“Challenges Facing the Reliable Performance of Autonomous Passenger Car and Truck Sensors and Systems”

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About Me

- Jim Buczkowski, Henry Ford Technical Fellow & Director
- University of Michigan, B.S. Computer Engineering, M.S. Electrical Engineering
- 36 years with Ford Motor Company
- Electronics Design and Manufacturing
- IT Manufacturing and Supply Chain
- Sync, Ford Global Architecture, ADAS ….
- Currently, Innovation, Electrical & Electronics, Connectivity
- Ford Research and Advanced Engineering

From the Lab to Consumers

Headlines:

- Near term promise for autonomous vehicles
- Much progress has been made to develop:
  - Sensor set and sensor fusion,
  - Data including high resolution maps,
  - computing power,
  - control algorithms,
  - and mechatronics.
- Successful implementations have been highly publicized
  - Google. Mercedes and Audi
  - Delphi, Bosch, Continental

However:

- Do demos reflect the readiness to “roll off the assembly line?”
- Vehicles are well maintained and are thoroughly tested before each trip.
- Do demos represent what the average customer will expect?

How do we transition the technology for the average consumer?

Defining Autonomous Driving

From Driver Always in Control to Driver Out of the Loop

Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems (SAE J3016)

Go Further

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***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
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
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
***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
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
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**

Go Further

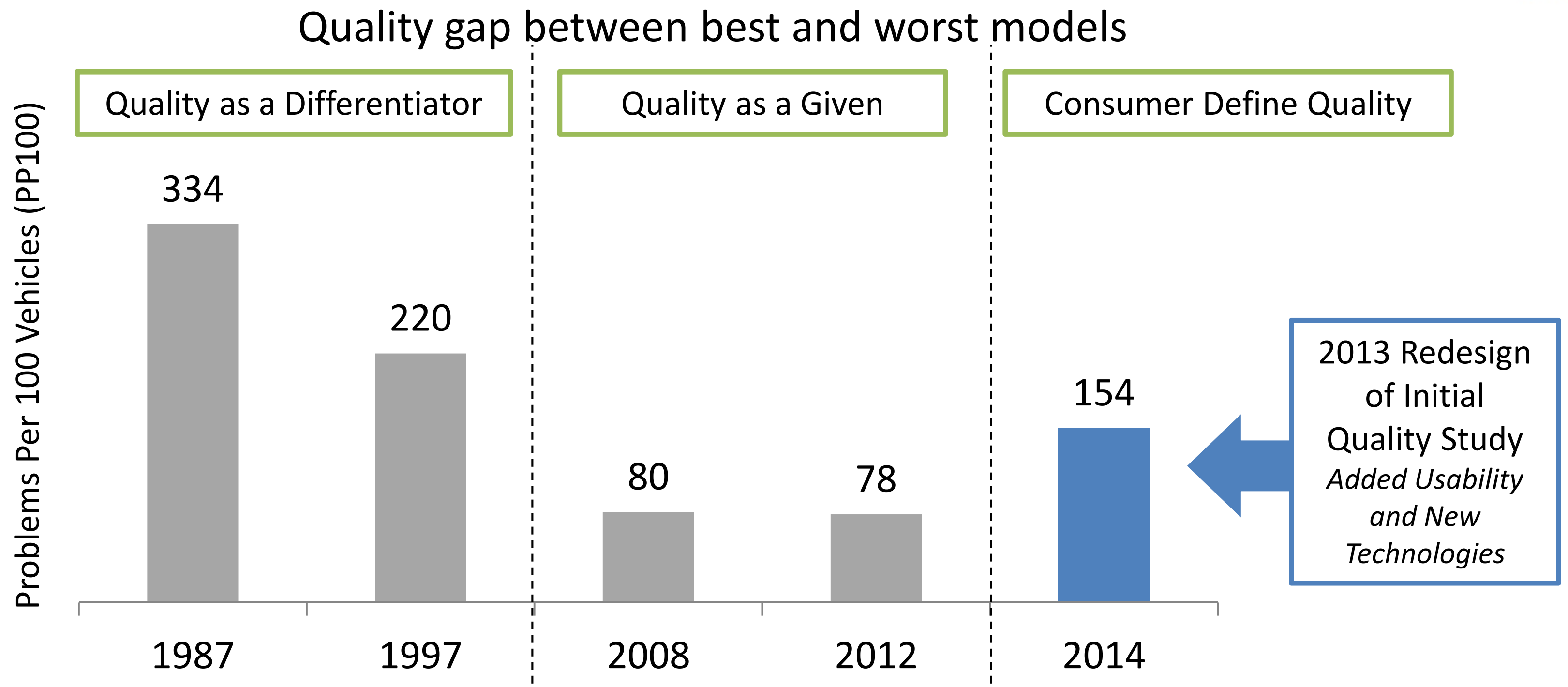
Consumer Expectations!

