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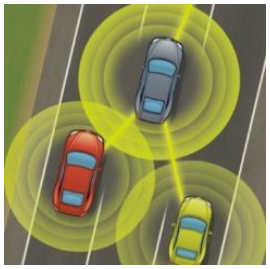

Self-Driving and Connected Vehicles of Tomorrow (and Today)

Richard Wallace, Director, Transportation Systems Analysis
Center for Automotive Research
rwallace@cargroup.org

Federal Reserve Bank of Chicago Detroit Branch
22nd Annual Automotive Outlook Symposium
May 29, 2015

The Center for Automotive Research

- Was founded in the late 1970s, as part of the University of Michigan, and became a stand-alone nonprofit corporation in 2003
- Conducts leading-edge **Research** that impacts the future of the global automotive industry
- Hosts **Events and Conferences** that engage industry leaders in the discussion of critical topics
- CAR's **Affiliates** — automotive manufacturers and suppliers benefit from advance access to research results and exclusive networking

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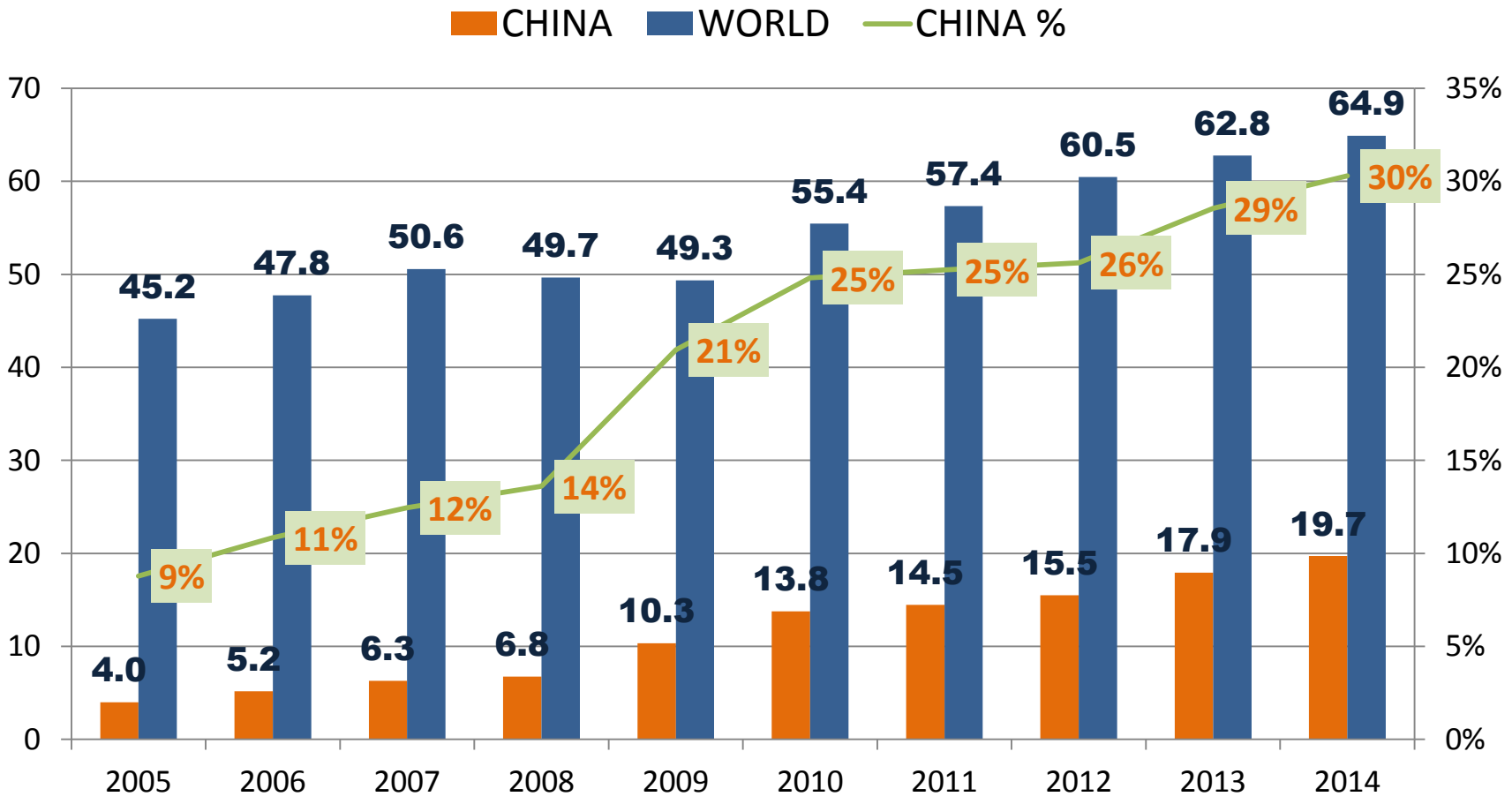
Vehicles Evolving Quickly along Several Dimensions

- Growth in vehicle communications and connectivity
- Increase in electronic content
- Proliferation of sensor-based safety systems
- Vast potential for aftermarket products
- Electrification of the powertrain
- Changing fuel economy standards

- In our white paper *Self-Driving Cars: The Next Revolution*, CAR and KPMG proposed that vehicle communication and sensor-based safety technologies, rooted in electronics and software, are converging to enable vehicles that drive themselves, with enormous implications.
  - http://www.cargroup.org/?module=Publications&event=View&pubID=87

Global Light Vehicle Sales Also Evolving

Due to the shift in production and sales volumes, global manufacturers will increasingly locate R&D activities in emerging markets to address local market requirements – growing markets are creating a "gravitational pull."



