Infotainment in the Age of the Autonomous Vehicle

Storage Considerations

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Autonomous Vehicles

- Strategy Analytics' Autonomous Vehicles service has developed three scenarios for AV deployment. The "standard" scenario is shown in the included slides.

- Strategy Analytics forecasts significant near-term growth in the number of vehicles produced with L2 capabilties (i.e. ADAS) and modest growth in those with L3 capabilties.

- L4-L5 autonomous vehicles don't go into higher volume production (defined as millions of vehicles) until 2030.

SAE Automated Driving Levels

Level	Automation Type	Examples	Where Operational	If Automation Stops Working
	Driver performs part or all of the dynamic driving task			
0	No driving automation	No driving automation	Not applicable	Not applicable
1	Driver assistance	Adaptive cruise control OR lane centering (driver supervises)	Limited roads or modes	Driver resumes performing all of the dynamic driving task
2	Partial driving automation	Adapdtive cruise control AND lane centering (driver supervises)	Limited roads or modes	Driver resumes performing all of the dynamic driving task
	Automated driving system (ADS) performs all of the driving task			
3	Automated driving (conditional)	Automated driving in dense freeway traffic (low speeds)	Limited area, roads, and/or modes	Driver takes over after warning
4	Automated driving (high)	Automated driving within a city center (geo-fenced)	Limited area, roads, and/or modes	ADS brings vehicle to stop
5	Automated driving (full)	Automated driving anywhere	Everywhere, on-road	ADS brings vehicle to stop

