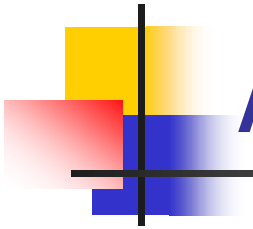
Autonomy and Real-time

An Autonomous Car Example

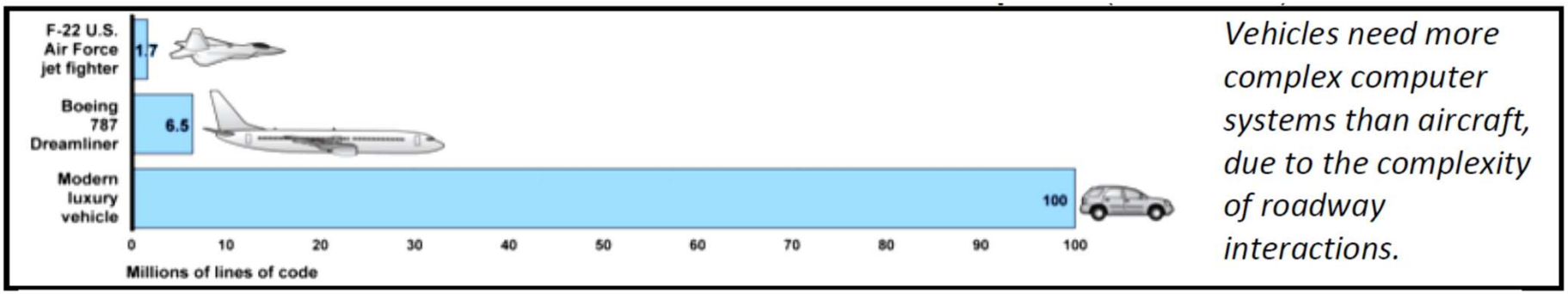


Autonomous Cars

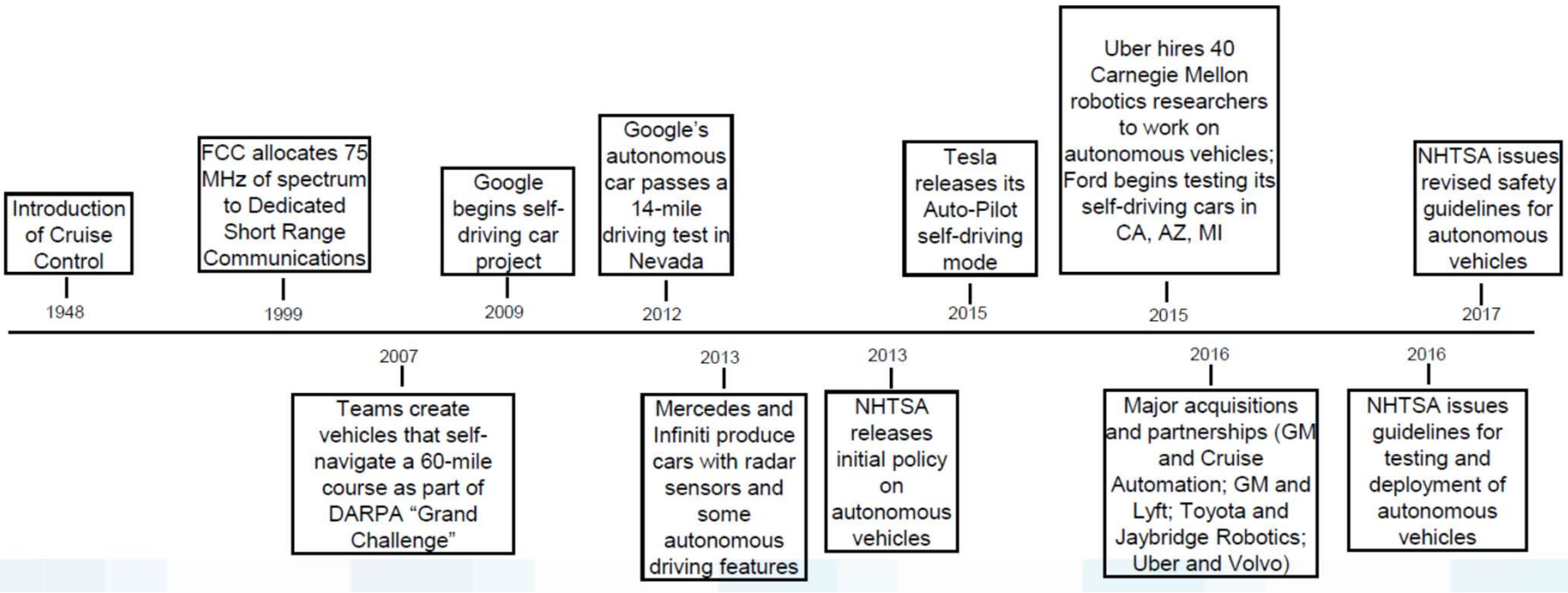
- 10 million autonomous vehicles expected by 2020
- In 10 years, fully autonomous driving will likely be the norm
- Expected: 90% reduction in vehicle crashes (autonomous cars don’t drink and drive, don’t text, don’t get tired and fall asleep at the wheel, and don’t have emotional issues that distract them from driving)

The Remaining 10% (Crashes)

- Will keep CPS/reliability researchers and engineers in business of a long time
- Consider the code complexity