Consumer Satisfaction = Meeting or Exceeding Expectations

What will Consumer’s Expect from Autonomous Driving

Quality and Consumer Expectations

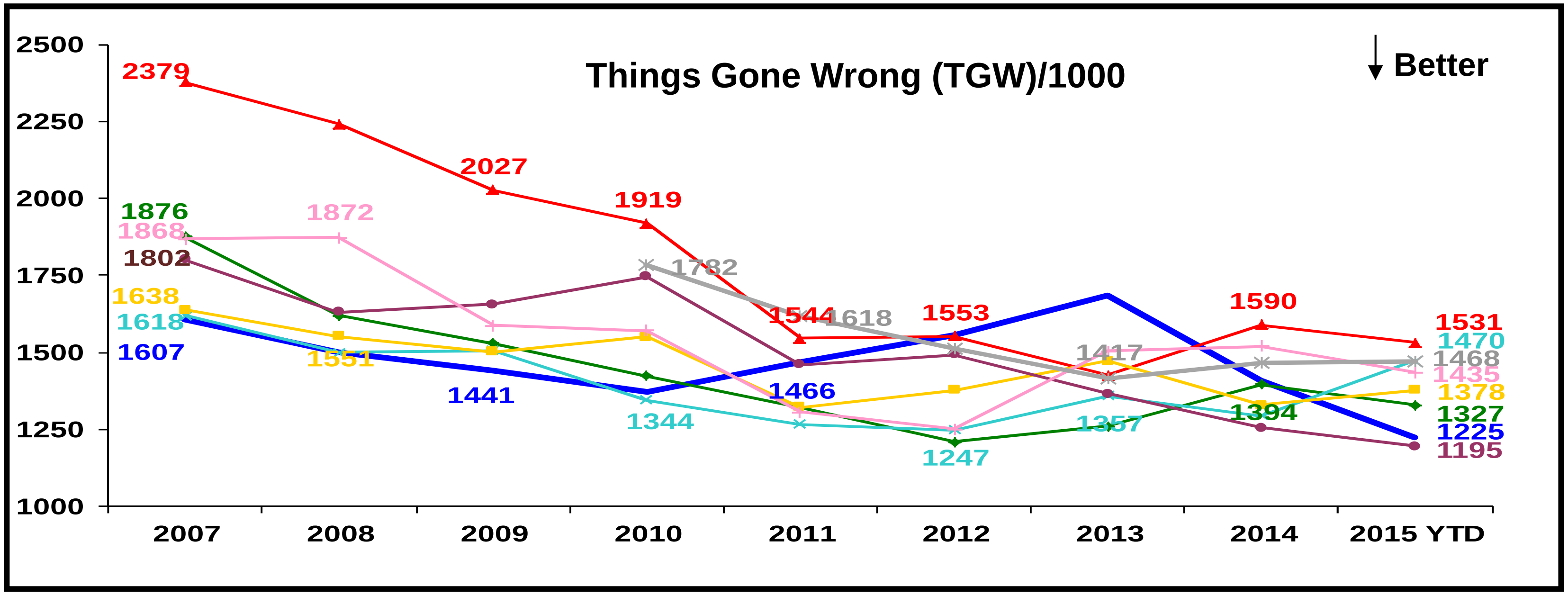
Go Further



Source: J.D. Power 1987 through 2014 U.S. Initial Quality Study (IQS)