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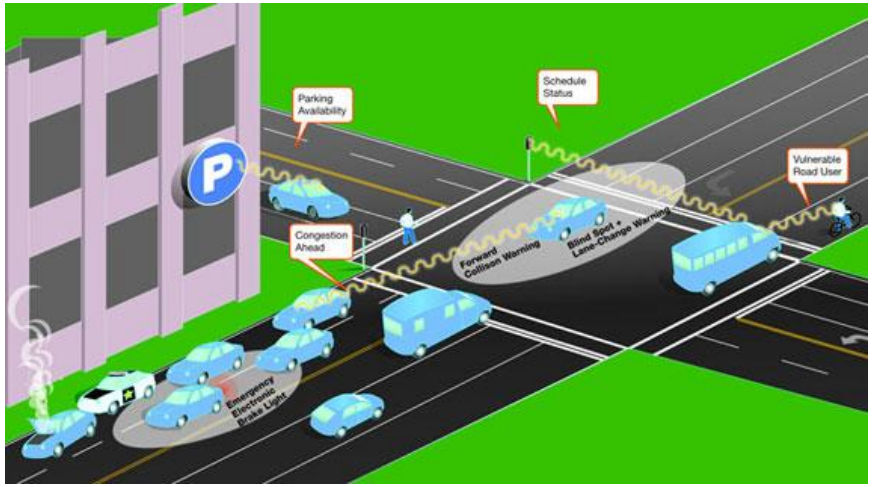
Connected Vehicles Defined

- Connected vehicles use any of a number of different wireless communication technologies to communicate with:
  - Each other
  - Roadside infrastructure
  - The “Cloud”
- Goals for connected vehicles are to enhance
  - Vehicle and roadway safety
  - Mobility
  - Environment (e.g., reduced fuel consumption)
  - Personal convenience



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Example Connected Vehicle Applications

Safety
Electronic Brake Lights
Traffic Signal Violation Warning
Stop Sign Violation Warning
Curve Speed Warning
Display Local Signage
Electronic Payment
Tolling
Parking
Automotive
Vehicle Diagnostics
Software Updates

Mobility
Traveler information
Weather Information
Navigation
Ramp Metering
Signal Timing Optimization
Corridor Management
Infrastructure Management
Weather Information
Winter Maintenance
Pothole Detection
Automated Mapping

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Existing Vehicle Connectivity Services in China

Changing consumer preferences will be one of the most important trends in the next 10 years, including demand for connectivity (telematics, navigation, and infotainment systems) and eventually automated driving

国外车企： (Foreign)

通用OnStar
丰田G-BOOK
福特Sync
宝马iDrive
日产CARWINGS
别克intellilink
凯迪拉克CUE系统
雪佛兰MyLink
奔驰COMAND
奥迪MMI
沃尔沃SENSUS
现代Blue Link

国内车企： (Domestic)

上汽inkaNet、iVoKa
一汽D-Partner
长安In Call
观致QorosQloud
比亚迪i系统
吉利G-Netlink
奇瑞Telematics
纳智捷Think+
华泰TIVI

Source: SOHU Auto, 2014

DARPA Urban Challenge (2007)

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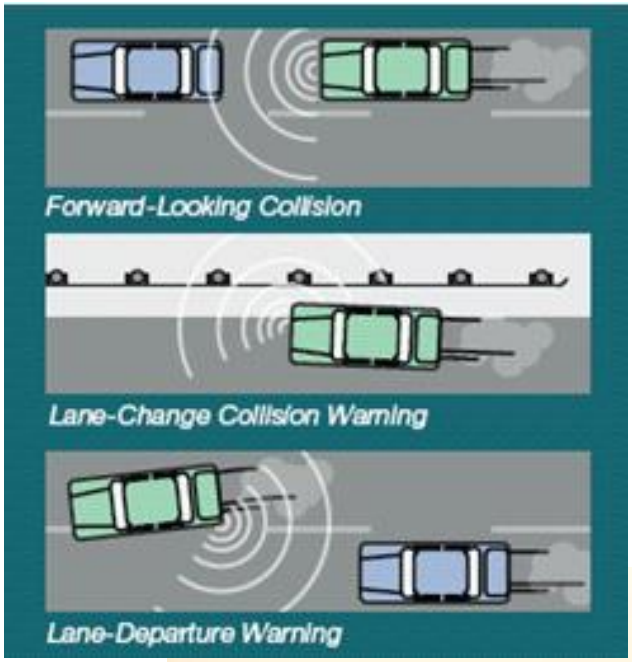
Available Today



Lane Departure Warning Systems Go Mainstream: $14.3 Billion Market by 2016 according to ABI Research

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And Coming Soon

Audi A7 Self-Driving Concept Car, "Jack"—drove itself >550 miles from S.F. to CES in January 2015