History



Courtesy of mcca.com

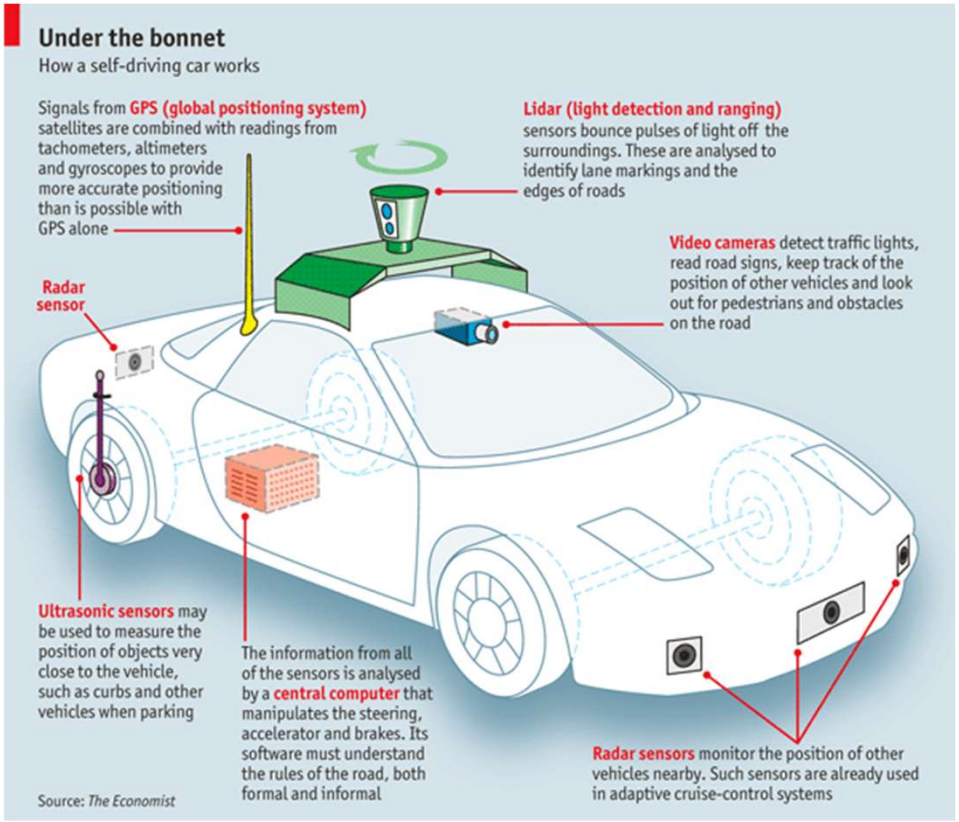
Levels of Automation

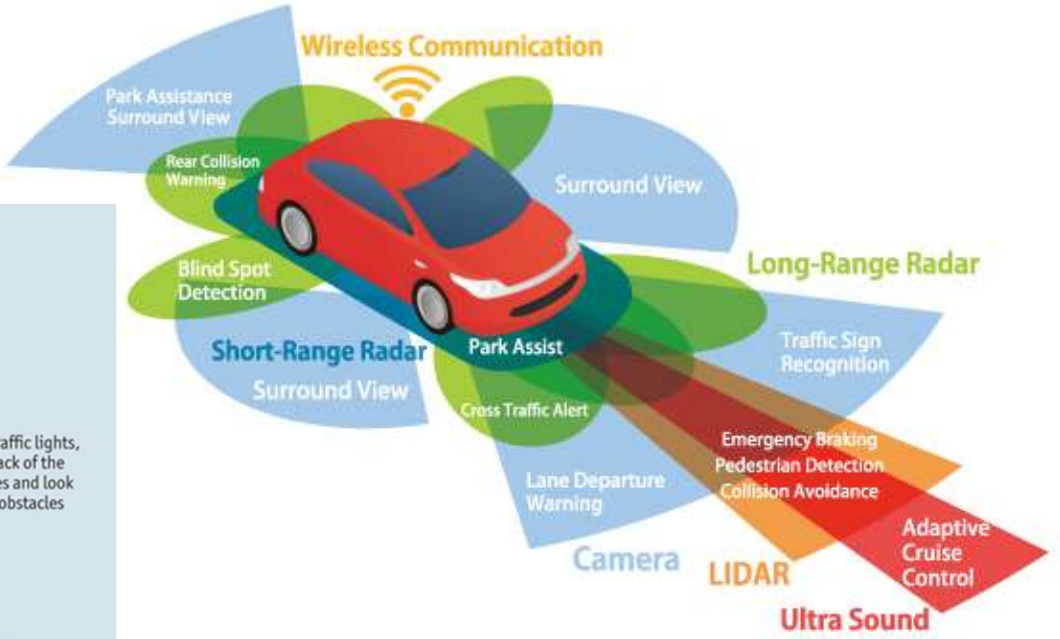
SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

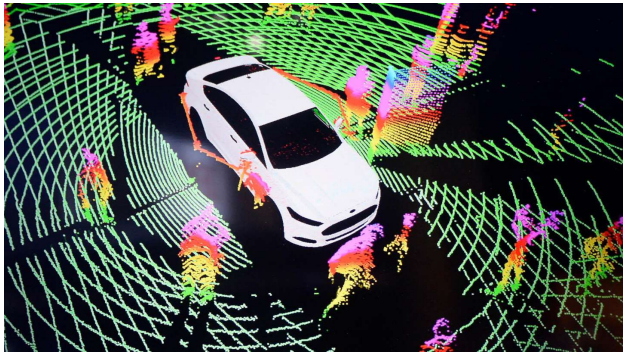
Full Automation

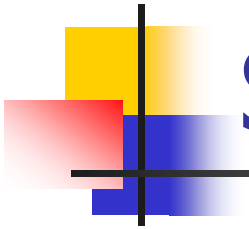
0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Sensors


Under the bonnet
How a self-driving car works
Signals from GPS (global positioning system) satellites are combined with readings from tachometers, altimeters and gyroscopes to provide more accurate positioning than is possible with GPS alone
Lidar (light detection and ranging) sensors bounce pulses of light off the surroundings. These are analysed to identify lane markings and the edges of roads
Video cameras detect traffic lights, read road signs, keep track of the position of other vehicles and look out for pedestrians and obstacles on the road
Radar sensor
Ultrasonic sensors may be used to measure the position of objects very close to the vehicle, such as curbs and other vehicles when parking
The information from all of the sensors is analysed by a central computer that manipulates the steering, accelerator and brakes. Its software must understand the rules of the road, both formal and informal
Radar sensors monitor the position of other vehicles nearby. Such sensors are already used in adaptive cruise-control systems
Source: The Economist


Wireless Communication
Park Assistance
Surround View
Rear Collision Warning
Surround View
Blind Spot Detection
Long-Range Radar
Short-Range Radar
Park Assist
Traffic Sign Recognition
Surround View
Cross Traffic Alert
Emergency Braking
Pedestrian Detection
Collision Avoidance
Lane Departure Warning
Adaptive Cruise Control
Camera
LIDAR
Ultra Sound



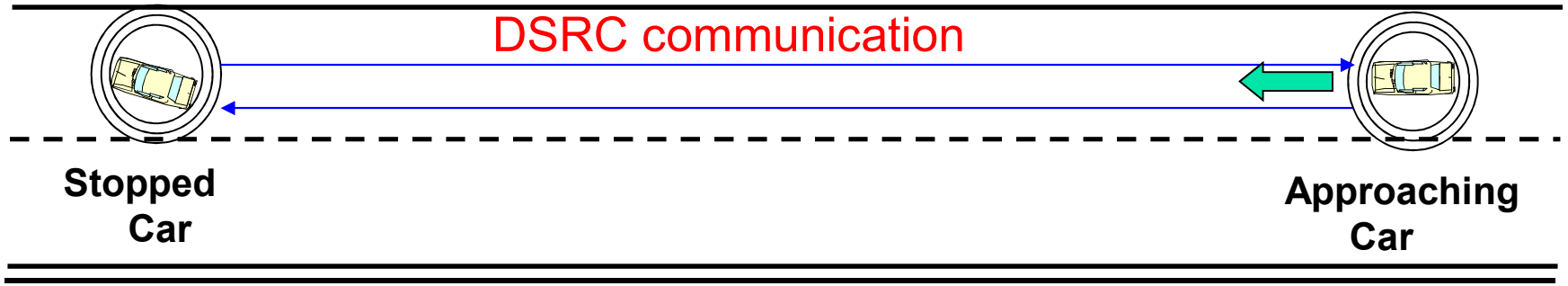


Sensors

- **Cameras:** Provide real-time obstacle detection to facilitate lane departure and track roadway information (like road signs).
- **Radar:** Radio waves detect short & long-range depth.
- **LIDAR:** Measures distance by illuminating target with pulsed laser light and measuring reflected pulses with sensors to create 3-D map of area.
- **GPS:** Triangulates position of car using satellites. Current GPS technology is limited to a certain distance. Advanced GPS is in development.
- **Ultrasonic Sensors:** Uses high-frequency sound waves and bounce-back to calculate distance. Best in close range.
- **DRSC Receiver:** Communications device permitting vehicle to communicate with other vehicles (V2V) using DSRC, a wireless communication standard that enables reliable data transmission in active safety applications.

V2V Safety Use Case

Forward Collision Warning (FCW)

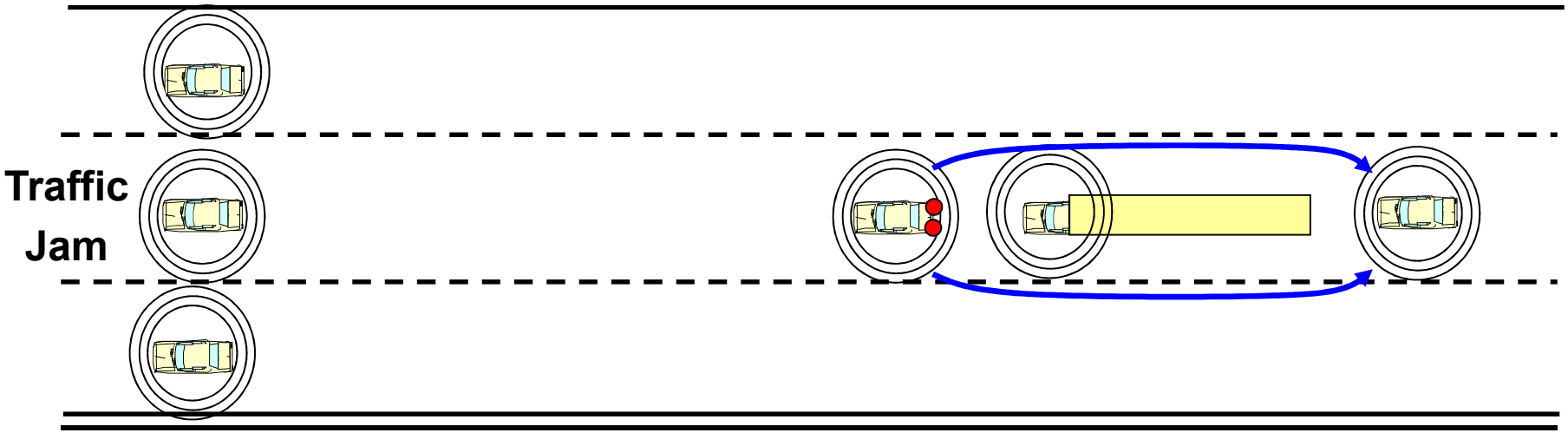


- If driver of approaching car does not stop, or slow appropriately, warning issued within car.