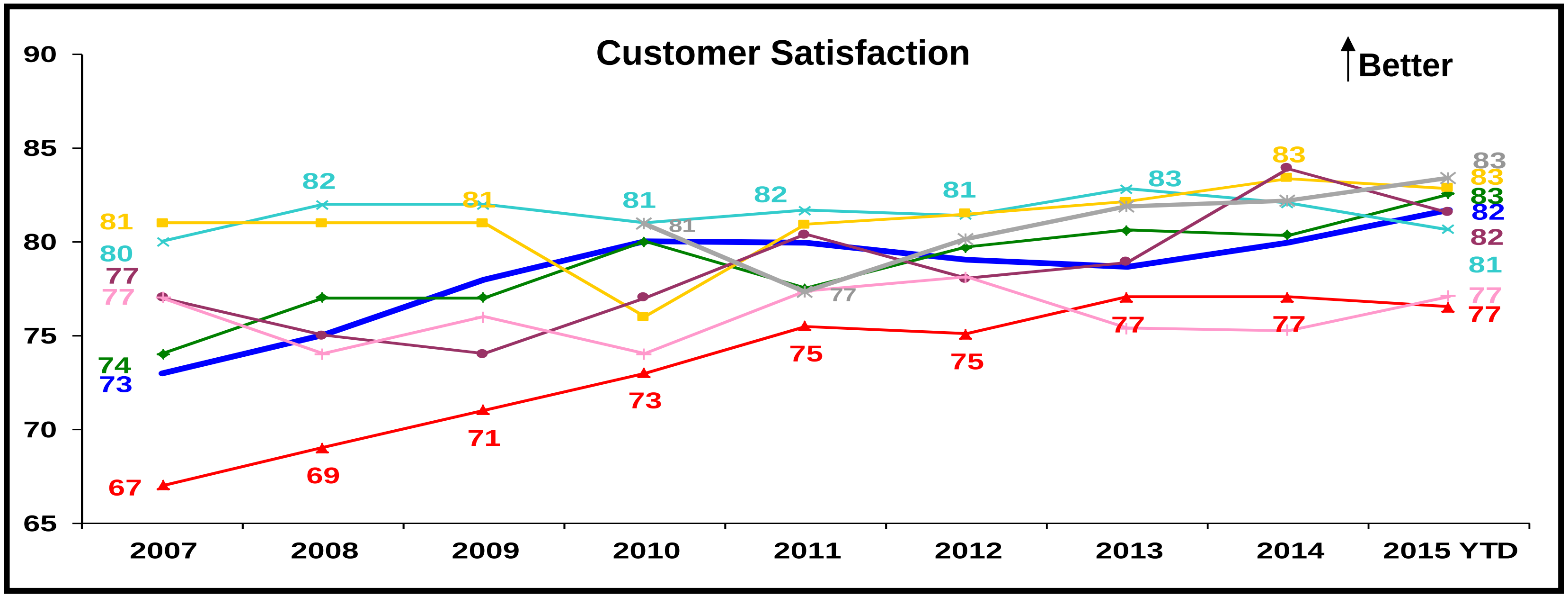
Progress on Quality has been significant in creating new differentiators!

Quality Gaps, as measured by Things Gone Wrong



Today's Expectations? Today's worst performing are better than the Best in 2007!

Auto Industry Satisfaction (Quality) Gaps Small



Consumer Expectations: Gap from the worst to the best is now half of 2017!

Consumer Expectations for Autonomous Vehicles

Engaged and ready to assume control

In the command position in case they are called upon

Completely detached from the drive experience

Possibly not even in the vehicle at times

Source: J.D. POWER McGRAW HILL FINANCIAL

Expectations for Automation are Very High! (“Completely detached from driving”)

Simple, Intuitive, Safe and Smart

IQS Over the Last 10 Years

Reported Problems	
Overall Vehicle Problems	↓
Reported Problems by Vehicle Category	
Interior Problems	↓
Feature / Control / Display Problems	↓
Ride and Handling Problems	↓
Exterior Problems	↓
Tire Problems	↓
HVAC Problems	↓
Engine / Transmission Problems	↓
Seat Problems	↓
Multimedia Problems	↑
Navigation System Problems	↑

Source: J.D. Power 1987 through 2014 U.S. Initial Quality Study (IQS)

Usability has Taken on Greater Importance

Increased Complexity

Design Issues: Soft "Inadequacies"

Industry Still Struggles with the Human-Machine Interface

Achieving Complexity While Keeping it Simple

- The industry has made great progress in addressing the quality of vehicles
- Differentiation in quality is now in a new set of areas, especially the Human- Machine interface
- “Experiences in Mobility” are now the differentiator
- Connectivity offers new, valued experiences that consumers want
- Through connectivity, the vehicle is part of a bigger ecosystem
- V2V Communication and Autonomous are new ecosystems that extend beyond the vehicle
- Satisfaction comes from: “<u>It Just Works</u>”

The challenge will be helping consumer’s understand more complex systems while meeting higher expectations for performance and availability