BMW Automatic Valet

Mercedes F015 Concept Car

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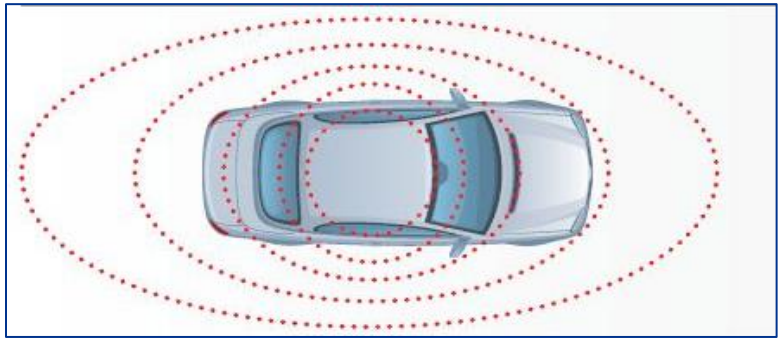
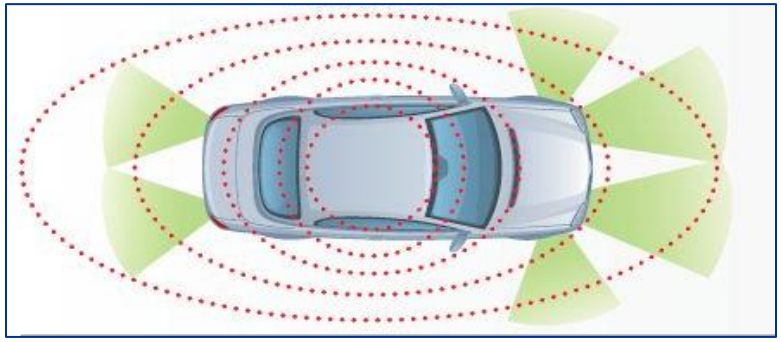
Convergence of Connected and Automated Vehicle Technology





Sensor-based Solution Only

- Cannot sufficiently mimic human senses
- Not cost-effective for mass market adoption
- Lack of adequate 360º mapping of environment in urban grids

Connected Vehicle Solution Only

- Dedicated Short Range Communication (DSRC) does not currently work with pedestrians, bicyclists, etc.
- DSRC-based Vehicle to Infrastructure (V2I) might require significant infrastructure investment
- Vehicle to Infrastructure (V2V) requires high market penetration

Converged Solution

- Convergence will facilitate adequate mimicking of human senses
- Convergence will reduce need for an expensive mix of sensors and reduce the need for blanket V2I investment
- Convergence provides functional redundancy to ensure that the technology will work 100 percent of the time

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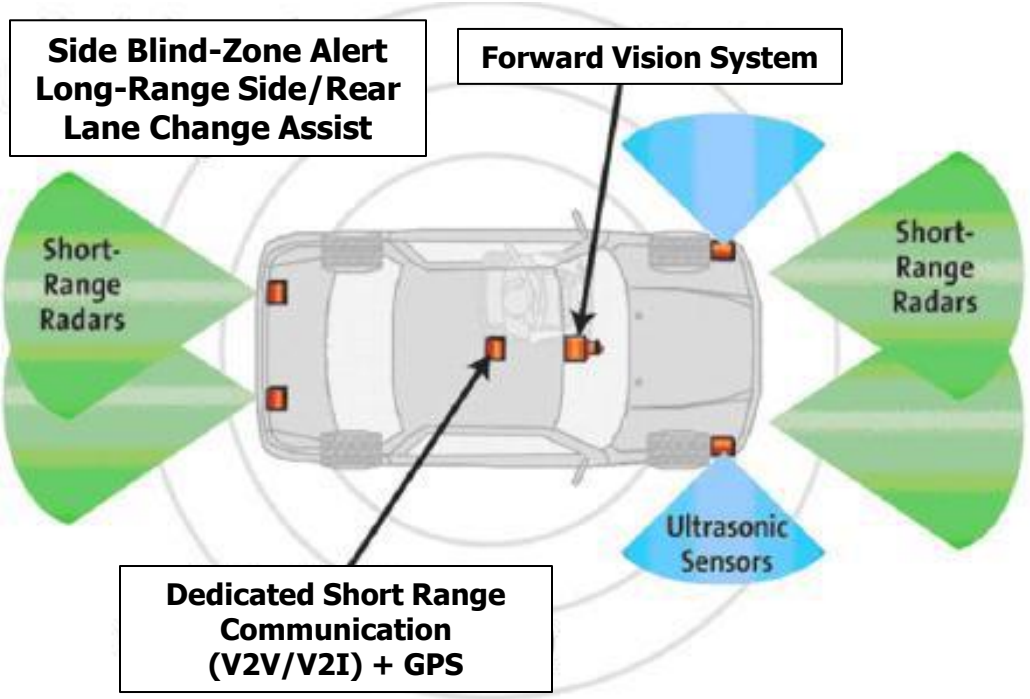
Connected and Automated