John Kenney, Toyota Info Technology Center

V2V Safety Use Case

Emergency Electronic Brake Lights (EEBL)

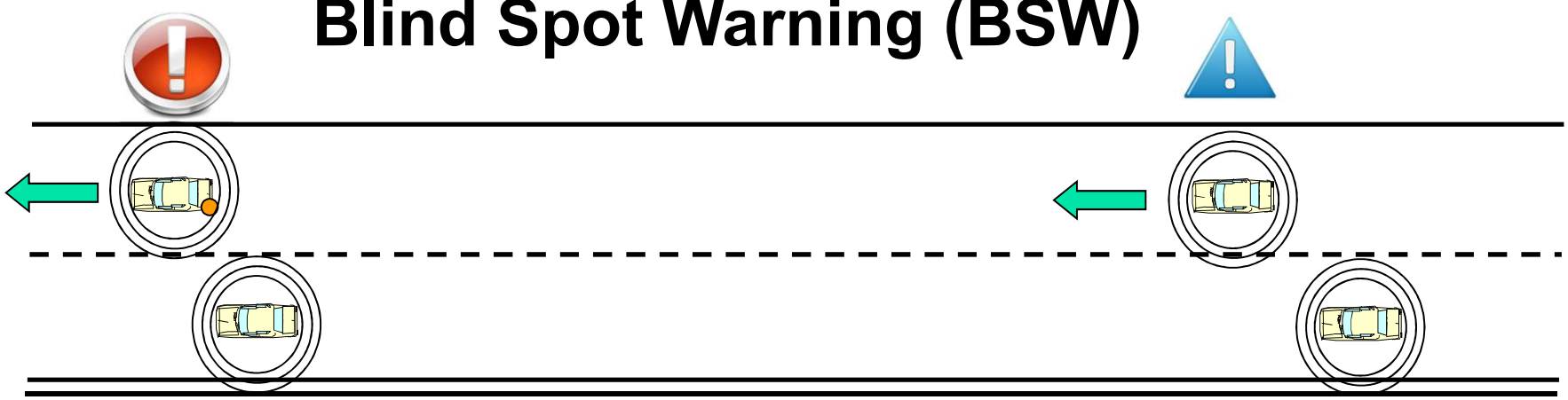


- High deceleration by car approaching jam. Trailing car Informed via DSRC within 100 ms.

John Kenney, Toyota Info Technology Center

V2V Safety Use Case

Blind Spot Warning (BSW)



Driver receives warning when showing intent to change lanes

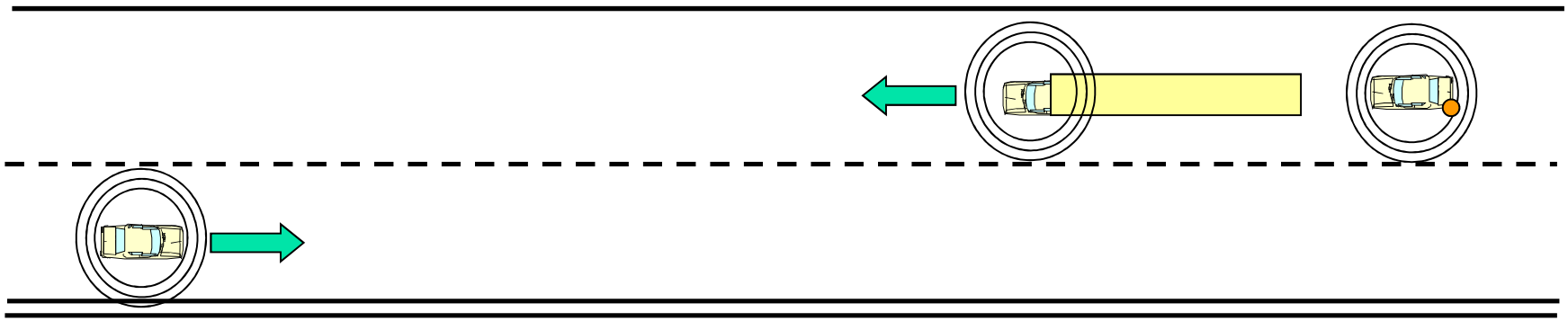
Normal driving – advisory indicator of car in blind spot

Note: Specific timing, format, or decision logic for advisories and warnings will likely vary for each car manufacturer

John Kenney, Toyota Info Technology Center

V2V Safety Use Case

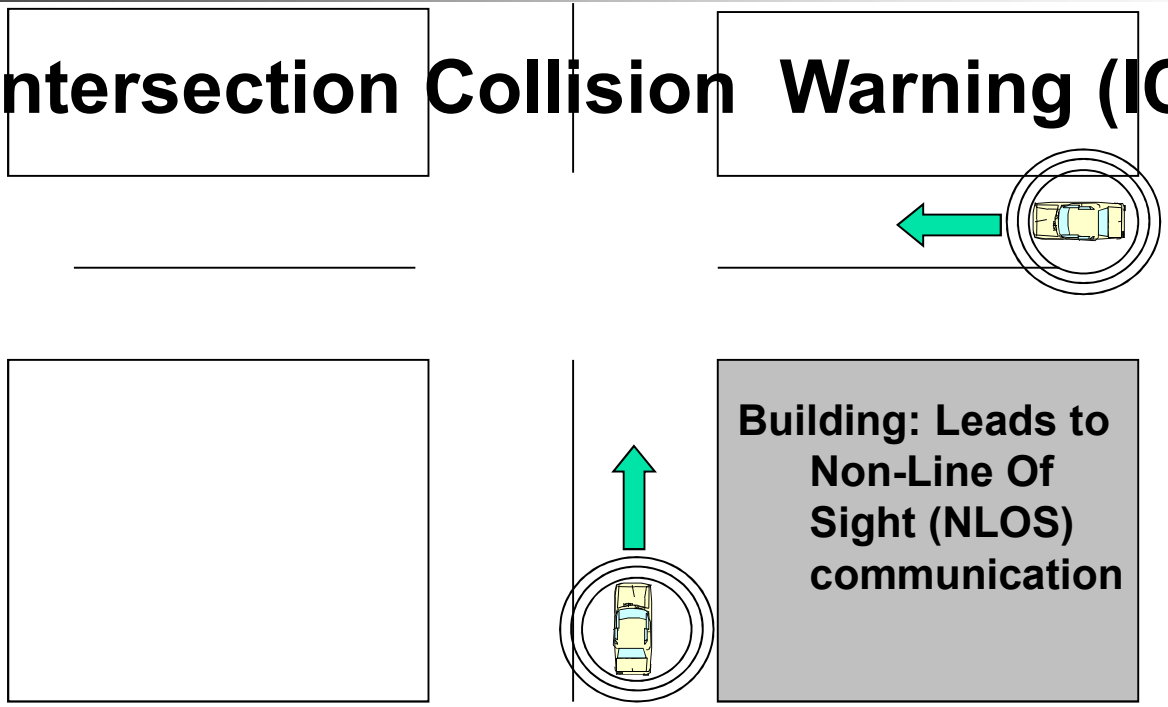
Do Not Pass Warning (DNPW)



- When showing intent to move to oncoming lane, driver receives warning if not safe to pass.

John Kenney, Toyota Info Technology Center

V2V Safety Use Case



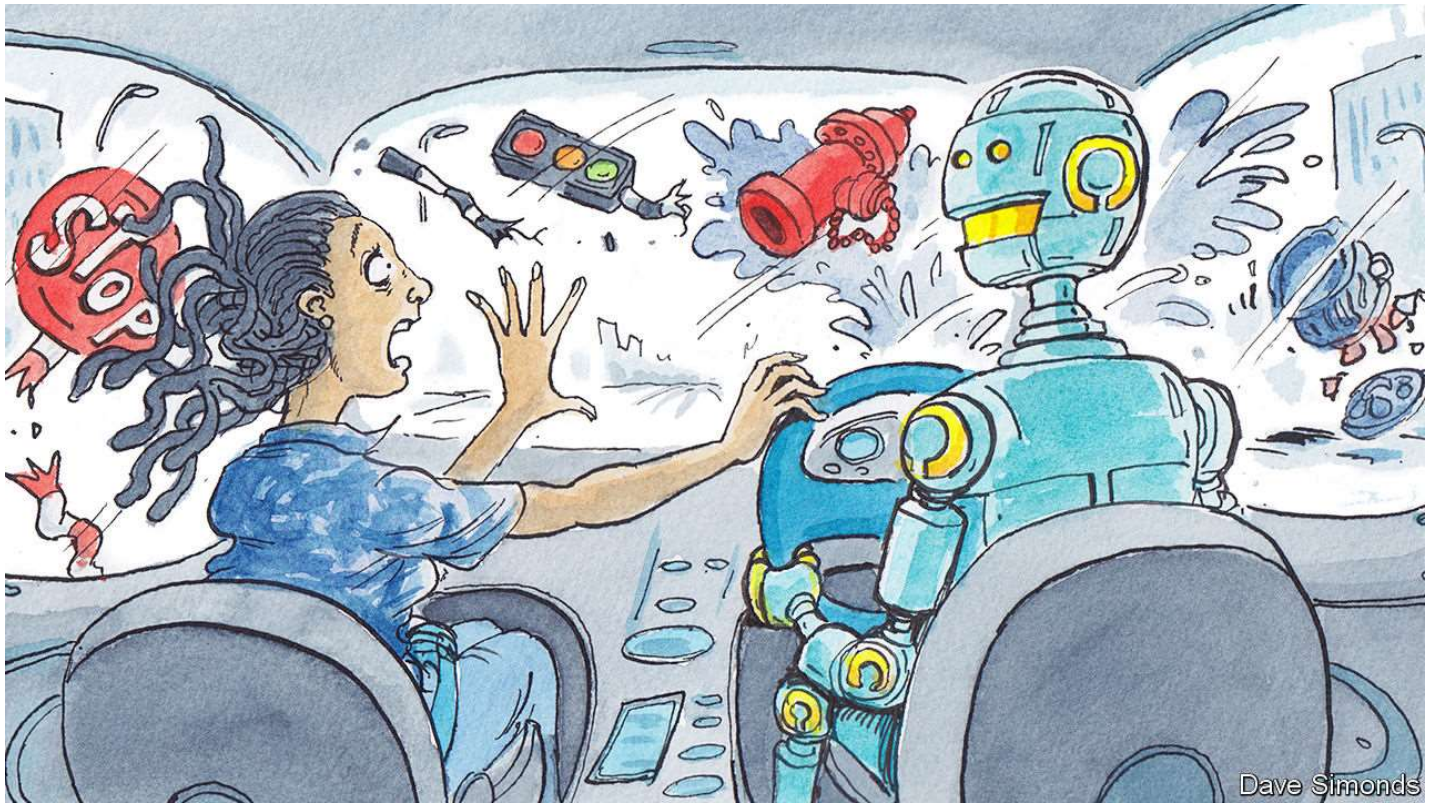
- If intersecting trajectories are indicated, driver is warned.

