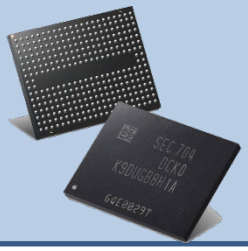
Data Storage in Cars



A car can generate about 25GB of data every hour and as much as 4TB a day, according to some estimates. This data is estimated to be worth as much $750B by 2030. Even without autonomous vehicles or everything electrified, cars have many computer systems and technologies controlling and storing data. DRAM and NAND solutions to handle these processes.

DRAM tends to be faster, with greater bandwidth for adaptive driving technologies while NAND is slower, nonvolatile memory - integral to navigation, customization, accident and collision information.

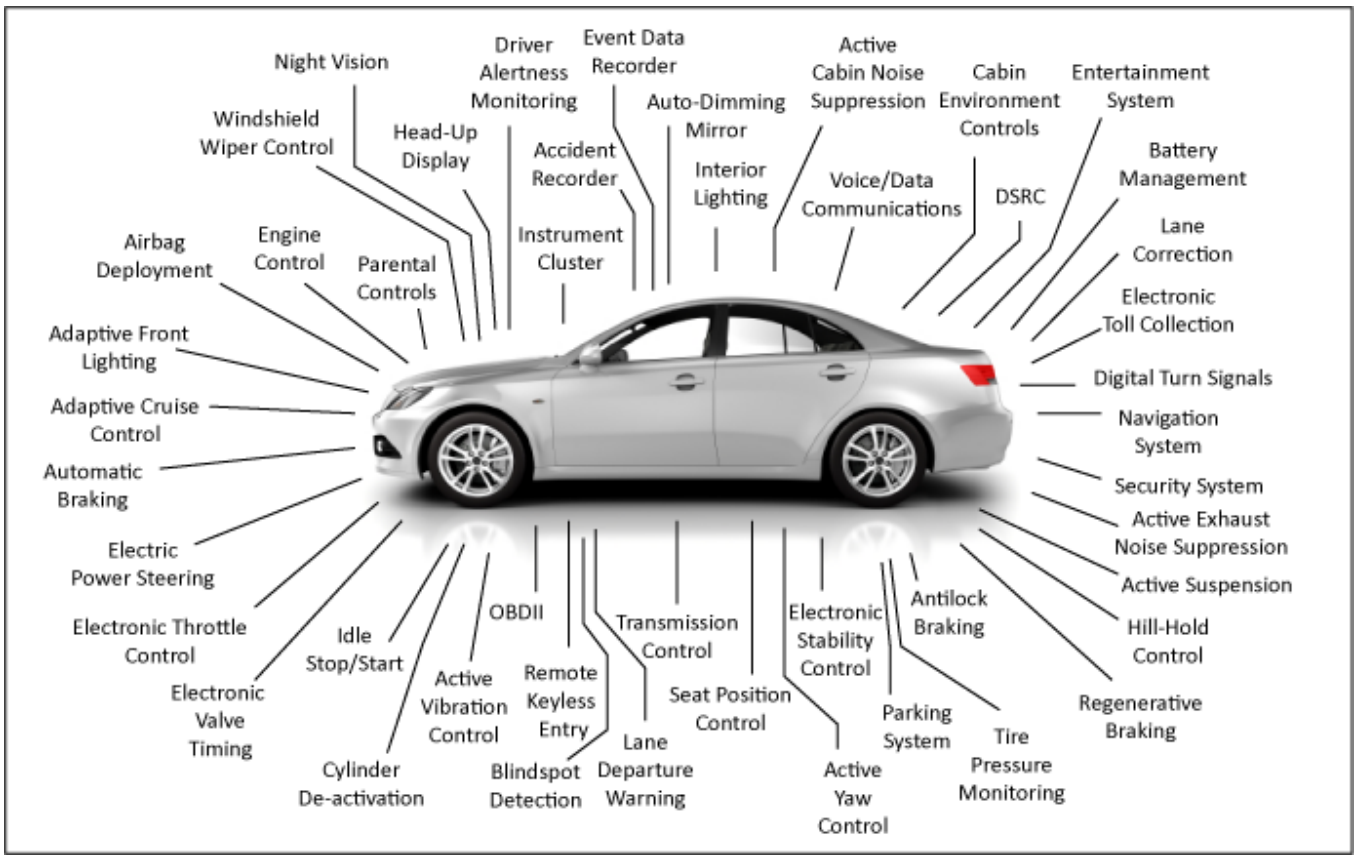
The largest NAND flash memory manufacturers: Samsung – 29.9%, Kioxia – 20.2%, Micron Technology– 16.5%, Western Digital (SanDisk) – 14.9%, SK Hynix – 9.5%, Intel – 8.5%.