Source: SAE, Auto Alliance

AV Production Forecast

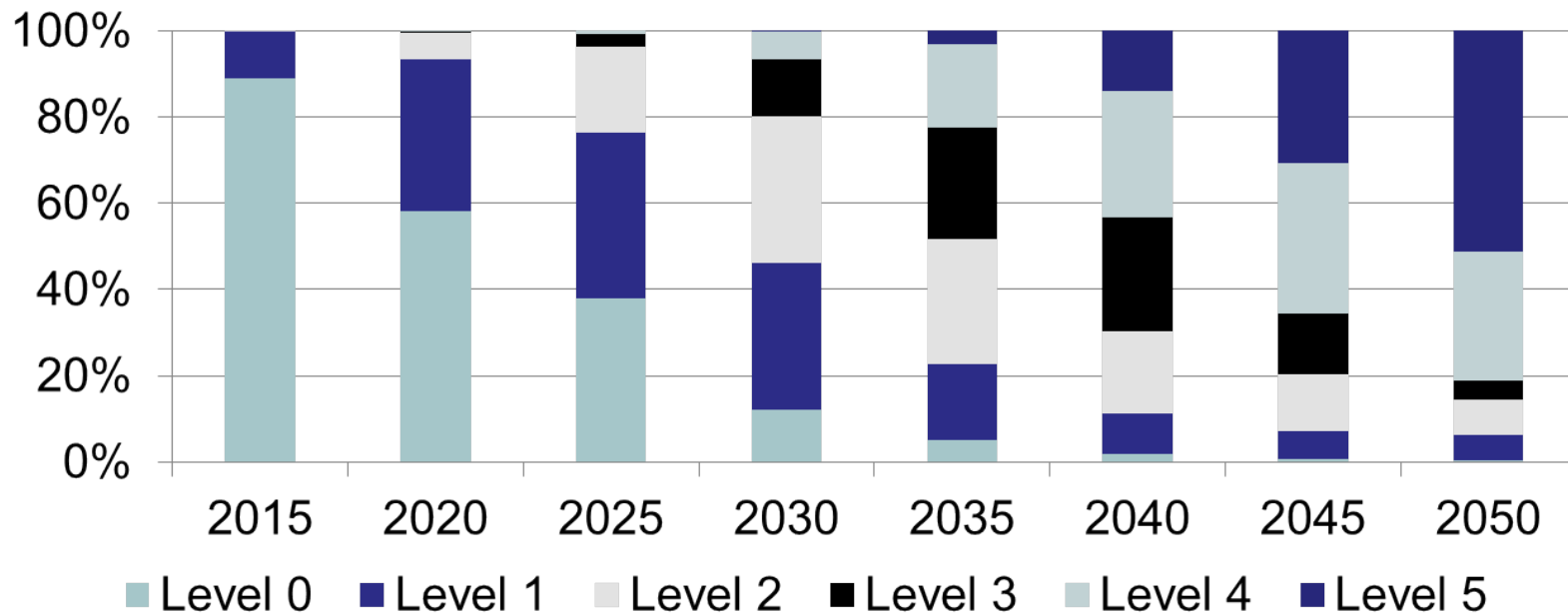## L2 – L5 Vehicle Production, 2015 – 2050, Est.
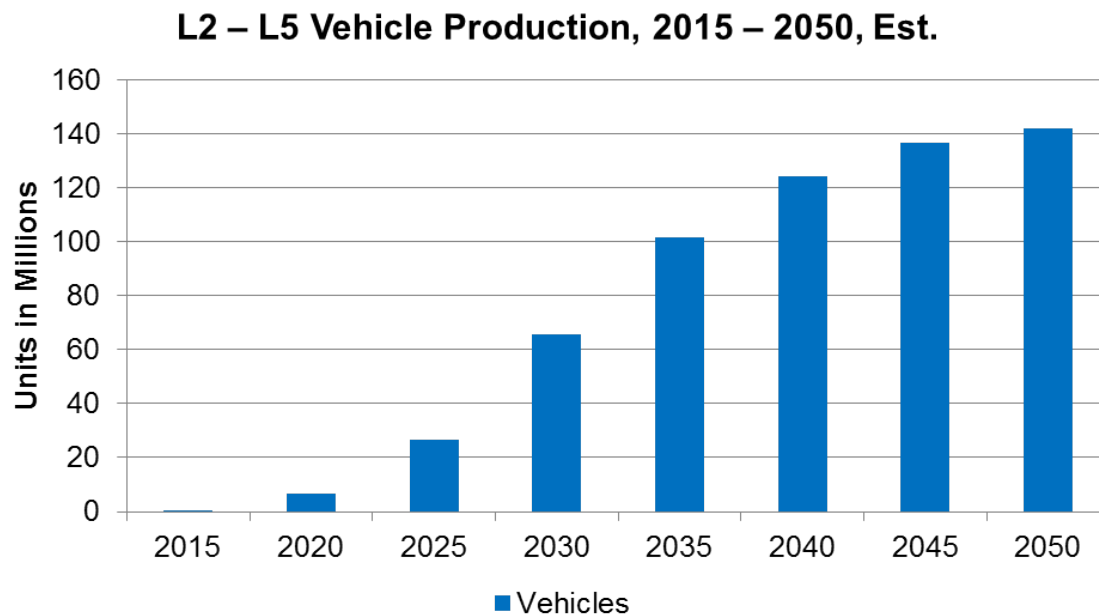
Production of Autonoumous Vehicles