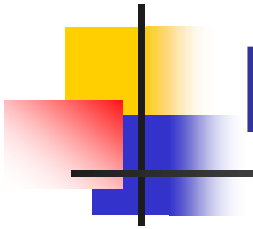
Liability

- Will courts treat autonomous vehicles as drivers and apply a negligence standard or as sophisticated technology and apply a product liability standard?
- How will liability be apportioned?
  - Fleet Operator/Service Providers
  - Vehicle manufacturers
  - Technology companies/software manufacturers
  - Local government's responsible for maintaining infrastructure

Robotic Rules of the Road

- Policy issues, formats, and standards





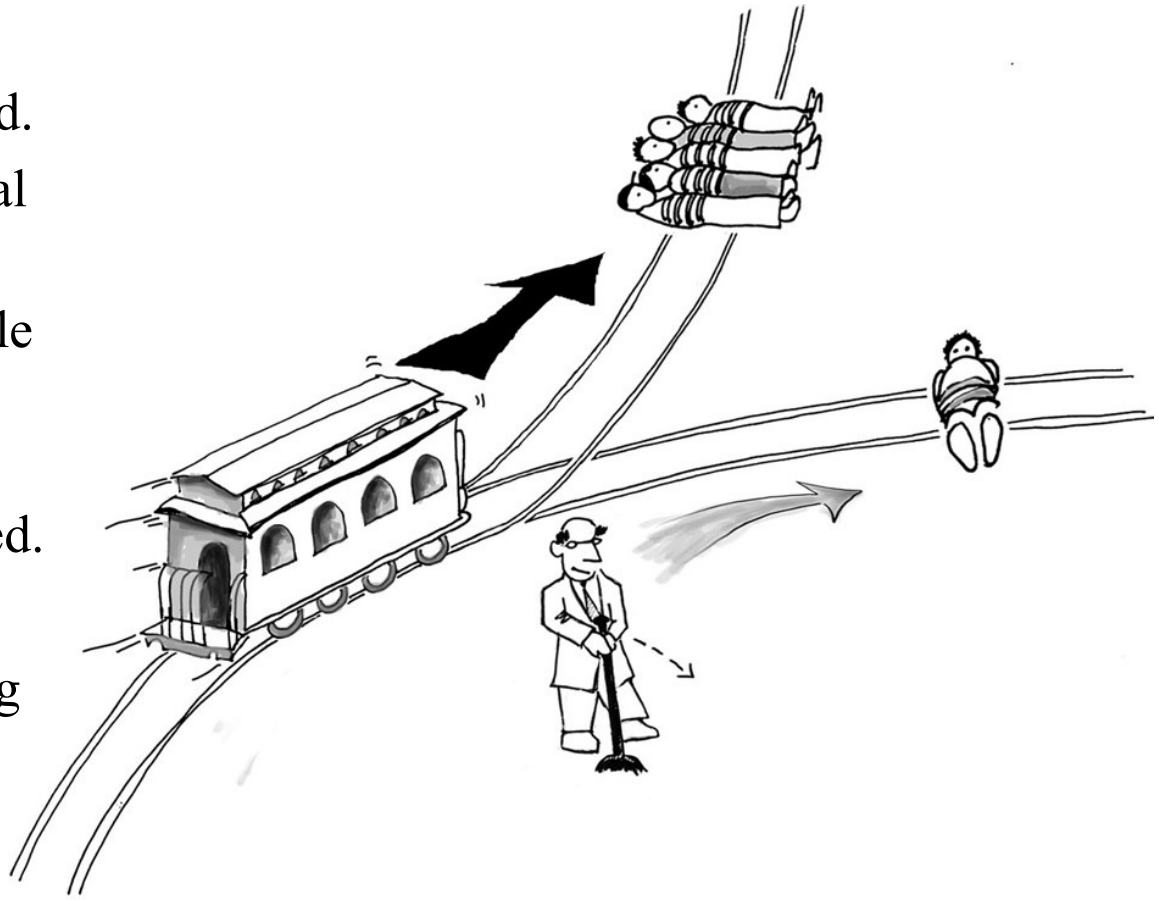
Ethical Considerations

"Human drivers may be forgiven for making an instinctive but nonetheless bad split-second decision, such as swerving into incoming traffic rather than the other way into a field. But programmers and designers of automated cars don't have that luxury, since they do have the time to get it right and therefore bear more responsibility for bad outcomes."