UFS (Universal Flash Storage) – responsive, advanced flash memory, multitask, durable, scalable.

eMMC (Embedded Multi-Media Card) – low cost, faster than SD Cards for smaller datasets, fragile.

Tesla will recall every Model S and Model X vehicle shipped with an 8GB eMMC NAND flash chip. NAND flash is rated for a fixed number of write cycles and the amount of data logged by Tesla cards will wear out the NAND flash, causing failure of the Medial Control Unit, which controls the rearview camera display, defrost/defog, and exterior turn signal lighting).

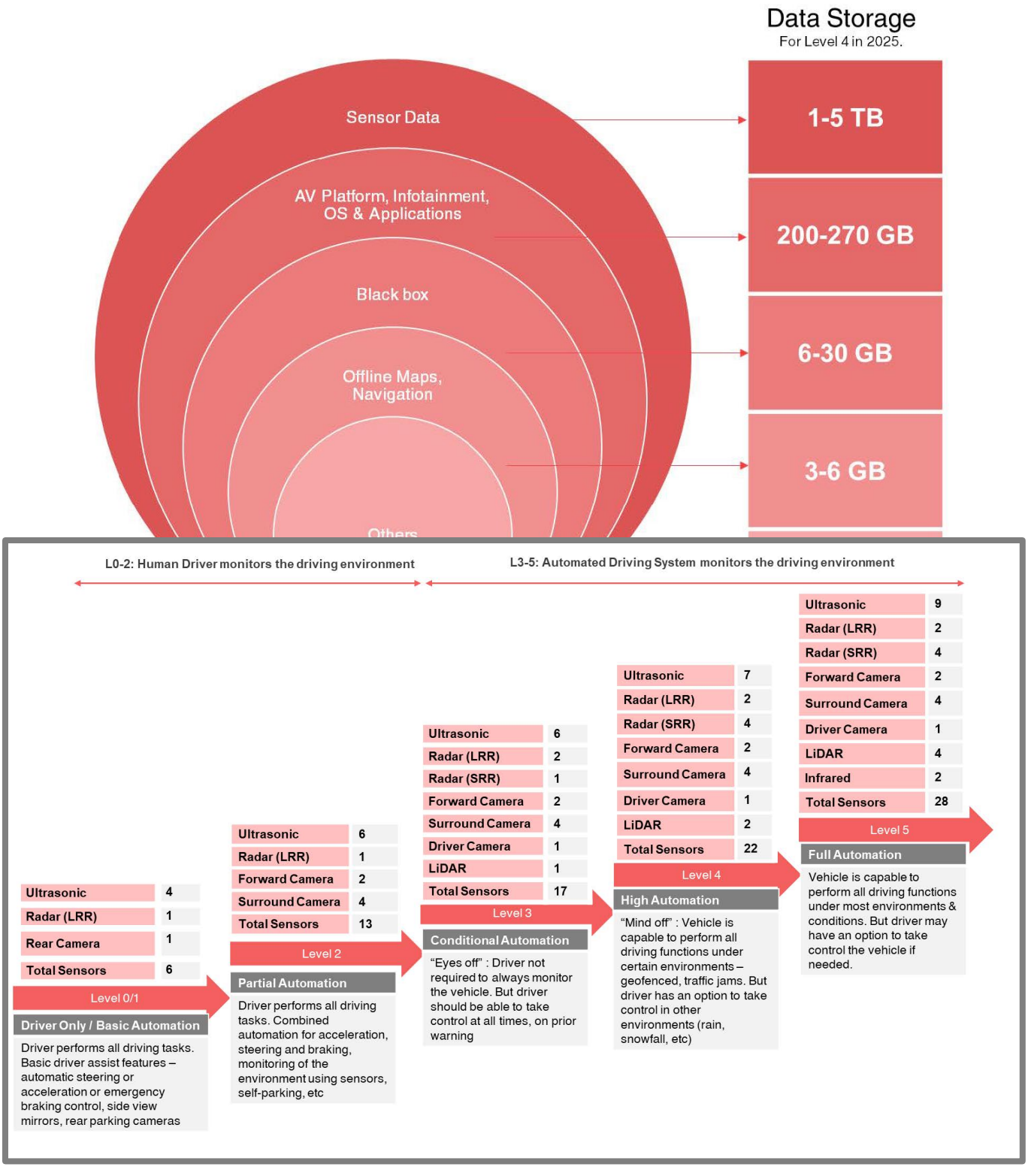
SD Card – faster for large files, handle shock well, reliable (however temperature, power supply and stability all have a significant impact on SD memory card storage reliability), power efficient, long lasting, easy to use - to swap, update, replace.