2020: 6.74 million L2, 3, and 4 vehicles. No L5 vehicles in production that year.
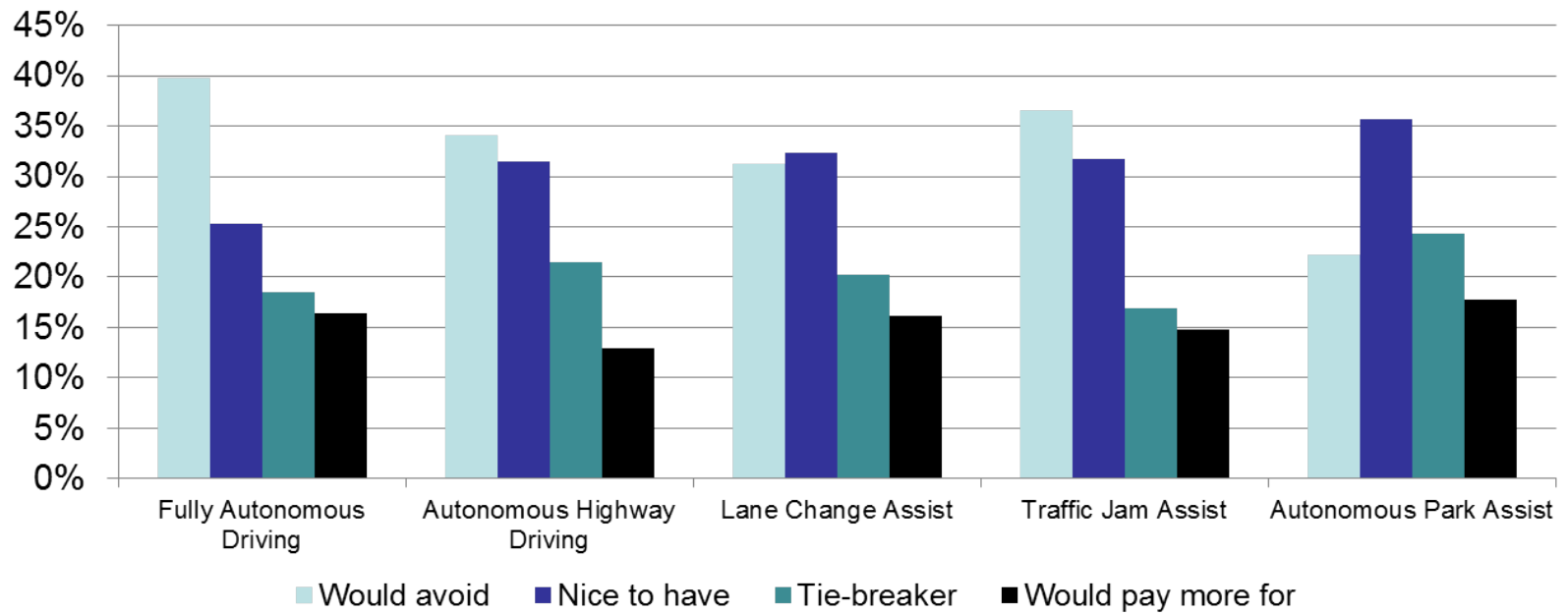
2050: 141.92 million L2, 3, 4, and 5 vehicles

Autonomous Vehicle Forecast by Level

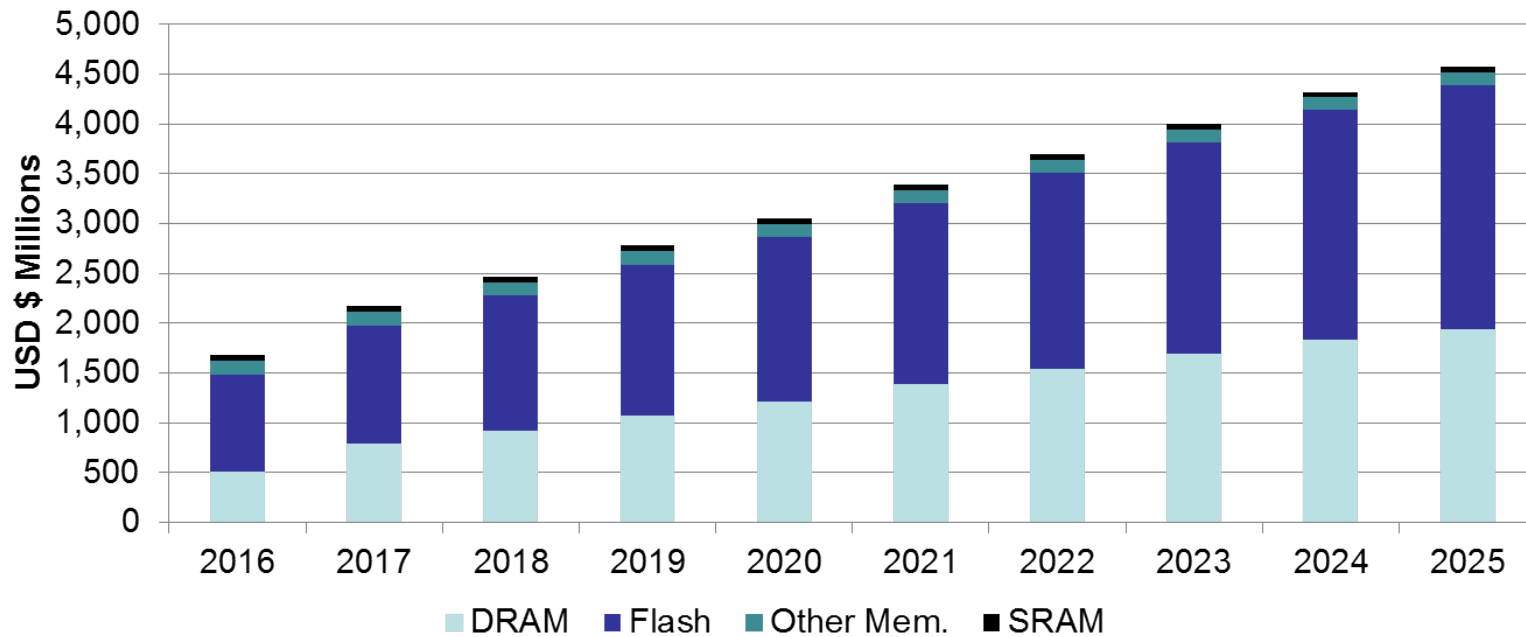# Consumer Opinions of AV Features – U.S. Market

