Road Vehicle Automation: Diverse Opportunities and Challenges

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ITS World Congress, Bordeaux
SIS 31 – October 7, 2015

Automation Is a Tool for Solving Transportation Problems

- **Alleviating congestion**
  - **Increase capacity of roadway infrastructure**
  - **Improve traffic flow smoothness**
- **Reducing energy use and emissions**
  - **Improve traffic flow smoothness**
  - **Aerodynamic “drafting”**
- **Improving safety**
  - **Reduce and mitigate crashes**

…BUT the vehicles need to be ‘connected’ to gain these benefits

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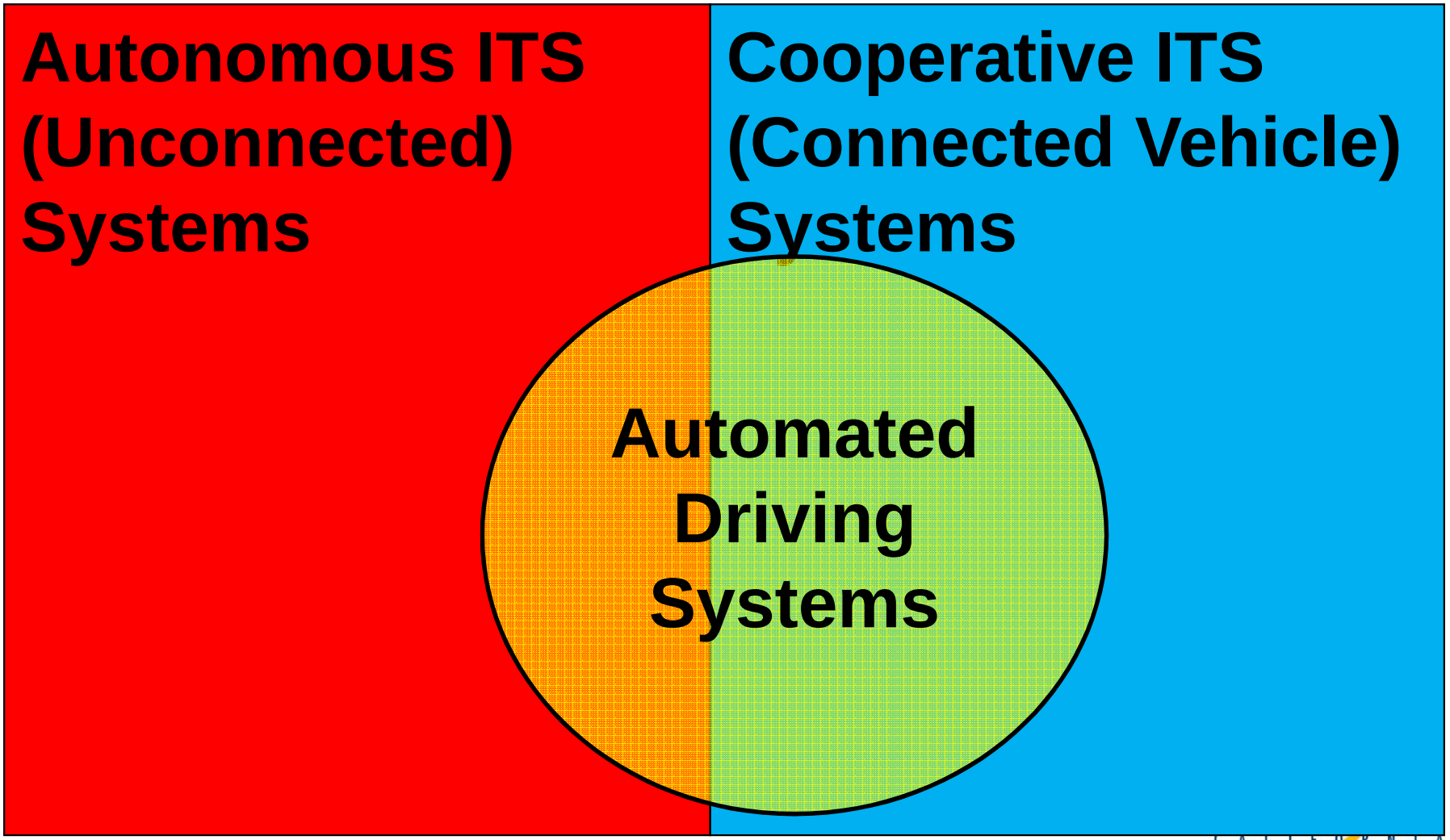
Autonomous and Cooperative ITS



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Diversity of Automation Concepts