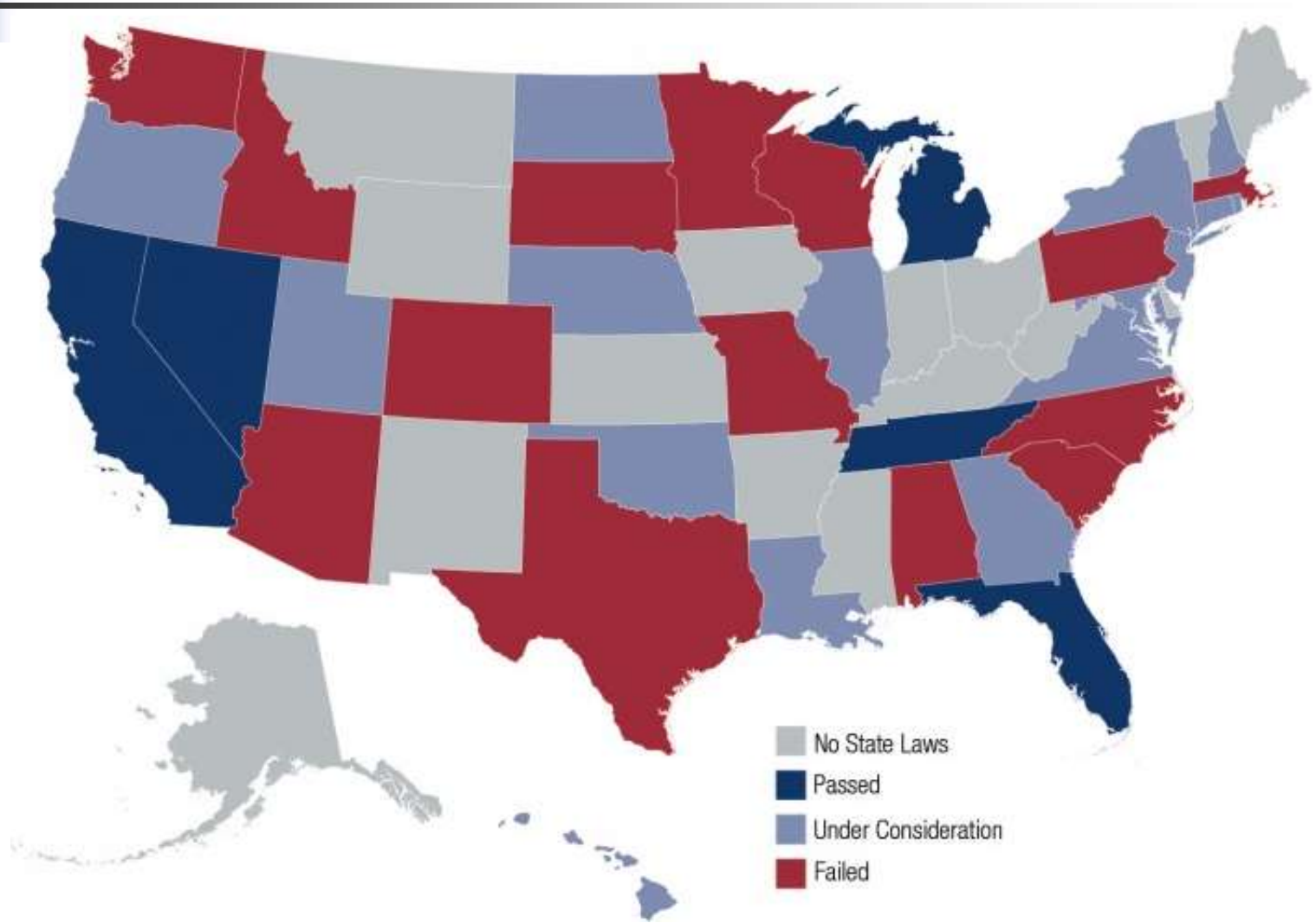
- Patrick Lin, The Atlantic

The Trolley Problem

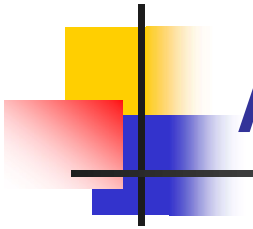
- A trolley's brakes have failed.
- You are controlling the signal switch.
- If you do nothing, five people will be killed.
- If you activate the switch, only one person will be killed.
- What do you choose to do?
- Critical distinction: Allowing death versus causing death?



State Laws



Computing Platforms for Autonomous Cars



- NVIDIA Tools for Autonomous Cars:
  - https://www.nvidia.com/en-us/self-driving-cars/drive-platform/
- NVIDIA Jetson TX1:
  - 64-bit ARM quad-core 1.91 GHz processor
  - 4 GB of DRAM memory
  - An integrated Maxwell GPU (shares DRAM with host CPU), 256 cores split into two streams)
- NVIDIA Jetson TX2
  - Six-core heterogeneous ARMv8 CPU
  - 8 GB of DRAM
  - An integrated Pascal GPU

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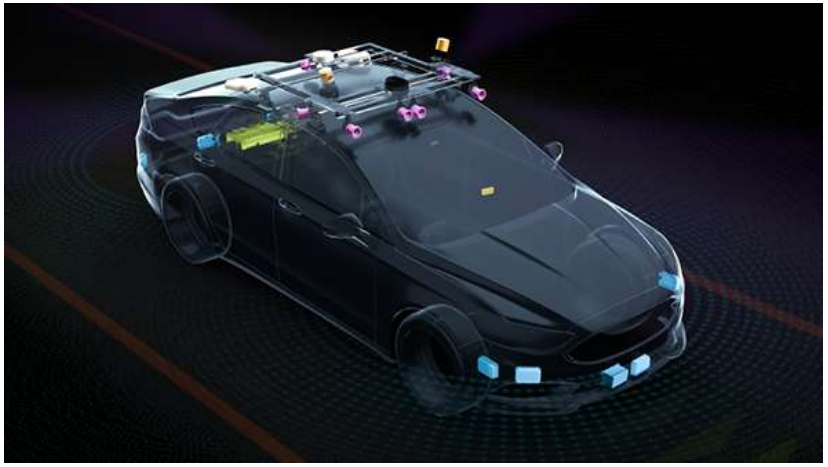
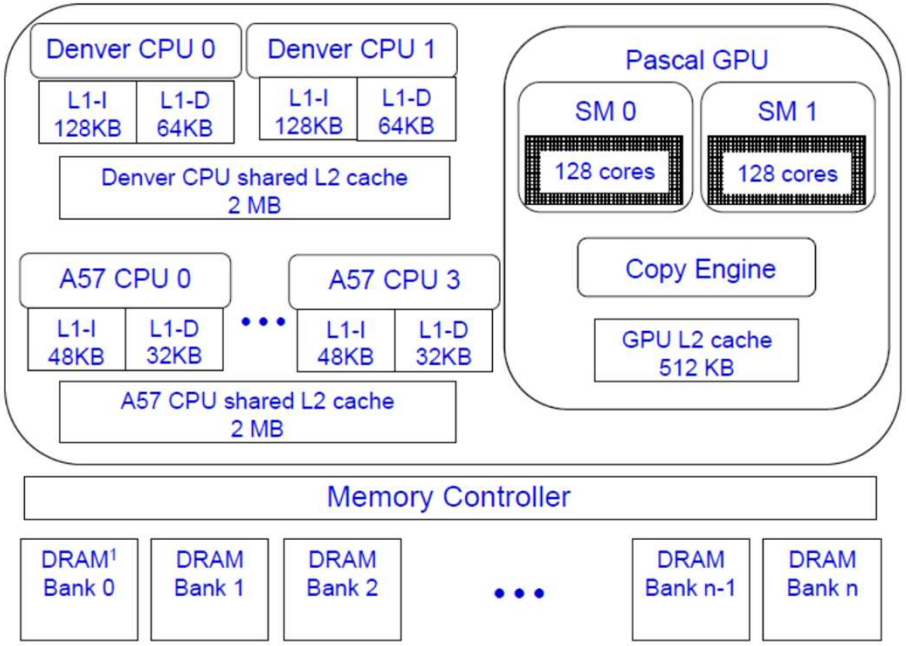
Computing Support for Autonomous Cars

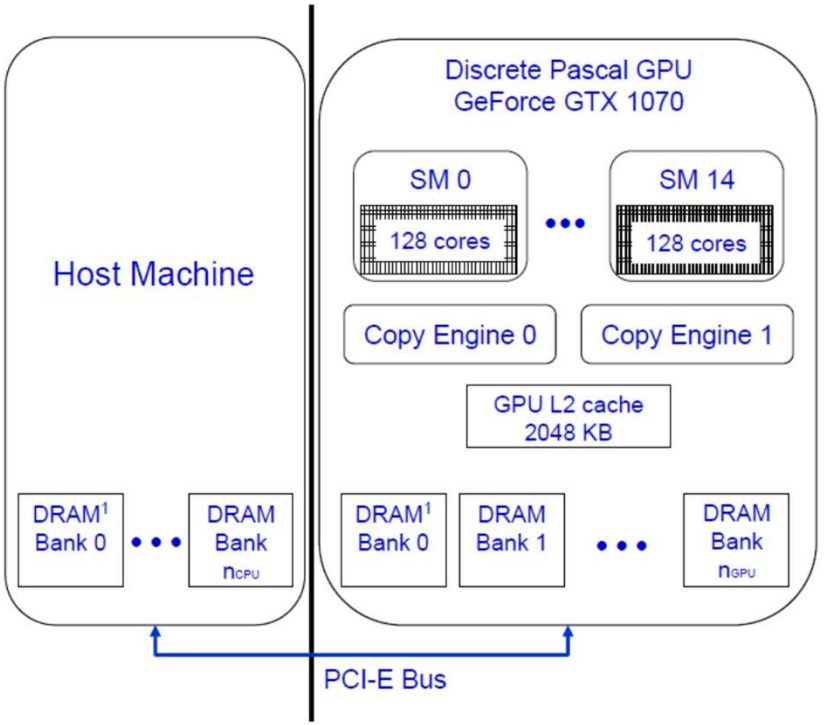
- GPUs
- Reference architecture
- Simulators