Automotive Memory Demand Forecast

Autonomous Vehicle Levels

Autonomous functionality levels will determine storage requirements

- L4-L5 vehicles largely eliminate the point of private ownership

- L3 vehicles are likely to be privately owned

- Infotainment requirements will be higher for majority of L3 vehicles than L4-L5 vehicles

Software and Data

- Infotainment
  - Navigation application (2.5 – 5 GB)
  - Map data (8 – 13 GB)
  - Media database (4 GB)
  - Other applications (media, smartphone projection, e.g. CarPlay, 2-4 GB, etc.)
  - OS (potentially multiple Oses, 500 MB – 1.5GGB per OS)
  - Hypervisor
  - Voice assistant (embedded client, storage req. varies widely)
  - Middleware
- High-resolution (HD) Map Data
  - Base map (varies widely, MB to GB in size)
  - Road furniture

- Dynamic data layer

- Autonomous Driving Software
  - Perception
  - Planning
  - Control
- Other Software
  - Security software (IDPS, in-vehicle network monitoring, firewall, etc.)
  - OTA client (select ECUs)
  - OTA agents (per ECU)
  - Data collection/processing agents (per ECU)
- Sensor Data
  - Cameras
  - RADAR
  - LIDAR
  - Ultrasonic

Data Collection

Intel Analysis

Autonomous Test Vehicles Raw Data Collection:
- 4TB/hour

Raw Data Collection Breakdown:
- 600GB/hour – radar
- 140GB/hour – lidar
- 3.2TB/hour – camera
- 40G/hour – sonar
- 6GB/hour – CANbus

Costs:
- $1M-$2M /AV vehicle in data center resources
- 10% of global data center infrastructure could be dedicated to connected car in 2030

**Current Production Vehicle Data Collection Rate:**

- 10 kb/km – for regular data collection on mass produced car with connected cam
- Assuming 20,000 km/year = 200 mb/car/year for single forward facing cam
- European OEM is collecting 1 petabyte of data from all cars in U.S. and Europe (8M vehicles, so 125 MB per vehicle)

- Raw vehicle sensor data will be processed on board — only necessary data will be stored or sent to the cloud
- Data may not be offloaded unless connectivity conditions are ideal, e.g. Wi-Fi is available. For example, when an AV returns to a facility for charging or maintenance would be an ideal time to offload non-critical but useful data to reduce bandwidth costs.
- "Black box" and other data storage regulations will need to be realistic (storing all recorded data is feasible for testing, not workable in large-scale fleets)

