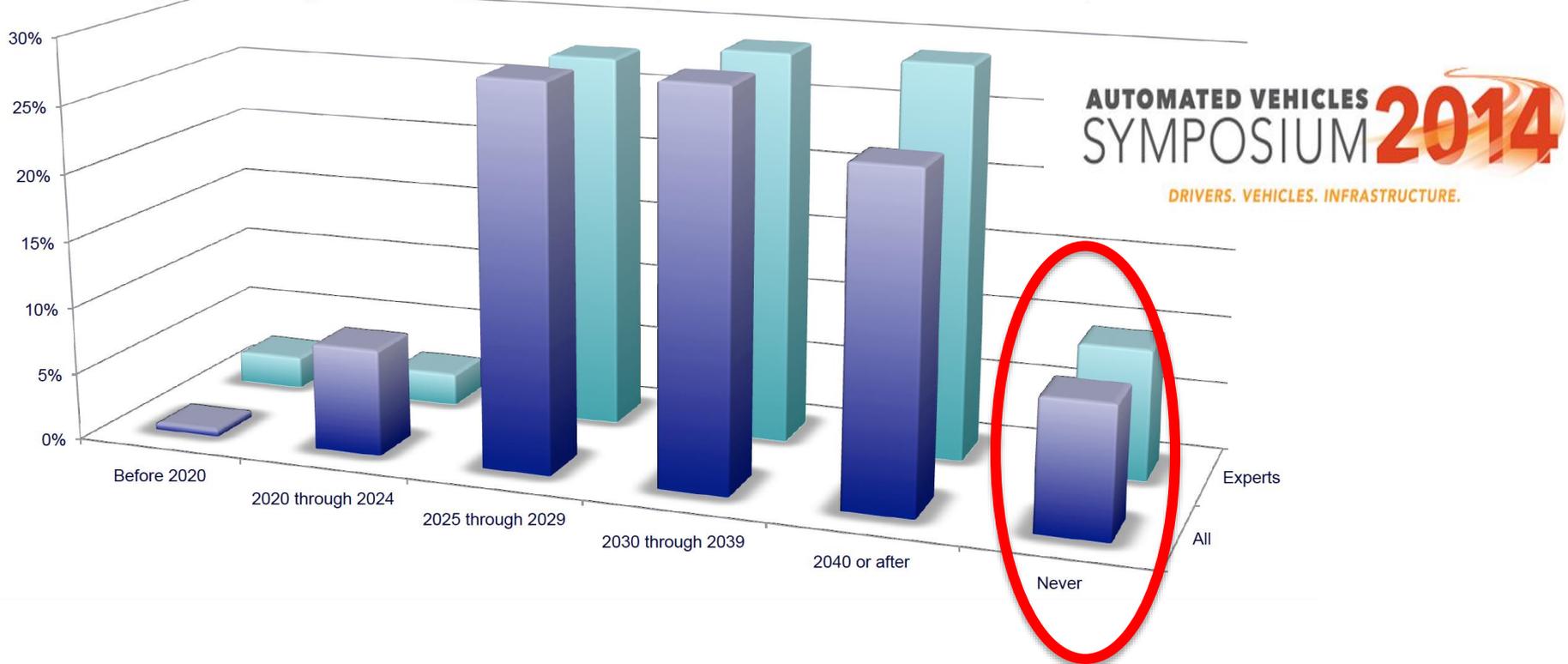
When do you expect to be able to trust a fully automated taxi to take YOUR elementary school-age child or grandchild to their school (with no licensed driver onboard)?



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)?



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 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)**
 - **Cost**
 - **“Use of technology”:** generational (millennials may be more accepting)

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Thank You

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