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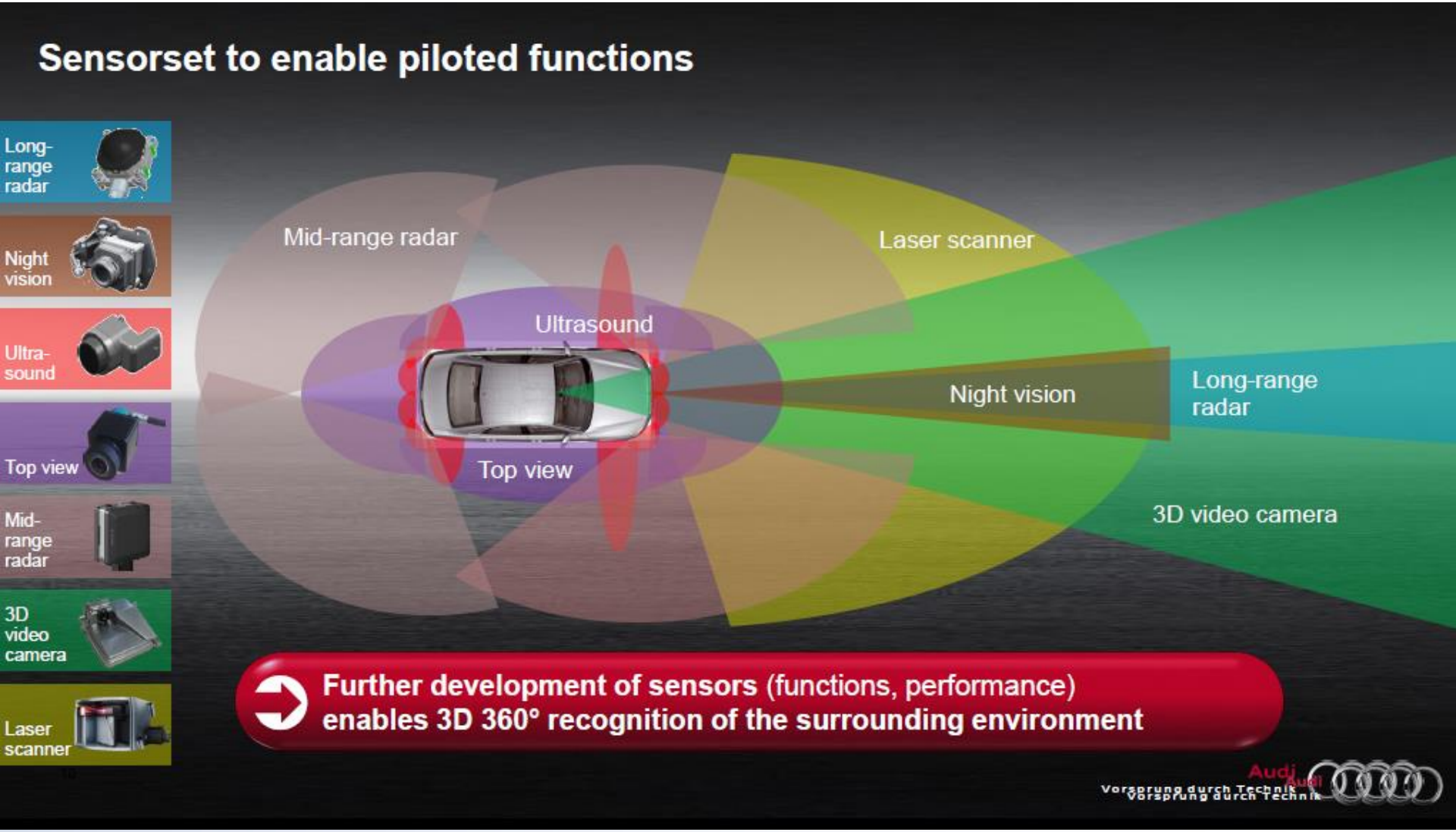
Audi Piloted Driving System: Vehicle Drove Itself from Silicon Valley to Las Vegas for CES 2015



Regulatory Environment Is Critical

- Automotive companies do not necessarily want connected-vehicle safety applications (in-vehicle signage, cooperative crash avoidance, etc.), or sensor-based ones, to be mandated anytime soon (based on CAR studies)
  - NHTSA announcement made in early 2014, generally positive, but vague on dates
    - Advanced Notice of Proposed Rulemaking released in August 2014
    - Decision date for heavy vehicles was set for 2014 (no word yet)
    - Does battle for spectrum complicate matters? Who will run security certificate management system?
    - Sec. Foxx recently urged NHTSA and industry to expedite deployment
  - Numerous sensor-based approaches under regulatory review
    - Blind-spot detection, pedestrian detection, etc.
- Market forces also are critical

The Market Will Not Merely Accept Self-Driving Vehicles; it will be the engine pulling the industry forward

The high cost of mobility

- The vehicle as a machine is used on an average for 2 hours a day
- The average American commuter now spends 250 hours a year driving a vehicle—resulting in lost productivity, lost time pursuing other interests, or lost serenity.
- The USDOT estimates that new urban area highways cost $8 million to $12 million per mile

Safety and the human toll

- In 2010, the U.S. had approximately six million vehicle crashes leading to 32,788 traffic deaths.
- More than 2.3 million adult drivers and passengers were treated in U.S. emergency rooms in 2009
- According to research from AAA, traffic crashes cost Americans $299.5 billion annually.

Running out of space

- "In some U.S. cities, parking lots cover more than a third of the land area, becoming the single most salient landscape feature of our built environment."[1]
- By 2020, the UN estimates that 84.4 percent of Americans will live in urban areas, with more than 28 percent living in urban areas of more than five million people.

Driving demographics

- "Gen Now" generation and "Digital Natives" view driving as a distraction from texting, not the other way around
- Distractions account for 18% of crashes with injuries, and 11% of drivers under age 20 involved in crashes with fatalities were reported to have been distracted.
- Older adults face mobility challenges of age-related impairments and are unable to continue driving.

KPMG

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[1]Ben-Joseph, Eran, Rethinking a Lot, MIT Press 2012, http://mitpress.mit.edu/catalog/item/default.asp?ttype=2&tid=12874&mode=toc, 7/20/2012.

Chinese Market Might Be More Eager for Automated Driving Than U.S.