High-resolution Maps for AVs
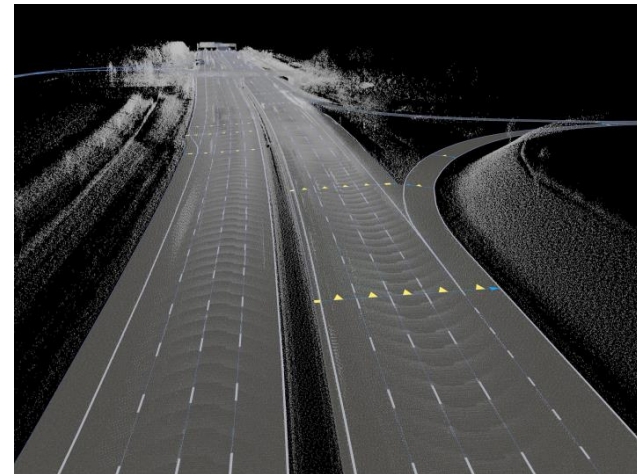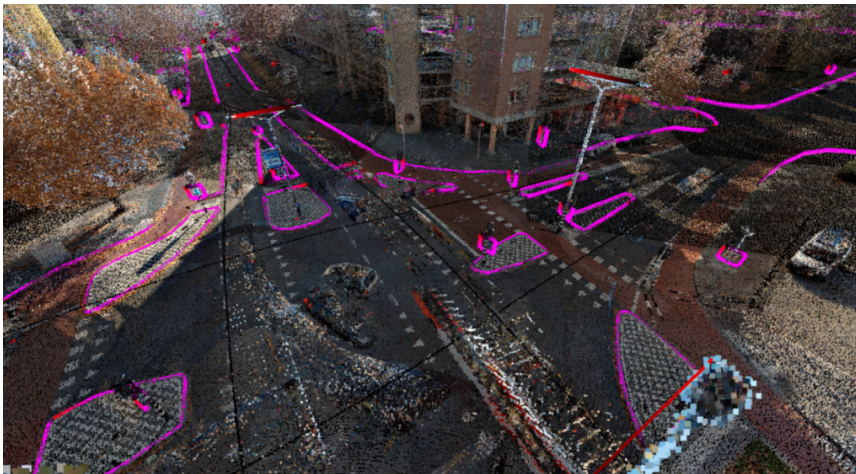
High-resolution map storage requirements vary widely, depending on the methods used to process and extract geospatial data.

Example Requirements:
- Mobileye: 10 kb / km
- Civil Maps: 100 – 300 kb / km

- Continental/Ygomi: 100 kb / km

Map content will be downloaded opportunistically (for specific routes, etc.)

A 100 km (62 mile) route would require 10 MB of storage.

Autonomous Vehicles On-demand Tiered Service Offerings

- Autonomous vehicle transportation service providers will offer different tiers and amenities will vary greatly by tier:
    - Efficient Transportation – Shuttles designed with limited infotainment capabilites, e.g. Wi-Fi hotspot, single interior display to show route information, designed for lower cost use by multiple passengers
    - Individual Pods – Personal space but limited features/functionality due to need to "ruggedize" interior for continuous use
    - Premium Transportation – Personal displays, navigation (destination selection, current route and location, etc.) functionality, Wi-Fi hotspot, hybrid digital assistant, etc.

Autonomous Vehicles

Q: When is a car not a car?

A: When it's autonomous.

The Future?

Many automakers show high-end interiors for their near-term and long-term visions for autonomous vehicles.

- Multiple large displays
- Interior surfaces act as displays
- Vision of the vehicle as an "experience"
- Numerous entertainment experiences available (movies, music, etc., being streamed to the vehicle, cached when connectivity is unavailable)

These features will be limited to vehicles offered via premium services.

- Mercedes' stated IVI system requirements: 64 GB in 2017, 512 GB in 2025

Source: Panasonic

Source: Mercedes-Benz

Source: Byton

Or Not?