Realities for the Autonomous Vehicle Design

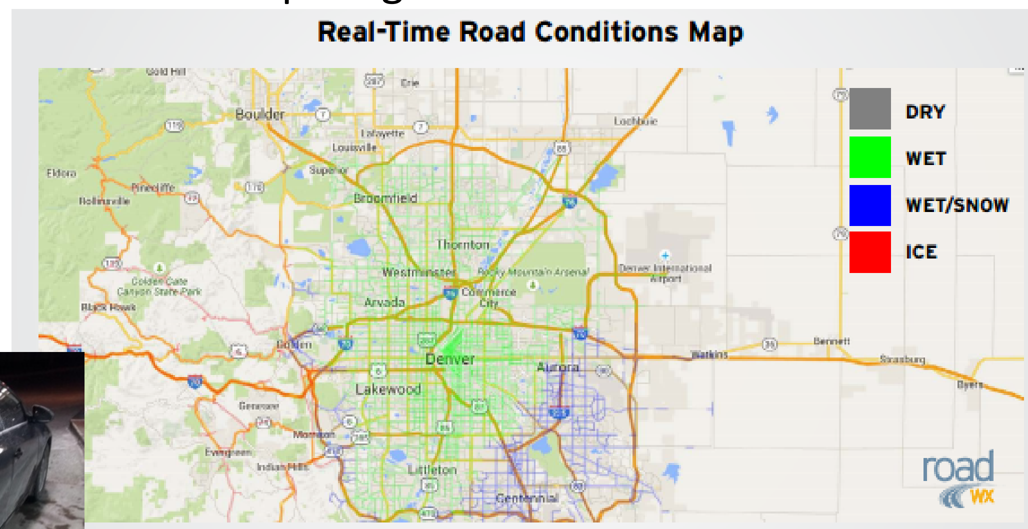
Weather, Maintenance, Human to Autonomous Interaction

“What percent of the time can I count on A/V mode?”

A/V Mode and Weather

Keeping Sensors Operational

Anticipating the Road Ahead



Today's annoyances for customers may result in limited operation of A/V systems

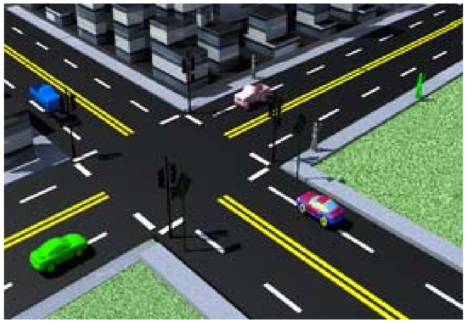
Vehicle Maintenance

Stone Chip impacting
Camera performance

Consumer's will still need to pay attention to the condition of their vehicle.

Sensing "Human Behavior"

- Mix of Human piloted and machine piloted vehicles
- "Right of Way" (Intersections)
- Passing Double Parked
- Strict adherence to the law?
- Under what conditions?



Programming Rules versus Programming Human Judgment?

What have we learned from other Complex Systems!

Powertrain Controls, Radar - Forward Collison Warning

Powertrain Controls

- Ford was one of the early pioneers in complex emissions control systems for our powertrains back in the early 1980's.
- We combined engine and transmission functions and eventually other features were integrated as well.
- Failures in these systems created the potential of stranding a customer requiring development of a "limp home" strategy as backup.
- Learned that the limp-home experience has to give the customer confidence they are safe to drive but it can't be so good (smooth or close to normal operation) that they don't take their vehicle in for repair.
- This has developed into a set of sophisticated algorithms which provide a range of actions from continued operation by inference/estimation of unavailable data through to shutdown of the affected system.

Robustness and Failure Mode Management are All Parts of Getting the Experience Right!

Forward Collison Warning

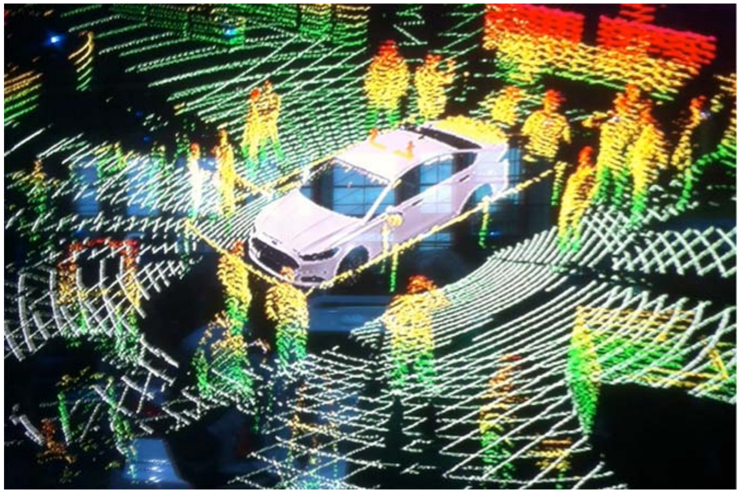
- Ford was quite aggressive with the launch of our Forward Collision Radar based system, part of something Ford calls "Democratization of Technology."
- Ford has worked carefully with Delphi to create a high performance affordable and reliable system.
- At launch, the feedback on dissatisfaction with the system fell into a few categories including:
  - Weather related – system conservatively calibrated
  - Packaging – close to front fascia, subject to minor damage
- Learned that the experience needs to be cascaded from the Customer to the component to assure we meet the right customer expectation
- Learned also to focus on "Graceful Degradation", or removing a feature due to weather or other conditions in a way that is understandable and acceptable to the customer.
- These lessons will be important to A/V radar and Lidar systems but given the complexity, we need to make sure we apply the "graceful degradation" across all parts of the A/V system.