- Automatic driving technology might prosper more quickly in China than in any other market due to the nation's huge consumer force and transportation challenges
- Recent Nielsen statistics show that Chinese consumers are more interested in autonomous driving technology than are American and German consumers.
- Automated vehicle technologies will consider local travel and traffic conditions and encourage global harmonization of standards across different regions (mapping, communications, the use of common hardware and/or software modules)
- Active players in China include SAIC, Chang'an, GAC, Volvo, BMW, GM, Alibaba, Baidu, and Huawei

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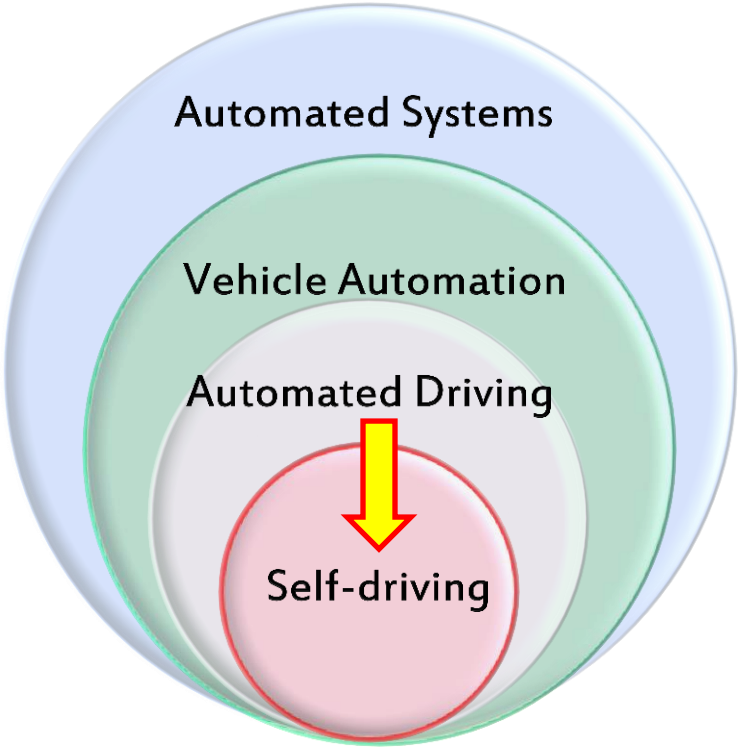
Automated System	Actuation Mechanism		
	Brake	Steering	Drivetrain
Antilock Brakes (ABS)	X		
Electronic Stability Control (ESC)	X		x
Adaptable Cruise-Control (ACC)	X		X
Autonomous Emergency Braking (AEB)	X		
Lane Keep Assist (nudge)	X	x	
Automated Parking Assistance		X	x
Automated Integrated Emergency Response	X	X	X
Automated Cruise-Control	X	X	X
Traffic-Jam Assist	X	X	X
Automated Parking	X	X	X
Automated Driving Systems	X (Plus Active Monitoring)	X	X
Full Automation (Self-driving)	All vehicle control and monitoring for entire trip.		

Of course, the technology has to work, too!



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Implications of Convergence and Self-Driving Vehicles

Crash elimination: Crash-free driving and improved vehicle safety could change the concept of a vehicle as we know it

Improved energy efficiency: Reduced energy consumption in at least three ways: more efficient driving; lighter, more fuel-efficient vehicles; and efficient infrastructure

Reduced need for new infrastructure: Self-driving can reduce the need for building new infrastructure and reduce maintenance costs

Data challenges: Issues related to data security, privacy, and data analytics and aggregation could crop up due to abundance of data in vehicles

Travel time dependability: Convergence can substantially reduce uncertainty in travel times via real-time, predictive assessment of travel times on all routes

New models for vehicle ownership: Self-driving vehicles could lead to a major redefinition of vehicle ownership and expand opportunities for vehicle sharing

Productivity improvements: Convergence will allow travelers to make use of travel time productively

New business models and scenarios: Convergence of technologies may realign industries such that ecosystem participants need to compete and collaborate at the same time

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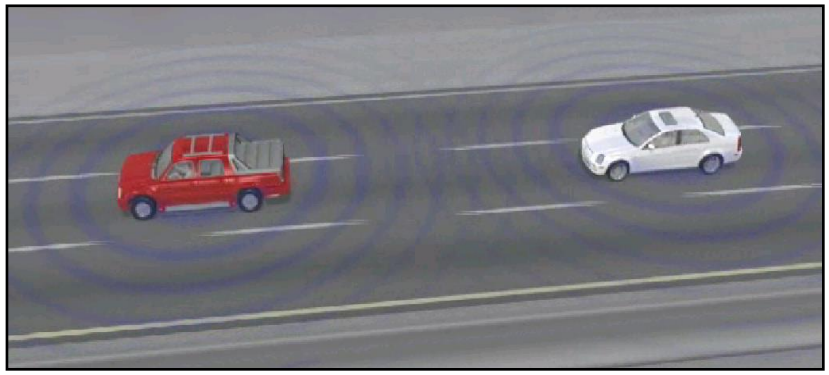
Vehicles That Cannot Crash

- Both communication- and sensor-based systems will provide crash avoidance
- Together, the two ultimately can result in vehicles that simply cannot crash under most scenarios
  - Eliminate crash fatalities and injuries, property damage, emergency room visit, etc.
  - Reduce need for vehicle repairs
- This requires convergence—neither sensors nor communications alone can accomplish this outcome

Connectivity for Safer Driving

- Greater situational awareness
  - Your vehicle can “see” nearby vehicles and knows roadway conditions that you cannot see
- Reduce or even eliminate crashes through:
  - Driver advisories
  - Driver warnings
  - Vehicle control



Connected vehicle technology has the potential to address 82% of the vehicle crash scenarios involving unimpaired drivers.