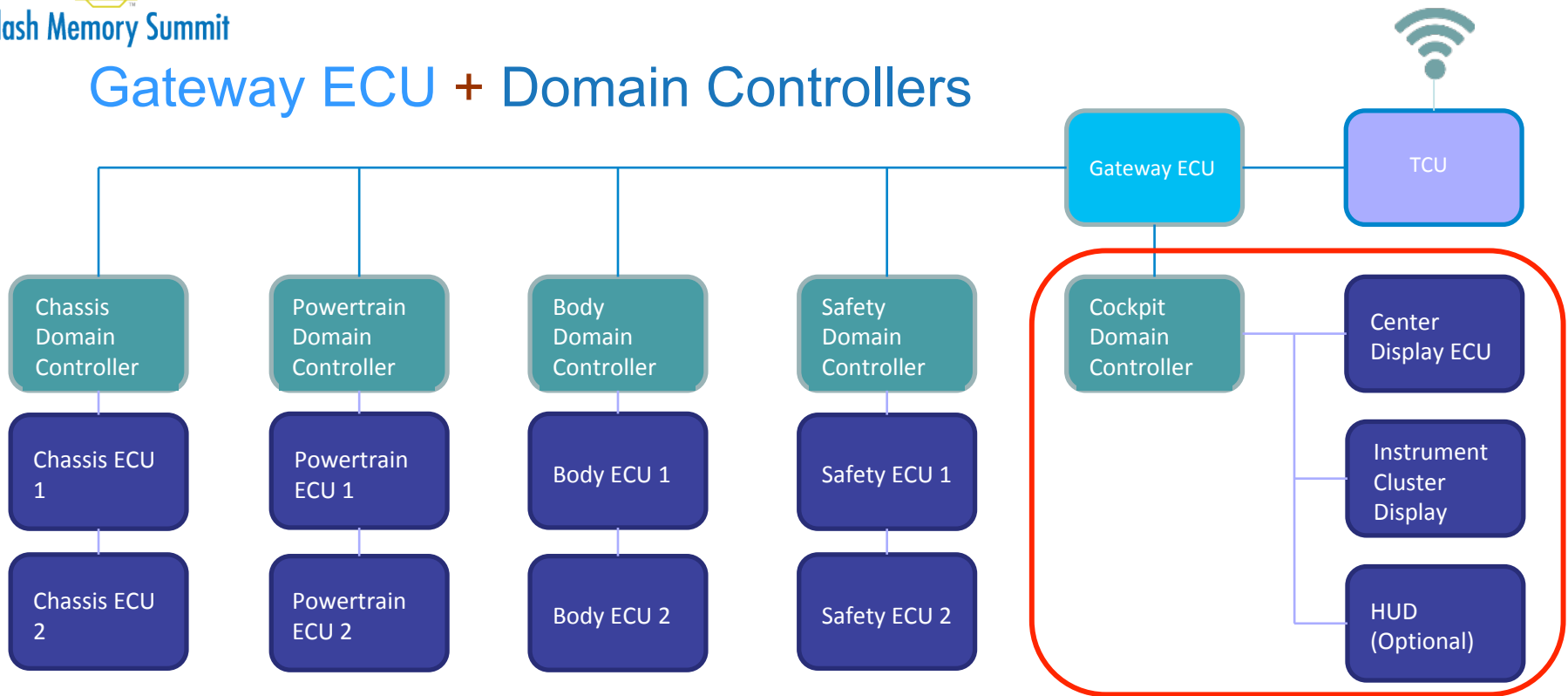Source: Tesla

Source: Strategy Analytics

Automakers, such as Tesla (pictured at left), and Tier 1s, such as Harman (pictured at right), are either installing or offering single display units for vehicles that combine instrument cluster and center display functionality.

Domain Centralization

Gateway ECU + Domain Controllers

Domain Centralization

Cockpit Domain Controller features:

- **Displays:** Support for multiple displays, incl. HUD
- **Radio:** AM/FM, digital radio, satellite radio (potentially)
- **Device Connectivity:** USB, Bluetooth, Wi-Fi
- **Smartphone Projection Support** (e.g. Android Auto, Apple CarPlay)
- **Hypervisor/Multi-core processor**: To support multiple OSes
- **Camera Input** (e.g. for backup cameras, surround view cameras, etc.)
- **Navigation**
- **Voice input/Digital assistants**
- **ADAS alerts** (e.g. as displayed on an instrument cluster)
- **OTA update support:** for navigation, maps, cluster, applications, OS, etc.