Must Get All Parts of the Experience Right!

Implications for Autonomous Vehicles

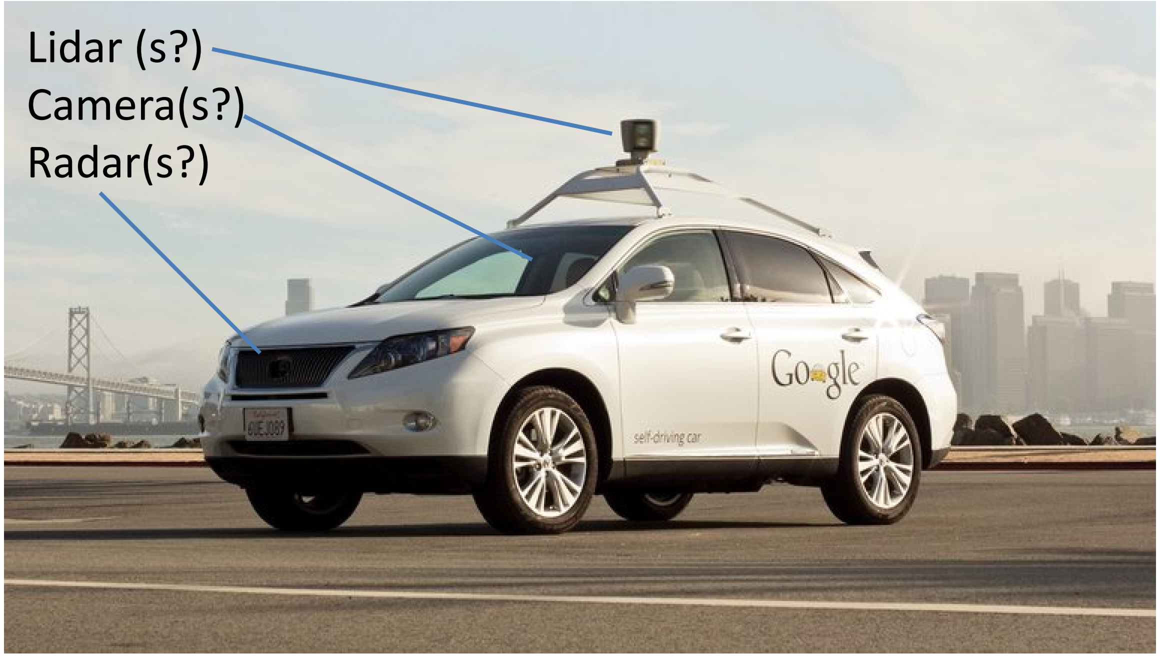
- Robustness must factor in real world customer use (abuse)
- We must fully understand a customer's expectation of the experience and design accordingly.
- A strategy for "Graceful degradation" must include a full understanding of the customer expectation for the experience. Example: Weather results in the system not available or does system drop from SAE level 4 or 5 to level 1 or 2?
- Customer expectation must be transferred into the system and component design requirements.

And re-engaging the customer is something new and yet to be developed



The Complexity of an Autonomous System

Sensors and Sensor Fusion

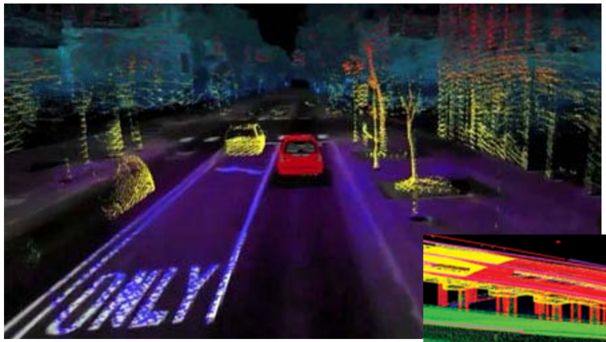


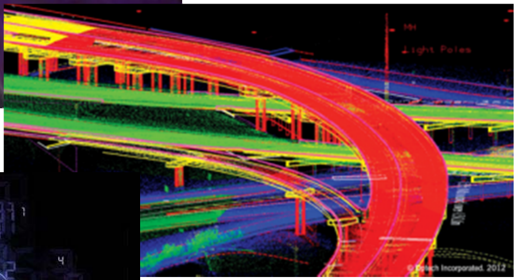
And…
- GPS/IMU’s
- Image Processing
- Hi-Res Map Data
- Connectivity
- Vehicle-to-Vehicle
- Other Vehicle Inputs
- Algorithms for:
    - Fusion
    - Calibration
    - Diagnostics
    - “Learning”
    - Analytics