Work Zone Notification

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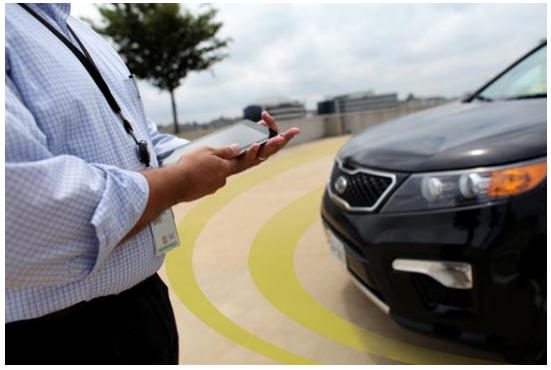
V2V Safety Pilot to Support Regulatory Decision-making

- V2V Driver Safety Clinics
  - Provided opportunity for non-professional drivers to test connected vehicle safety systems and provide feedback to the USDOT and industry (six locations)
- V2V Safety Pilot Field Test
  - Completed in Michigan
  - Thousands of equipped vehicles concentrated in Ann Arbor
    - Includes light vehicles, heavy truck, buses, etc.; nearly 3,000 vehicles fielded (headed to 9,000 and then 20,000+)
- Both provided important input to NHTSA's decision on regulatory intent
  - Announcement came out in Feb. 2014
  - Heavy vehicle announcement is overdue
- DOT planning several V2I pilot deployments next
  - RFP recently released (proposals now in)

SAFETYPILOT



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Reduced Need for New Infrastructure

- Currently, we spend about $75 billion annually in the U.S. on roads, highways, bridges, etc., in support of human drivers with all their (our) shortcomings
  - Thus, we have rumble strips, wide lanes, significant gaps between vehicles, etc.
  - Self-driving vehicles could be tightly spaced into platoons with up to 500 % more capacity than we have today with no additional space
  - Intersections could achieve 200 times more throughput through intelligent signal control based on “flight path” through the intersection
- Identifying sufficient funding for road, highway, and bridge maintenance and repair has proven difficult

SARTRE:

Safe Road Trains for the Environment

Concept: Platooning system

- Up to five vehicles (plus lead vehicle)
- Mixed traffic environment
- Builds on existing vehicle safety systems and equipment
- No road-side infrastructure

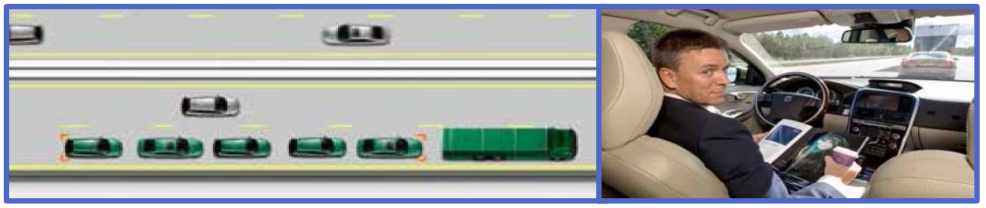
Duration: 3 years (9/2009 – 9/2012)

Budget: €6.4 million (60% from European Commission, Framework 7 Programme)

Partners: Ricardo (lead), Institut Für Kraftfahrzeuge (IKA), Idiada, SP Sweden, Tecnalia-Rbtk, Volvo Cars, and Volvo Technology

Equipment: Cameras, radar, GPS, and communication units (802.11p)

Benefits: Fuel consumption savings of 10-20%



Timeline

- Concept development and feasibility
- Simulator testing
- Closed testing at Volvo Proving Ground in Sweden (12/2010)
- Public highway testing near Barcelona, Spain (5/2012)
- Final event at Volvo Proving Ground in Sweden (9/2012)

Sources: CAR "International Survey of Best Practices" 2013 and Ricardo Quarterly Review Q4 2012

SARTRE Video

http://www.youtube.com/watch?v=tasa3D1vVTc

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Data Challenges & Opportunities

- Data security/ cybersecurity
- Threats to personal privacy
- Data analytics and aggregation
- Driver distraction

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Standards

- CV standards regime is fairly mature and includes many active organizations, but standards are still incomplete
  - ASTM, IEEE, SAE, Most Cooperation, OmniAir, …
  - US DOT, FCC, AASHTO, TIA, others
  - DSRC standards
    - ASTM E2213-03 provides for wireless, high bandwidth, short-range communication
    - SAE J2735 covers message set dictionaries and strives for interoperability
  - Wireless Access in Vehicular Environments (WAVE)
    - IEEE 1609 includes five active standards
  - Shortcomings remain that hinder full interoperability
    - When standards are "complete," CV market will boom (like cable)
- NHTSA has issued a preliminary statement about self-driving vehicles, generally advising states not to act prematurely, but in general is still investigating its options for possible mandates
  - Forward crash warning, blind-spot warning, lane-keeping, and so on
  - Only working at the component/subsystem level now, it seems

CAV Cybersecurity

- February 2015: “Modern cars are ripe targets for hackers, senator warns” (*Tracking & Hacking: Security & Privacy Gaps Put American Drivers at Risk,* AKA the *Markey Report*)
- February 2015: “Using a laptop, the hacker dialed the car's emergency communication system and transmitted a series of tones that flooded it with data. As the car's computer tried sorting it out, the hacker inserted an attack that reprogrammed the software, gaining total remote control” (*60 Minutes, “*DARPA Dan” segment)
- January 2015: “BMW cars found vulnerable in Connected Drive hack” (*PCWorld*)
- March 2015: [Paraphrasing] not a big concern for Tesla (Elon Musk)
- April 2015: Letter Report “Review of the *Status of the Dedicated Short-Range Communications Technology and Applications [Draft] Report to Congress”* prepared by the Transportation Research Board of the National Academies also questions security and privacy aspects of the DSRC system

Vehicle Manufacturers and “BIG DATA”

Digital leads

Ability to use social media and online behavior to generate 60–70% of sales leads digitally