- **Goals to be served by the automation system**
  - **Comfort/convenience, congestion relief, travel time saving, energy and environment, safety…**
- **Roles of driver and automation system**
  - **Levels of automation**
- **Complexity of operational design domain**
  - **Degree of segregation from other road users**
  - **Traffic complexity (speed, density, mix of users)**
  - **Weather and lighting conditions**
  - **Availability of I2V, V2V data**
  - **Standardization of signage and pavement markings**

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SAE J3016 Definitions – Levels of Automation

SAE Level	Name	Narrative Definition	Execution of Steering/ 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**

Example Systems at Each Automation Level

Level	Example Systems	Driver Roles
1	Adaptive Cruise Control OR Lane Keeping Assistance	Must drive other function and monitor driving environment
2	Adaptive Cruise Control AND Lane Keeping Assistance Traffic Jam Assist (Mercedes, Volvo, Infiniti)	Must continuously monitor driving environment (system nags driver to try to ensure it)
3	Traffic Jam Pilot Automated parking with supervision	May read a book, text, or web surf, but be prepared to intervene when needed
4	Highway driving pilot Closed campus driverless shuttle Driverless valet parking in garage	May sleep, and system can revert to minimum risk condition if needed
5	Automated taxi (even for children) Car-share repositioning system Drives anywhere people can drive	No driver needed

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Improving Safety

- **Current U.S. traffic safety sets a very high bar:**
  - **3.3 M vehicle hours between fatal crashes (375 years of non-stop 24/7 driving)**
  - **65,000 vehicle hours between injury crashes (7+ years of non-stop 24/7 driving)**
- **How much safer does an automated system need to be? (2X? 5X? 10X?)**
- **How do you determine that the automated system has reached its safety goal?**

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No Automation and Driver Assistance (Levels 0, 1)

- **Primary safety advancements likely at these levels, adding machine vigilance to driver vigilance**
  - **Safety warnings based on ranging sensors and V2V/V2I communicated information**
  - **Automation of one function facilitating driver focus on other functions**
- **Driving comfort and convenience from assistance systems (ACC)**
- **Traffic, energy, environmental benefits depend on cooperation**
- **Widely available on cars and trucks now**

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Partial Automation (Level 2) Impacts

- **Probably only on limited-access highways**
- **Somewhat increased driving comfort and convenience (but driver still needs to be actively engaged)**
- **Possible safety increase, depending on effectiveness of driver engagement**
  - **Safety concerns if driver tunes out**
- **(*only* if cooperative) Increases in energy efficiency and traffic throughput**
- **When? Now (Mercedes, Infiniti, Volvo)**

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Conditional Automation (Level 3) Impacts

- **Driving comfort and convenience increase**
  - **Driver can do other things while driving, so disutility of travel time is reduced**
  - **Limited by requirement to be able to re-take control of vehicle in a few seconds when alerted**
- **Safety uncertain, depending on ability to re-take control in emergency conditions**
- **(*only* if cooperative) Increases in efficiency and traffic throughput**
- **When? Unclear – safety concerns could impede introduction**

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High Automation (Level 4) Impacts – General-purpose light duty vehicles

- **Only usable in some places (limited access highways, maybe only in managed lanes)**
- **Large gain in driving comfort and convenience on available parts of trip (driver can sleep)**
  - **Significantly reduced value of time**
- **Safety improvement, based on automatic transition to minimal risk condition**
- **(*only* if cooperative) Significant increases in energy efficiency and traffic throughput from close-coupled platooning**
- **When? Starting 2020 – 2025?**

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High Automation (Level 4) – Special applications

- **Buses on separate transitways**
  - **Narrow right of way – easier to fit in corridors**
  - **Rail-like quality of service at lower cost**
- **Heavy trucks on dedicated truck lanes**
  - **(cooperative) Platooning for energy and emission savings, higher capacity**
- **Automated (driverless) valet parking**
  - **More compact parking garages**
- **Driverless shuttles within campuses or pedestrian zones**
  - **First mile/last mile access to line-haul transit**
- **When? Could be just a few years away**

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Full Automation (Level 5)

- **Electronic taxi service for mobility-challenged travelers (young, old, impaired)**
- **Shared vehicle fleet repositioning (driverless)**
- **Driverless urban goods pickup and delivery**
- **Full “electronic chauffeur” service**

- **Many decades away because ubiquitous operation without driver poses huge technical challenges**