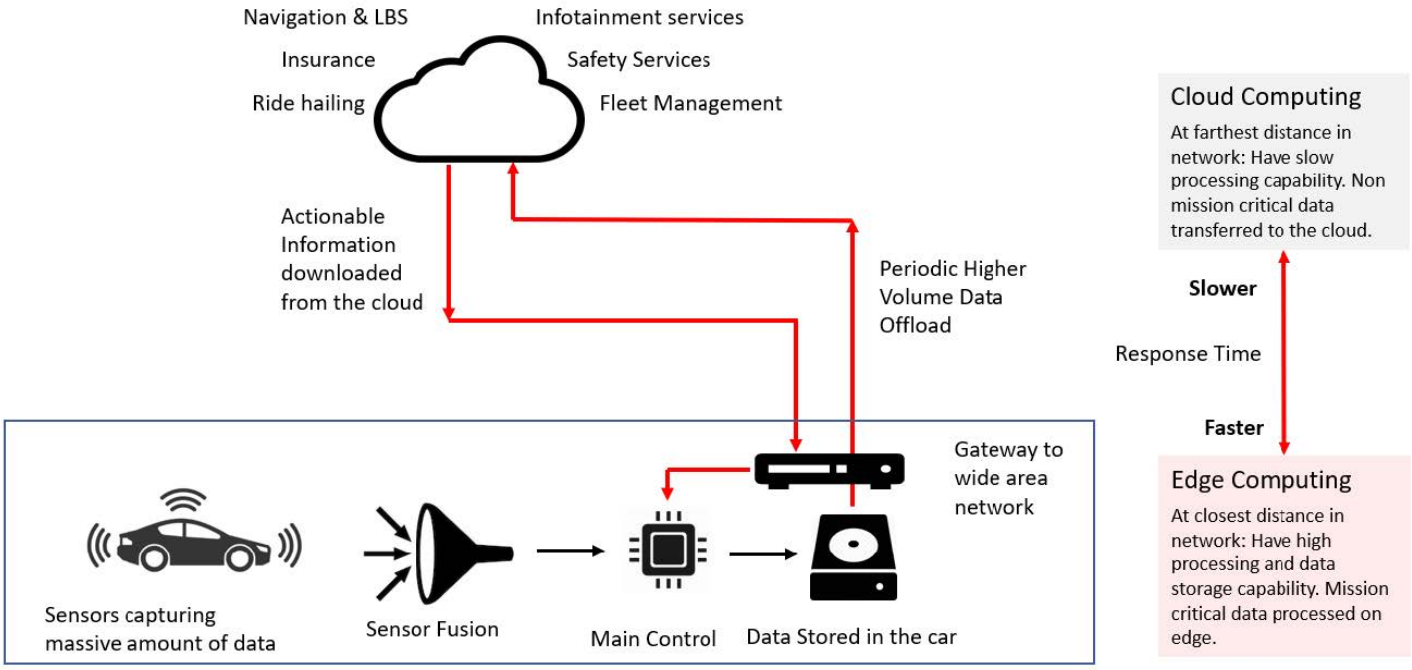
Now, Change the Data Storage Equation to Factor in EVs & Autonomous Vehicles