Shuttles and Pods

- For typical transportation, shuttles are more efficient, from a utilization standpoint, and cost-effective in terms of interior features and equipment.
- Many companies are focused on shuttles and autonomous pods.
- Large touchscreens, Navya shuttle (lower left image) - Inside 15-inch touchscreen / outside facing screen (2x 38 inch displays)

Source: e.GO Mobile AG/ ZF

Source: Local Motors

Source: Navya

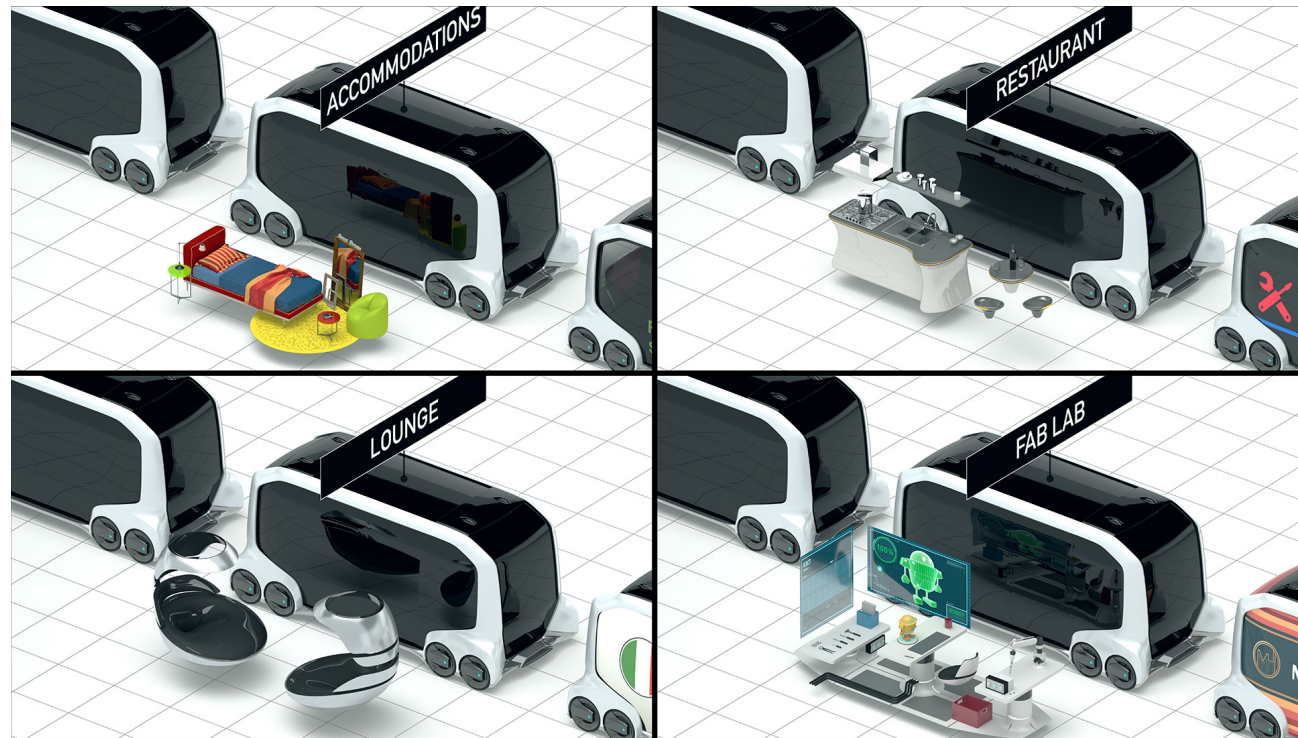Source: Drive.ai

Toyota's e-Palette Platform

Toyota's vision is for fully autonomous (SAE L5) shuttles that can be reconfigured on demand, depending on desired function.

24-hour turnaround to reconfigure a vehicle for a new function.

Functions include:
- Hotel
- Restaurant
- Retail Store
- Transportation
- Micro-factory

Autonomous Vehicles

Thank you!