Warranty costs reduction, predictive maintenance

2–3% reduction possible in a $2 billion to $3 billion warranty bill for OEMs

User and dealer satisfaction

User loyalty, feature usage analytics, dealer satisfaction prediction – enabling tailored maintenance packages, insurance, and apps/features

Internet aggregators

Vehicle transaction pricing to become transparent, reducing bands of pricing fluctuation

Product performance analysis, production, and supply chain

Predicting product and component performance, reducing product development costs

Advanced mobility services, dynamic navigation, and parking

Value-added services with facilities to integrate navigation and parking slots/reservations, EV charging spots, and car sharing

Source: Frost & Sullivan

New Models of Vehicle Ownership

- Beyond ZipCar on steroids, can lead to “mobility as a service” as the next dominant paradigm in U.S. (& global) transportation
- Technology will support instant personalization of whatever vehicle you happen to be in through user profiles, reconfigurations, etc. (e.g., Visteon e-Bee concept)

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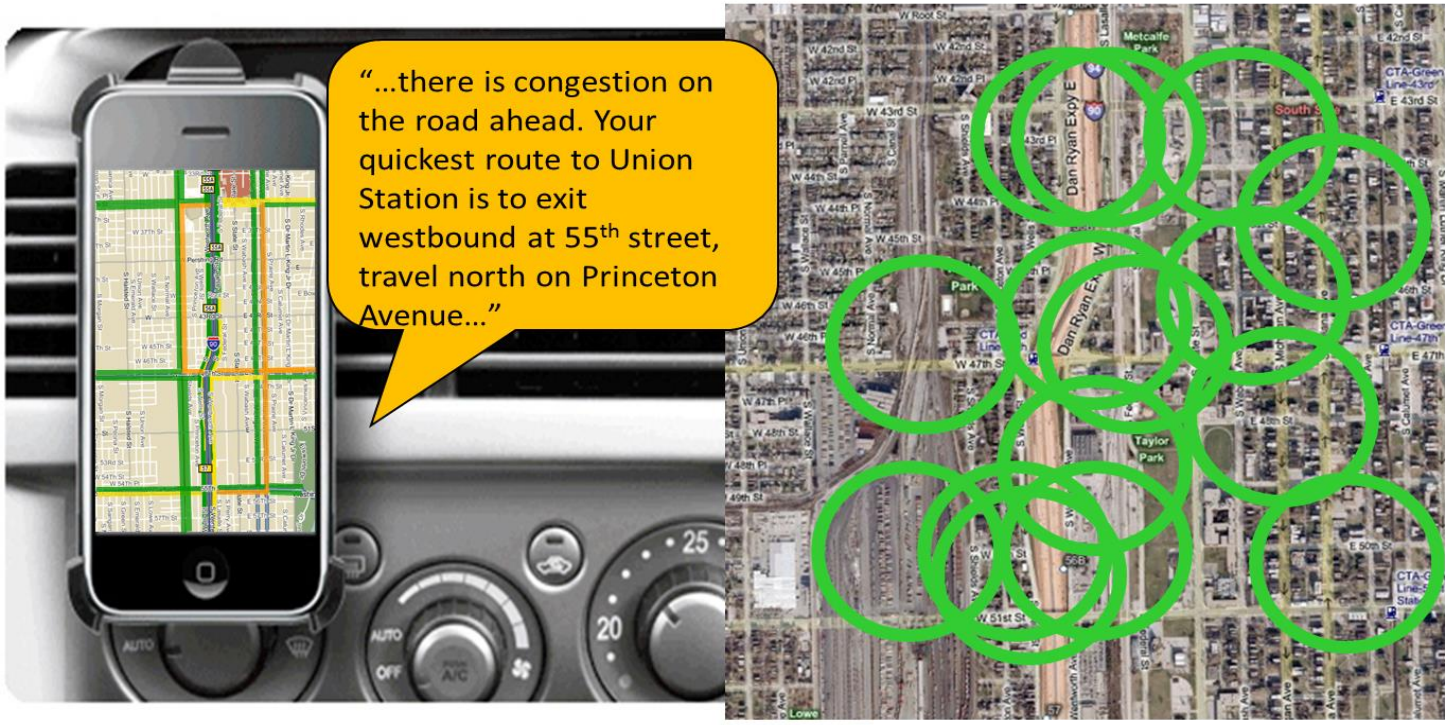
Increased Travel Time Dependability

- Driven by real-time data and enhanced predictive algorithms based on rich data environment
- Fewer to zero crashes further improves travel time estimates



dash/ipod: http://www.crunchgear.com/wp-content/photos/dloventmount.jpg
map: http://www.traffic.com/

map: http://www.bing.com/maps

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USDOT Applications for the Environment: Real-Time Information Synthesis (AERIS)

- Has identified five "transformative concepts" that use connected vehicle technology for enhanced environmental performance

1. Eco-Integrated Corridor Management
2. Eco-Signal Operations
3. Low Emissions Zones
4. Eco-Traveler Information
5. Eco-Lanes