GPU: NVIDIA Jetson TX2

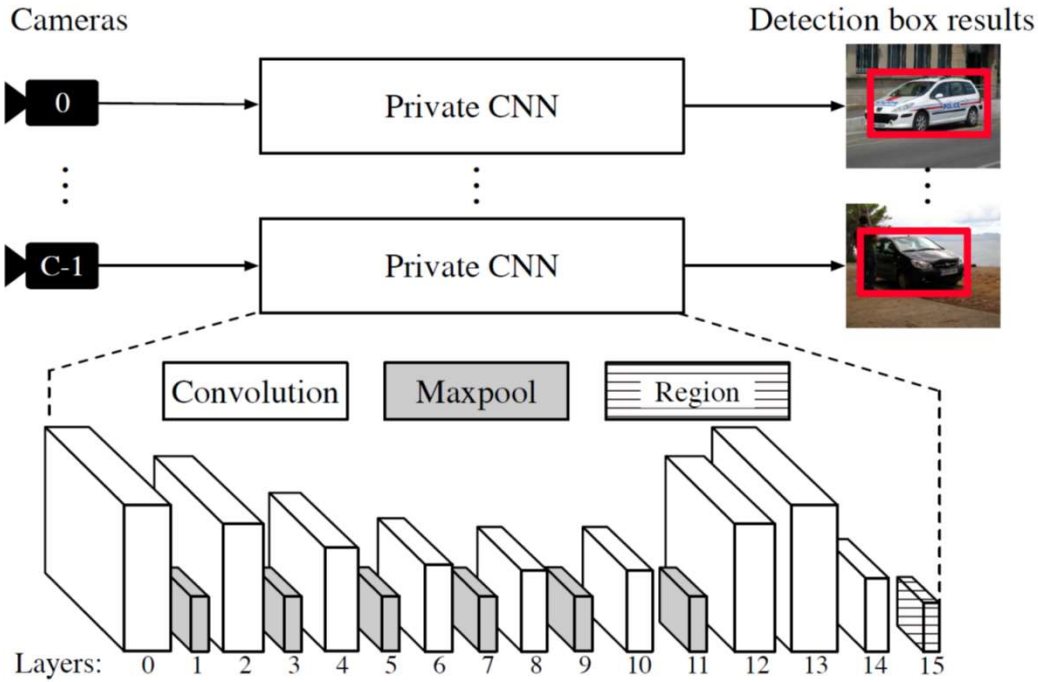


[1]DRAM bank count and size depend on device package



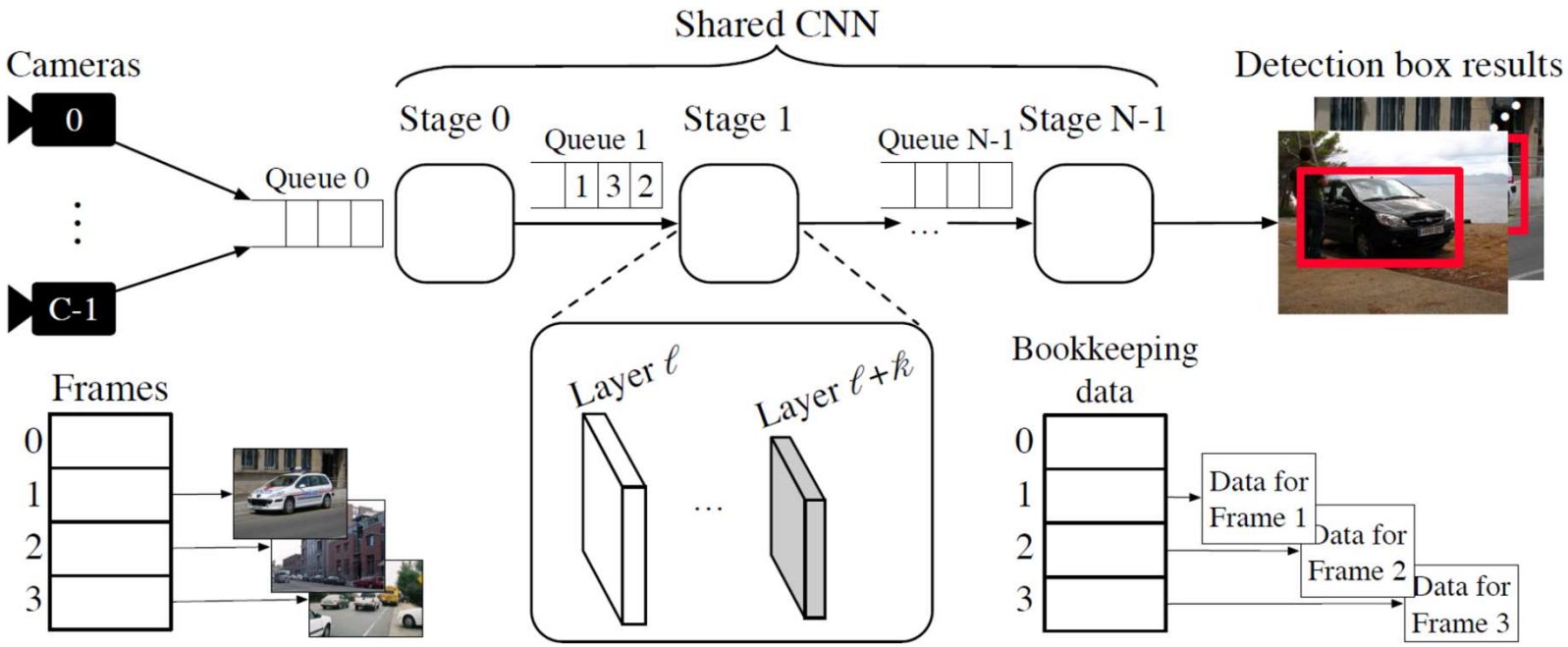
"AI" for Autonomous Cars

- Deep neural networks are being considered a promising candidate for machine intelligence and machine vision for autonomous driving



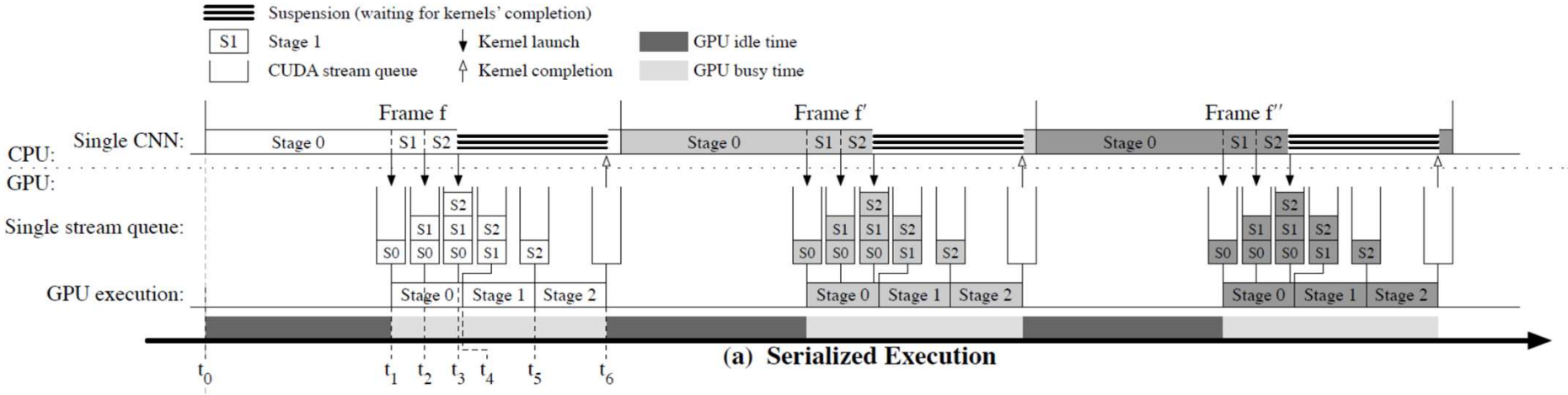
Sharing AI Tasks

- A single hardware platform may handle multiple AI streams, raising scheduling questions