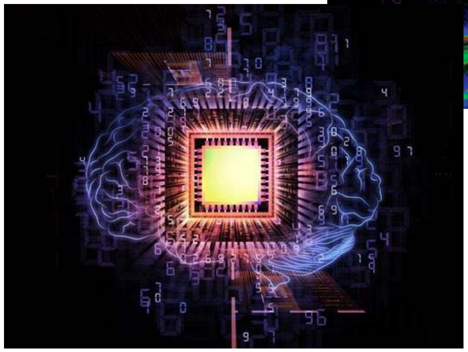
A View of the Critical and Important Technology for A/V's

Technology

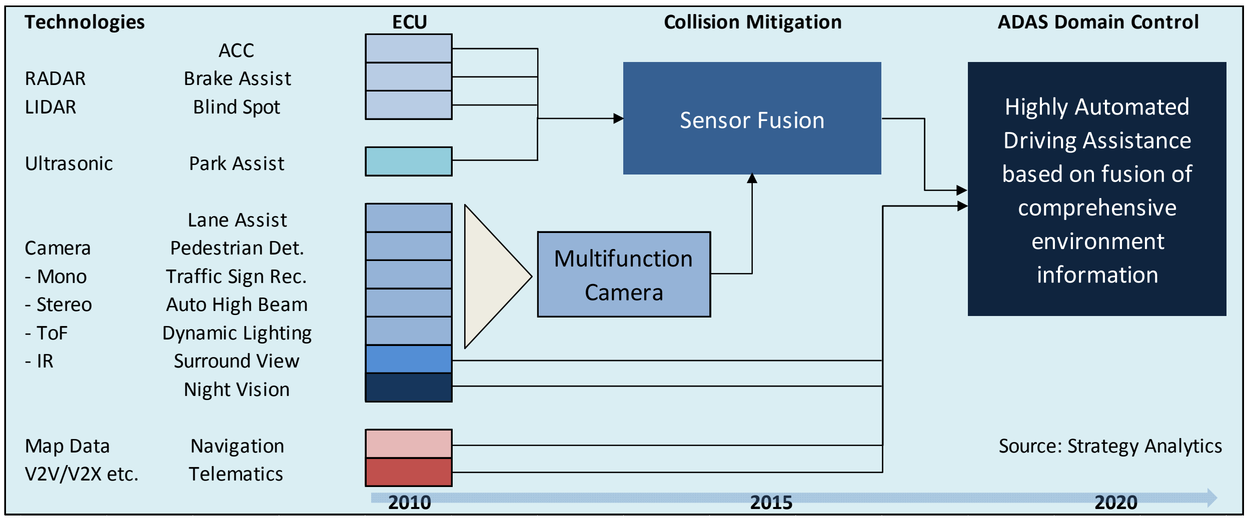
- LIDAR's for 360º Real-time Awareness
- 3D Mapping Data
- Sensor Fusion
- Connectivity
- Software Integration & Testing
- Algorithm Capability and Maturity
- Vehicle Control Input and Actuation
- On Board Computing Platform
- High Performance Off-Board Computing and Analytics







Evolution of the Architecture



And…

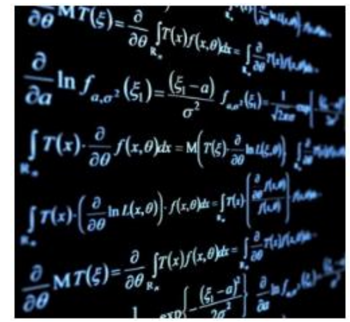
- Compute Power
- Hardware Integration
- Data Storage
- Hypervisors
- Fault Tolerance
- Deep Learning
- Gateway
- "Communication" manager
- Analytics

Examples of the Areas for Development

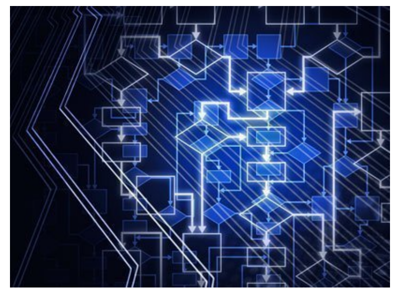
(Illustrative of the areas Autonomous Vehicle Developers are focused)