The United States is moving full speed ahead on development of electric vehicles. For us, smart grids may address climate change objectives via smart cities, utilities, and EVs, with little emphasis on a move to mass transit. In the US, 75% of commuters drive alone. China had no rapid transit through 1990 but now has 25 cities with comprehensive rail. The US has 34 miles (total) of high-speed rail. The US spent more than $47 billion on 1,200 miles of new and expanded transit lines from 2010 to 2019 (mostly on bus routes). The United States constructed over 870K miles of roads between 1950 and 2017 (to the moon and back – almost twice). Cities such as Dallas and Portland have light rail systems and several other large cities have combined light and commuter rail. Contrast that with the Grand Paris Express and Crossrail in London, each with ridership in the millions each day.

The fact is that people in the states do not rely on mass transit the way they do in other parts of the world. Data storage and computing infrastructure needs for vehicles are rapidly changing. The storage requirements for electric vehicles will range from 2TB to 11TB to support different automotive autonomy levels. Vehicles will be designed to gather, process, and store more and more data, both locally as uploaded to the cloud.


Data Storage
For Level 4 in 2025.
Sensor Data
AV Platform, Infotainment, OS & Applications
Black box
Offline Maps, Navigation
Others
1-5 TB
200-270 GB
6-30 GB
3-6 GB
L0-2: Human Driver monitors the driving environment
L3-5: Automated Driving System monitors the driving environment
Ultrasonic 4
Radar (LRR) 1
Rear Camera 1
Total Sensors 6
Level 0/1
Driver Only / Basic Automation
Driver performs all driving tasks. Basic driver assist features – automatic steering or acceleration or emergency braking control, side view mirrors, rear parking cameras
Ultrasonic 6
Radar (LRR) 1
Forward Camera 2
Surround Camera 4
Total Sensors 13
Level 2
Partial Automation
Driver performs all driving tasks. Combined automation for acceleration, steering and braking, monitoring of the environment using sensors, self-parking, etc
Ultrasonic 6
Radar (LRR) 2
Radar (SRR) 1
Forward Camera 2
Surround Camera 4
Driver Camera 1
LiDAR 1
Total Sensors 17
Level 3
Conditional Automation
"Eyes off" : Driver not required to always monitor the vehicle. But driver should be able to take control at all times, on prior warning
Ultrasonic 7
Radar (LRR) 2
Radar (SRR) 4
Forward Camera 2
Surround Camera 4
Driver Camera 1
LiDAR 2
Total Sensors 22
Level 4
High Automation
"Mind off" : Vehicle is capable to perform all driving functions under certain environments – geofenced, traffic jams. But driver has an option to take control in other environments (rain, snowfall, etc)
Ultrasonic 9
Radar (LRR) 2
Radar (SRR) 4
Forward Camera 2
Surround Camera 4
Driver Camera 1
LiDAR 4
Infrared 2
Total Sensors 28
Level 5
Full Automation
Vehicle is capable to perform all driving functions under most environments & conditions. But driver may have an option to take control the vehicle if needed.

There will be infrastructure needs for transmission of stored data to the cloud to build machine learning models and drive new services. Level 3 and above autonomous vehicles will use a combination of cloud and edge computing to optimize the requirements of AI computing systems, real-time response, and transmission costs. Experts believe in-vehicle storage will move from SLC/MLC NAND to UFS/embedded SSD for Level 3 to Level 5 autonomous vehicles.



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