Scheduling AI Tasks

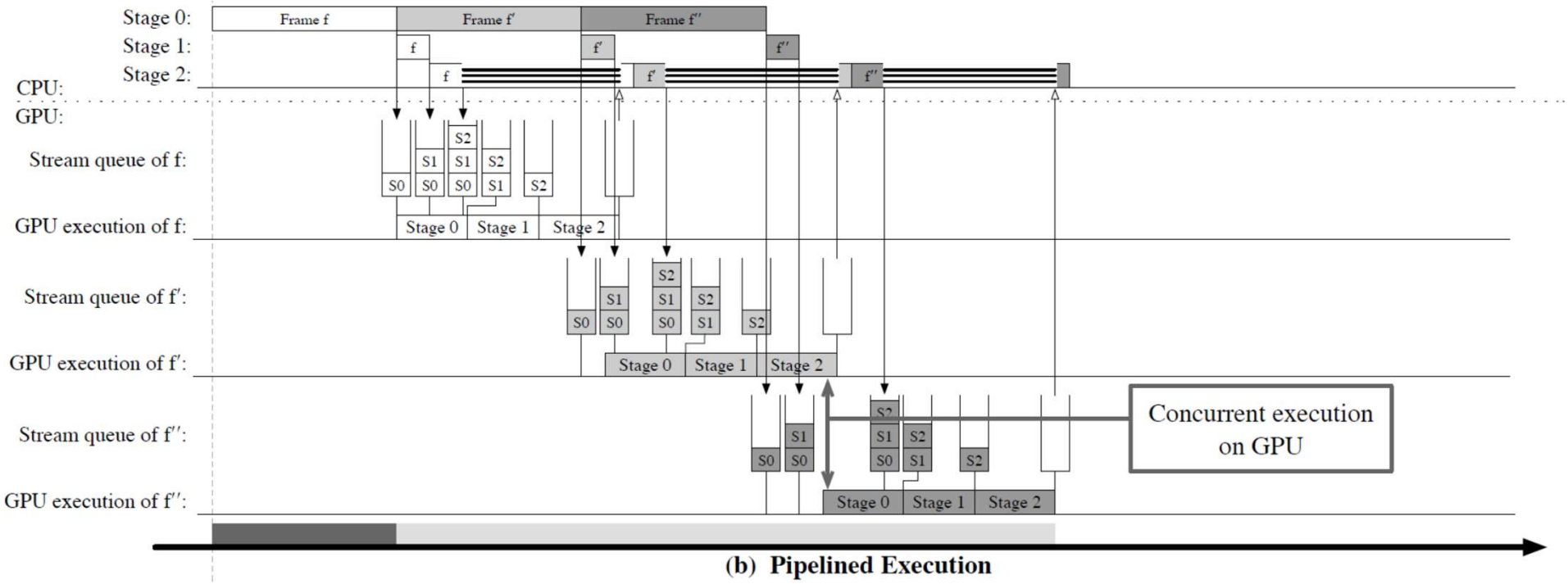
Option 1: Serialized execution



Courtesy of Ming Yang et al. "Re-thinking CNN Frameworks for Time-Sensitive Autonomous-Driving Applications: Addressing an Industrial Challenge" RTAS 2019

Scheduling AI Tasks

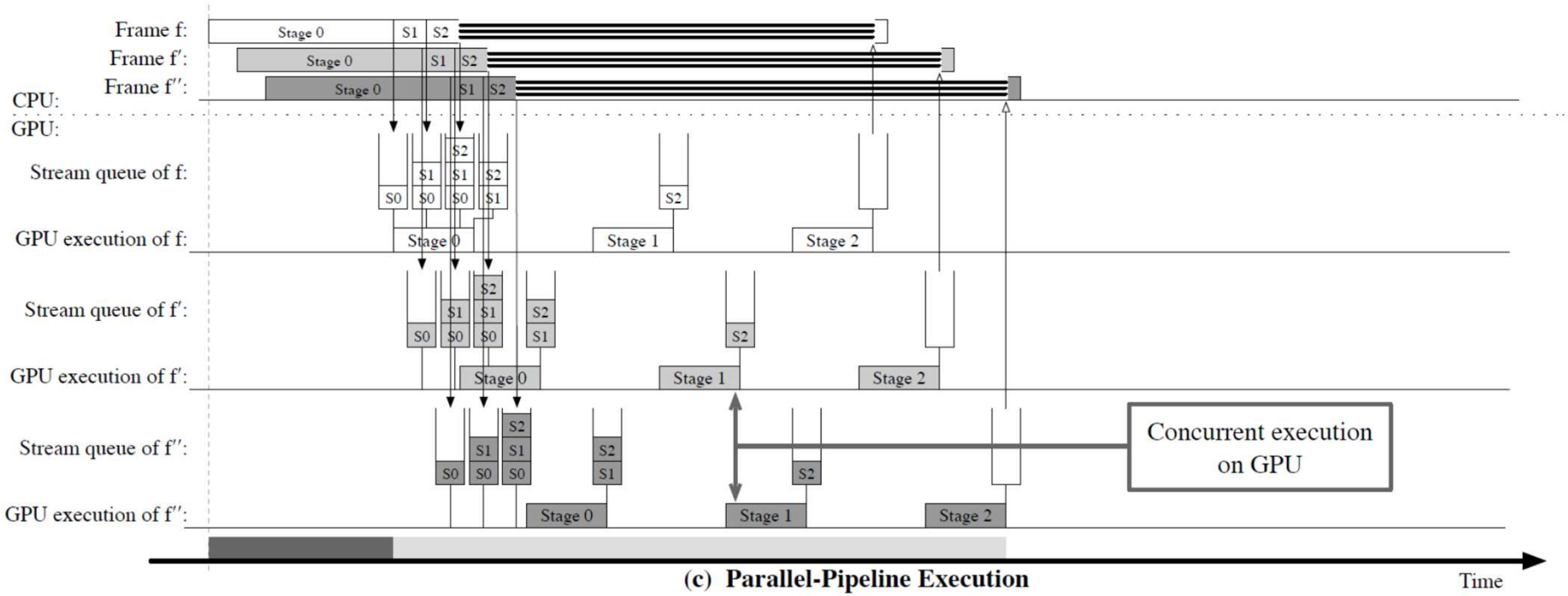
Option 2: Pipelined execution



Courtesy of Ming Yang et al. "Re-thinking CNN Frameworks for Time-Sensitive Autonomous-Driving Applications: Addressing an Industrial Challenge" RTAS 2019

Scheduling AI Tasks

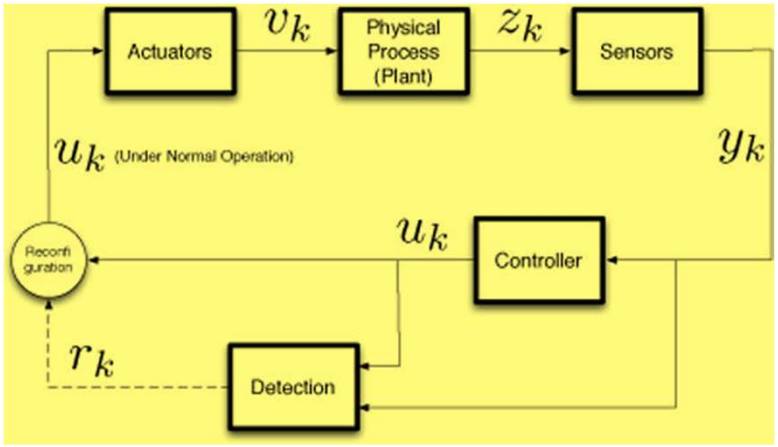
Option 3: Parallel pipeline execution

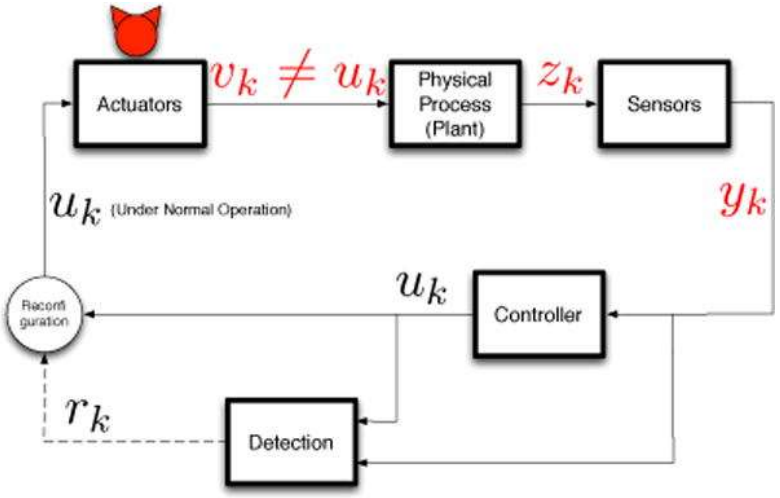


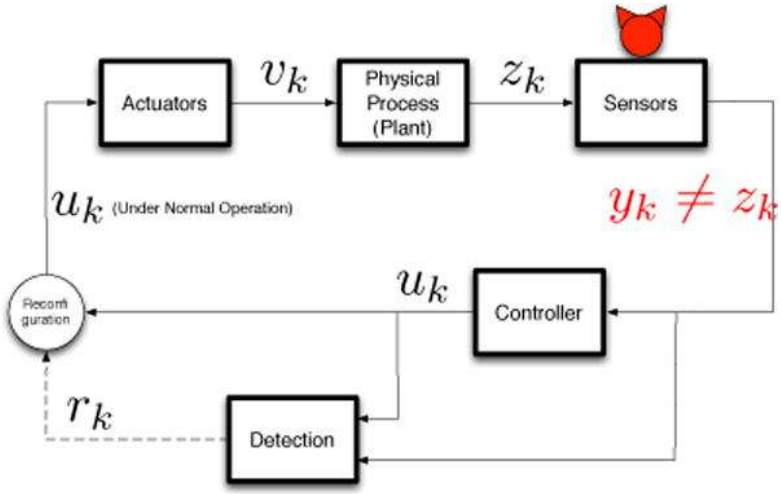
Courtesy of Ming Yang et al. “Re-thinking CNN Frameworks for Time-Sensitive Autonomous-Driving Applications: Addressing an Industrial Challenge” RTAS 2019