Go Further

Mapping
- Fused images from LIDARs, RADARs & cameras create 3D prior maps with accuracy
- Lane markings, traffic signals, etc.) are extracted from the data and annotated in the maps Sensing
- Long and mid-range radar fused with LIDAR-derived tracks
- Traffic light/sign detection

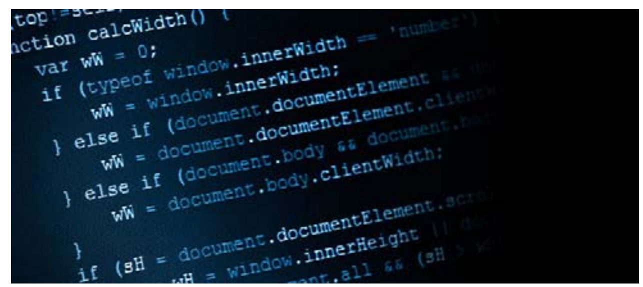


Obstacle Classification
- Anything above the ground plane and not in the 3D map
- Classifying vehicles pedestrians, bicycles, soccer balls, etc.



Behavioral Attributes
- Mission planning – determine optimal routes from point A to B
- Path planning

Driving
- Nominal driving – i.e., essentially lane keeping with ACC stop & go functionality
- Near limit handling driving – to enable avoidance maneuvers
- Lane changes, driver-initiated and automatic
- Merging
- Passing, driver-initiated and automatic
- Restricted Autonomous modes

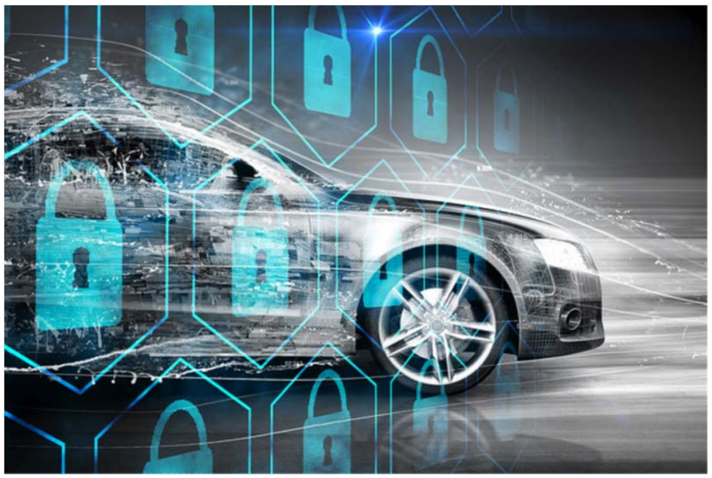


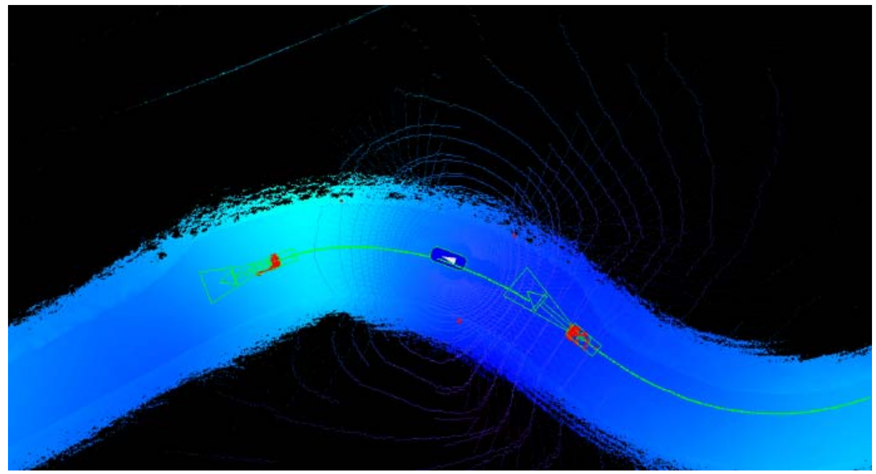
Vehicle Platform
- Redundant systems
- Graceful degradation of operation

The Autonomous Vehicle System

- A new ecosystem made of sensors, compute power, connectivity, data and analytics.
- No single enabler to deliver Autonomous Operation.
- A system that needs rules and to learn behaviors.
- Autonomous systems will draw on experience learned from driver assistance technologies (Level 2 and 3; for example forward collision radar and camera based technologies)
- To reach level 4 and 5, Autonomous developers will also need to adopt new philosophies going beyond what currently is effective for Level 2/3 technologies including the use of Lidar and High-Res maps.

A system of systems!