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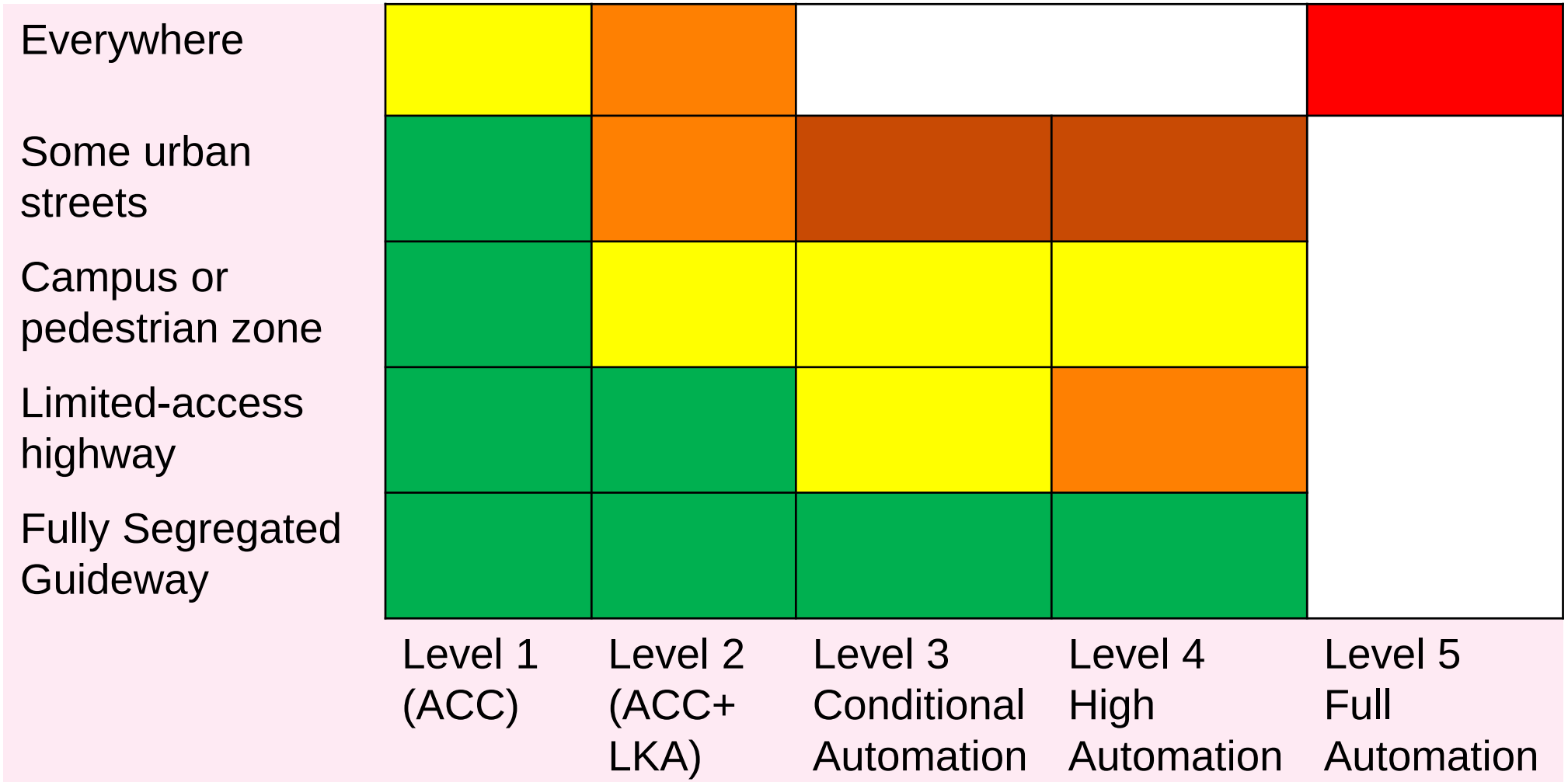
Personal Estimates of Market Introductions
** based on technological feasibility **



Why will Level 5 take so long?

- **Impossibility of specifying and designing for all hazards the vehicle will encounter**
  - **Other road users, environmental conditions, internal fault conditions…**
- **No viable methods exist to develop and verify complex safety-critical software making life-or-death decisions**
- **Sensor signal processing to achieve near-zero false negatives and false positives**
  - **Distinguishing genuine hazards from benign objects**

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Fundamental Challenges in Defining Automation Regulations

- **Balancing need to protect public safety with desire to encourage technological innovation**
- **Automation blurs the traditional boundary between federal responsibility for regulating new vehicle equipment and state responsibility for regulating how vehicles are operated in U.S.**
- **Lack of technical standards to provide baseline references for performance, safety or testing protocols or procedures**
- **Lack of national standards and diversity of state approaches**
- **Cultural differences between automotive and information technology industries**
- **Self-certification vs. third-party certification**

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