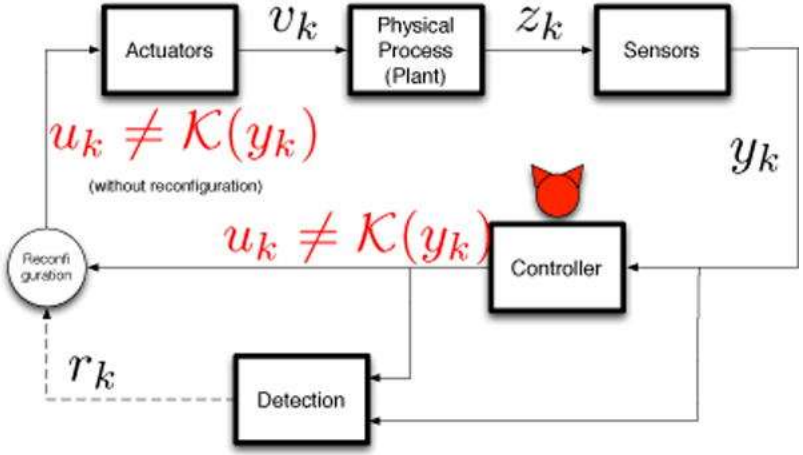
Security Threats

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6512826/

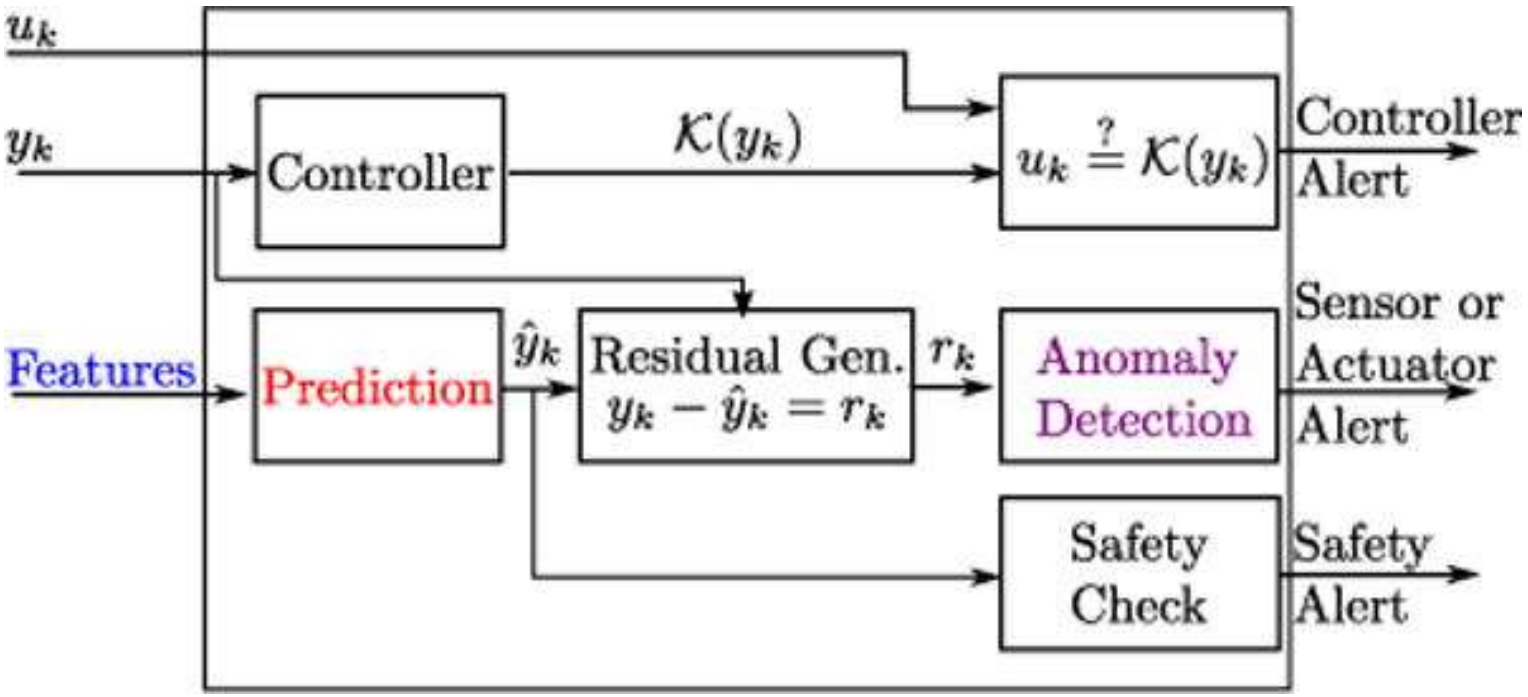








Exploiting Physical Properties to Detect Attack



https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6512826/

Exploiting Timing Properties to Detect Attack

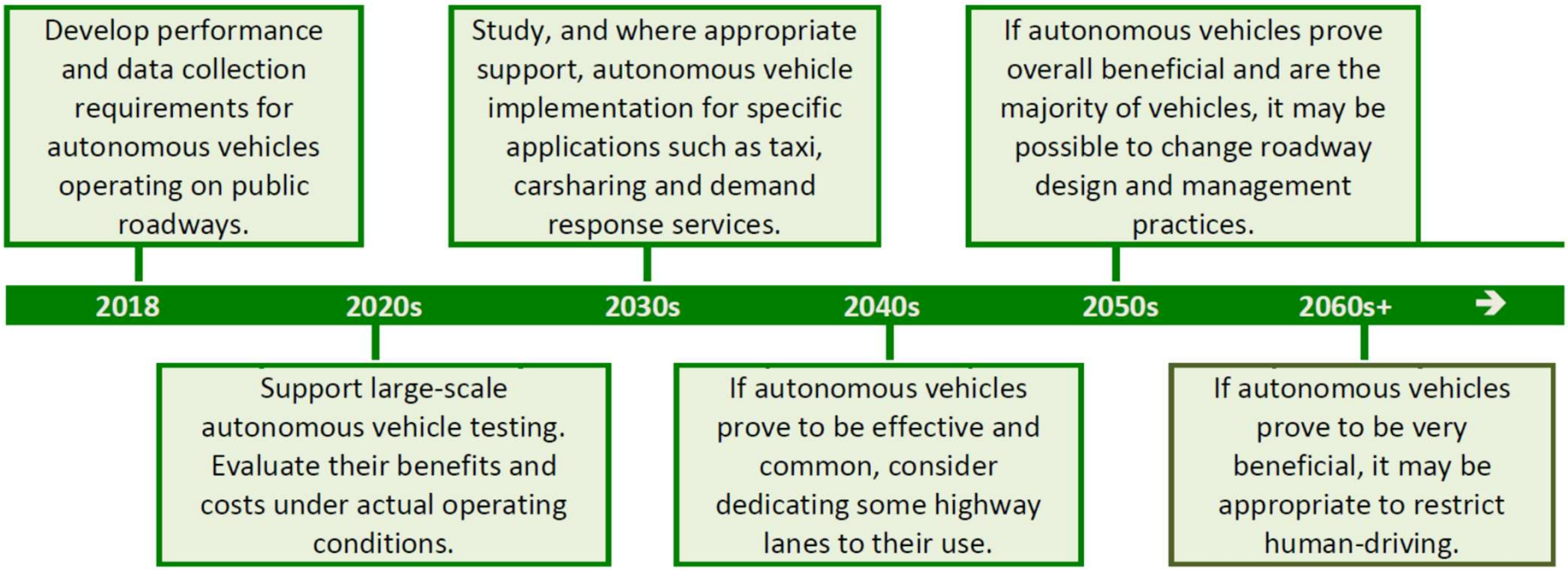
Insight:

- Intrusion will modify timing.
- Modified timing can be detected by an external observer.
- A secure core can watch code timing of other cores

Chkpt. #	No Injection			Code Injection		
	WCET	Actual	Chkpt	WCET	Actual	Chkpt
Chkpt 0 - 1	3	2	pass	3	2	pass
Chkpt 1 - 1	5	3	pass	5	3	pass
Chkpt 1 - 2	7	5	pass	7	5	pass
Chkpt 2 - 2	4	3	pass	4	3	pass
Chkpt 2 - 3	3	2	pass	3	16	fail

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6512826/

The Future


Develop performance and data collection requirements for autonomous vehicles operating on public roadways.
Study, and where appropriate support, autonomous vehicle implementation for specific applications such as taxi, carsharing and demand response services.
If autonomous vehicles prove overall beneficial and are the majority of vehicles, it may be possible to change roadway design and management practices.
2018
2020s
2030s
2040s
2050s
2060s+
Support large-scale autonomous vehicle testing. Evaluate their benefits and costs under actual operating conditions.
If autonomous vehicles prove to be effective and common, consider dedicating some highway lanes to their use.
If autonomous vehicles prove to be very beneficial, it may be appropriate to restrict human-driving.