Source: Jacob Cotrill – US Chamber of Commerce

Security

Security/Privacy

Go Further

WIRED

"HACKERS REMOTELY KILL A JEEP ON THE HIGHWAY—WITH ME IN IT"

AUTHOR: ANDY GREENBERG.ANDY GREENBERG SECURITY
WIRED - DATE OF PUBLICATION: 07.21.15

The Washington Post

"Car hacking' just got real: In experiment, hackers disable SUV on busy highway"

AUTHOR: MICHAEL E. MILLER JULY 22

PC

"The Next Frontier in Car Hacking"

AUTHOR: DOUG NEWCOMB AUGUST 14, 2015

H

"SENATE BILL AIMS TO LOCK HACKERS OUT OF CONNECTED CARS"

Author: Alexander Howard Senior Editor for Technology and Society,
The Huffington Post 7/21/2015

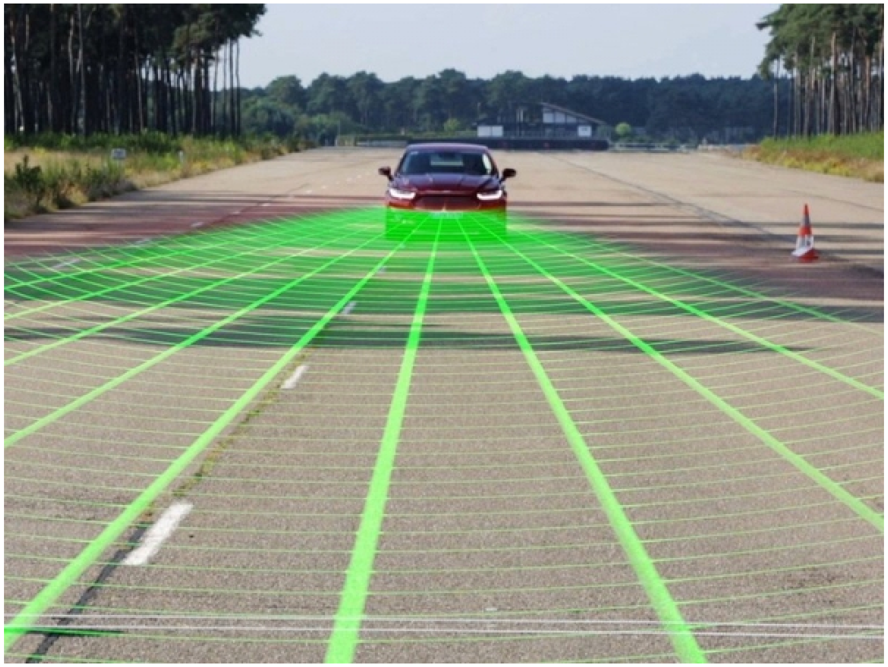
Cyber Security is a reality, requires up-front work and is a process that requires continuous vigilance!

Autonomous Vehicle – Possible Security Considerations

Proposed by IHS Automotive (*Not Ford's View*)

Security Golden Rules	
Requirements	**Key Information**
Hardware Integrity	▸ Hardware-based security is required for every MCU ▸ Tamper-proof: Prevention and detection
Software Integrity	▸ Unauthorized access must be detectable ▸ Unauthorized alteration must not be feasible
Data Integrity	▸ Unauthorized access must be detectable ▸ Unauthorized alteration must not be feasible
Communication Integrity	▸ Unauthorized modification from outside vehicle must be detected by receiver ▸ Unauthorized in-vehicle communication must be detectable, but should not be feasible
Access Control Integrity	▸ Authorized access must be well defined ▸ Unauthorized access must be detectable ▸ Diagnostic access during development must be removed

SOURCE: Egil Juliussen, Ph.D. Director Research, Infotainment & ADAS, IHS Automotive March 26, 2014



Summary & Closing Remarks:

Summary & Conclusions:

- Autonomous Capability is feasible … now we need to work on the details.
- Considerable work yet on adaptive, self learning etc. to assure high reliability and availability.
- Work still required on high volume Manufacturability.
- Engineers are drawing on the previous experience of launching complex automotive systems.
- A complex but generous set of sensors will help with redundancy and fail safe modes.
- Safe and effective control transfer methods back to a human driver represents work still needed to be completed.
- In the right environment and under the right conditions, automated driving can move out of the lab into real world applications.
- Success will be measured by Customer Satisfaction especially around simple and intuitive.

Other Credits/Thanks to:

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- Jim McBride
- Jerry Engelman
- Jay Zhou
- Alan Hall
- Alan Prescott
- Emily Frascaroli

JD Power:

- Kristin Sowle

Q&A

Thank You