EVOLUTIONS IN MOBILITY TECHNOLOGY

OBSERVATIONS FROM SOFTWARE DEFINED VEHICLE (SDV) DEVELOPMENT

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  - Digitalization & Product Upgrade
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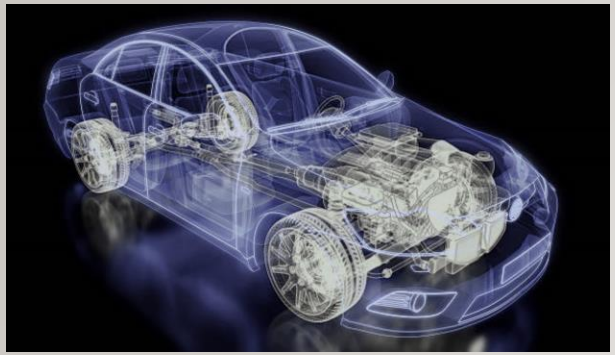
  - Continuous Vs. Linear
- **Execution Headwinds**
  - Cultural, Technical, Organizational
- **Takeaway**

Introduction

Emergence of SDV

EMERGENCE OF SDV – A BRIEF HISTORY



2000: One off device
Day 1: Best version

2010: Smartphone on Wheels
Consumer Desire

C Connected
A Autonomous
S Services
E Electrified

2015: Four Pillars
Smart Mobility

XPENG
LUCID *

NEV

NEW ENERGY VEHICLES

Consumers

Frequent Refresh & New Functions

Vehicle As A Platform

Control & Flexibility

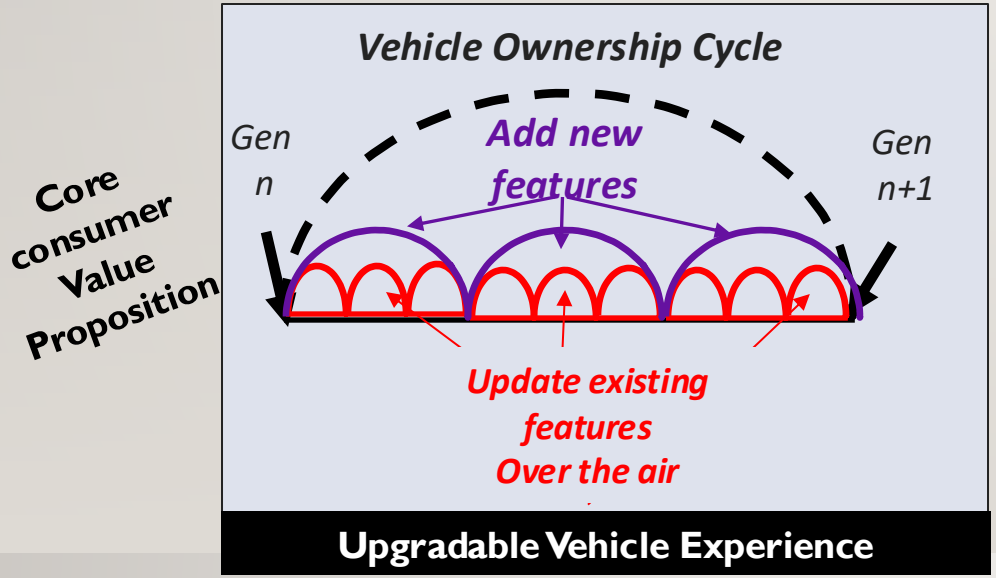
OEMs

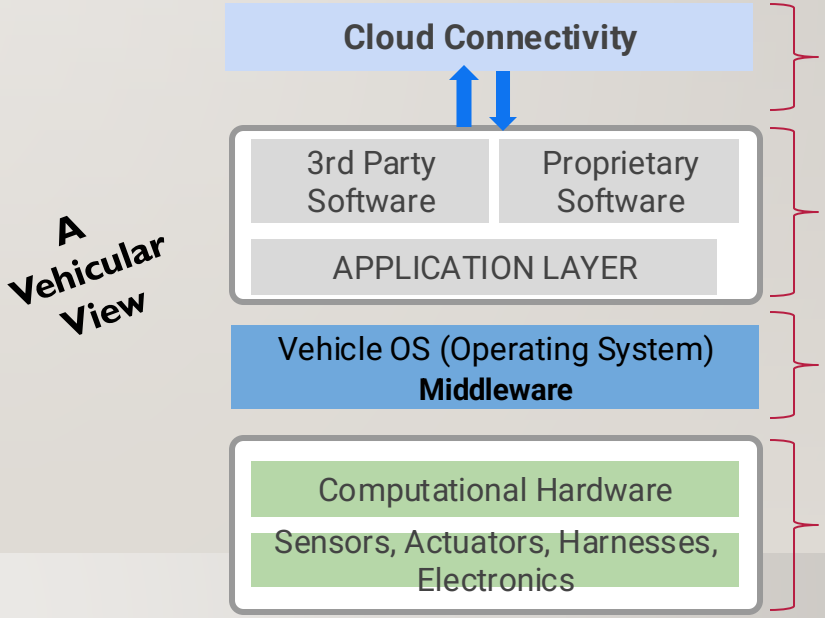
Software Defined Vehicle (SDV)

* Formerly Atieva, rebranded as Lucid Motors in 2016

WHAT IS SDV?