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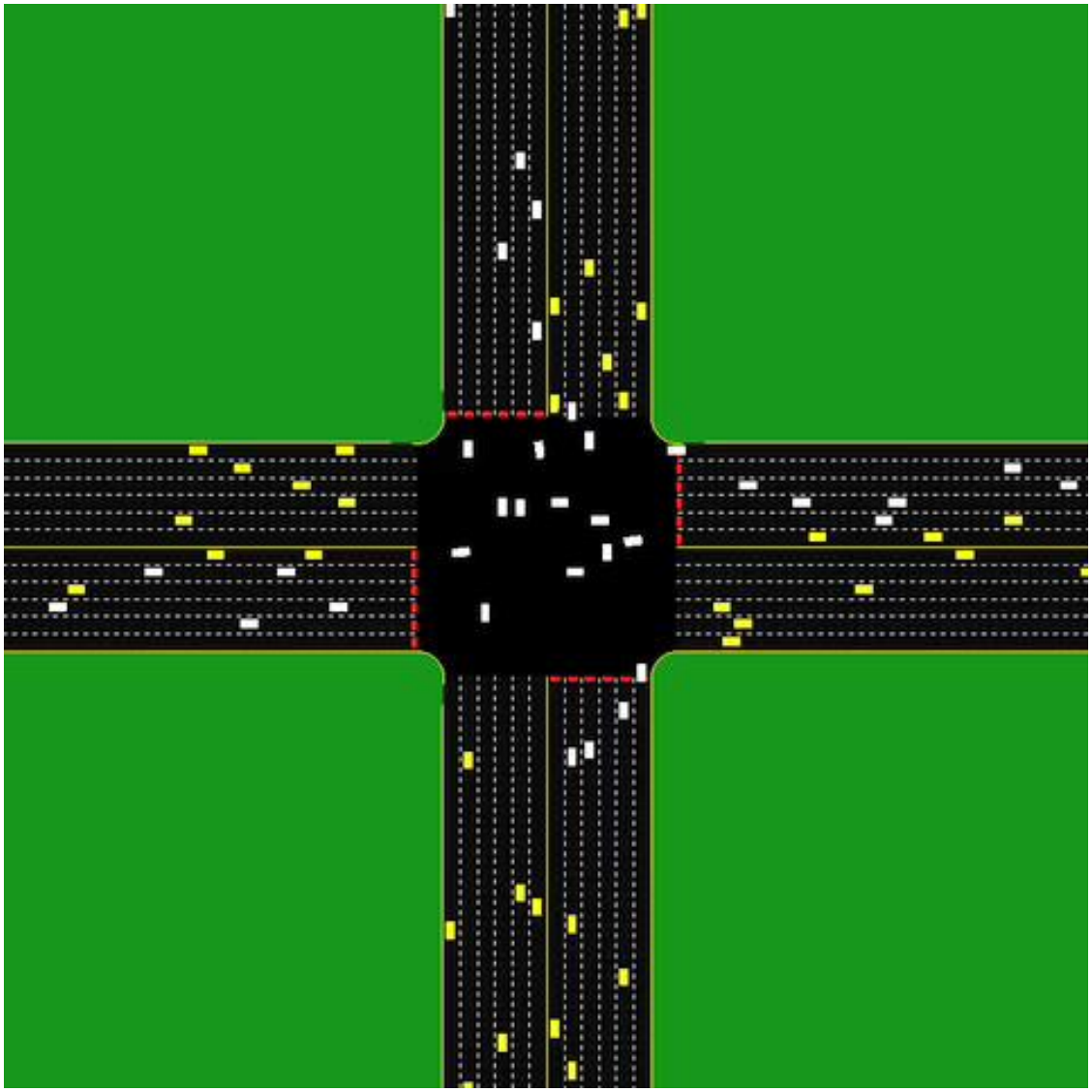
Advanced Eco-Signal Operation



The URL for the eco-signal operations video is: http://www.cs.utexas.edu/~aim/

Source: University of Texas, Prof. Peter Stone

Mercedes-Benz Long Drive

The URL for the Mercedes Long Drive video is: https://www.youtube.com/watch?v=CKqJccK_EkM

Recent Developments in China

- **BMW partners with Baidu to test self-driving cars in China -** "BMW is embarking on a further research project which will pave the way for highly automated driving in China as well," BMW said in a statement http://www.techtimes.com/articles/16791/20141001/bmw-partners-with-baidu-to-test-self-driving-cars-in-china.htm
- **Volvo Cars demos self-driving cars in Beijing -** Bringing the technology to China is part of Volvo Cars' efforts to demonstrate how self-driving vehicles addresses the global sustainable mobility challenges and contribute to the societal development http://www.greencarcongress.com/2015/03/20150327-volvo.html
- **Alibaba Partners SAIC on $160 Million Connected Car Fund -** Alibaba Group is starting a 1 billion yuan ($160 million) fund with SAIC Motor Corp., China's largest automaker, to develop a connected car that may go on sale next year http://www.bloomberg.com/news/articles/2015-03-12/alibaba-partners-saic-on-160-million-connected-car-fund

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Predicting ‘When” Is Tough, But We Do So Anyway

- Vehicles with some self-driving capability already exist
- We foresee vehicles that can smoothly maintain their lane and safe headway control at highway speeds by 2018 or so
  - Mary Barra recently announced that GM will have Cadillacs with “Super Cruise” by late 2016 (2017 MY)
  - Tesla can send over-the-air software updates to all its models ever built as it is developed and verified; could enable this functionality today if the software is ready to send out
    - Hint: automation is all about software, neural networks, deep learning,…
- V2V and V2I built in about the same time, maybe 2019
  - Super Cruise will include DSRC
- Production vehicles that can go driveway to destination self-driving: 2025 or later
  - Mixed traffic for years to come—average age of the fleet today is 11.4 years; thus, about half of the vehicles that will be on the road in 2025 already are.

CAR Management Briefing Seminars

- August 3-6, 2015
- Traverse City, Michigan
- Our 50th year
- Sessions include:
  - Connected and Automated Vehicles: Competition, Rules, and Interesting Times
  - Global Strategies: The Maturing of China's Auto Market

50th ANNIVERSARY MBS

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