- "A transformation where the physical and digital components of an automobile are **decoupled** and features, functionality, and operations are **defined through software**." "Digital components—such as modules for safety, comfort and infotainment, and vehicle performance would be regularly developed and deployed **through over-the-air updates**." *Eclipse SDV consortium*
- "Vehicle manages its operations, adds functionality, enables new features primarily or entirely **through software**." *BlackBerry QNX*
- "Software defined vehicles are more flexible and **upgradable**, use and share data, and are **connected to the cloud**. This means they can be **improved over time**, similar to what customers expect from other **digital devices**" *Sonatus*





ARCHITECTURAL MOTIVATIONS

Growth of C.A.S.E

- New functions → More ECUs
- **Not Scalable**

ECU - Electronic Control Unit

De-couple HW & SW

- **Not open to expansion**

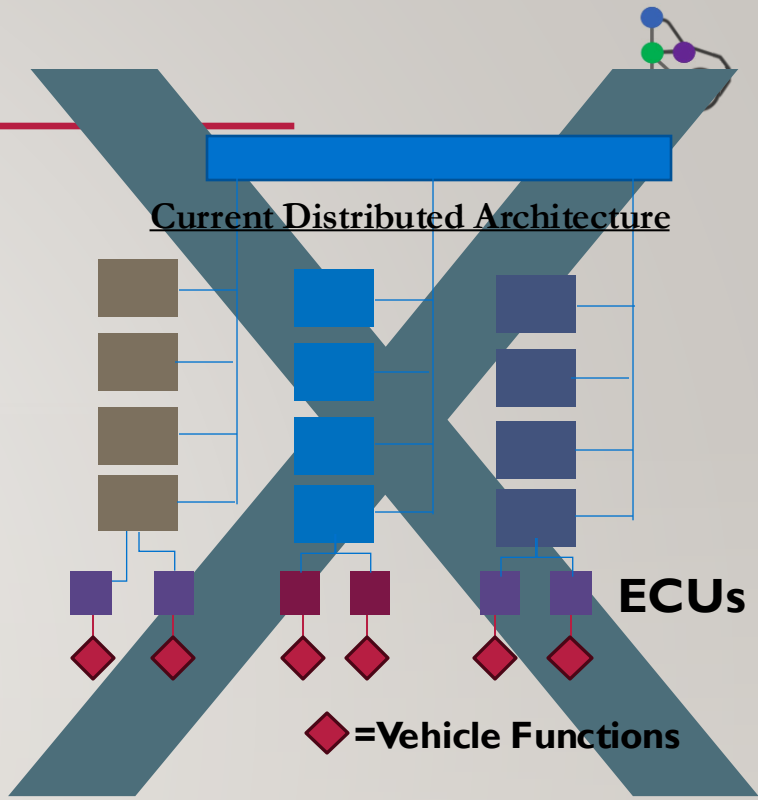
Centralized Computing platform

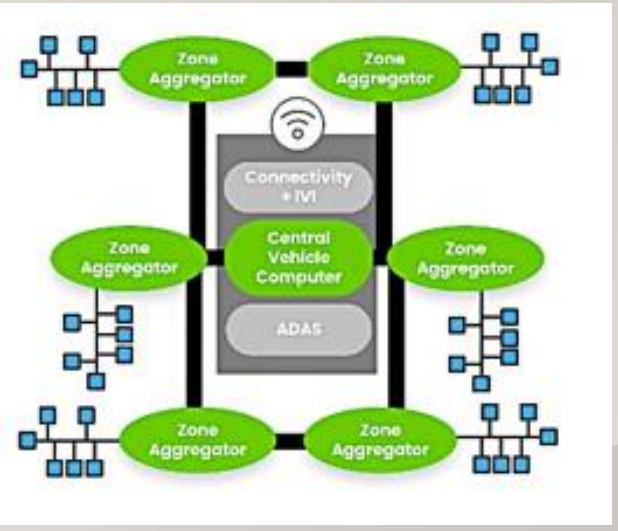
- **Not suitable for complex computational**

Ethernet Communication

Current data network

- ***Not* designed for high volume of data**





New architecture (NXP)

HW=Hardware SW=Software

WHY SDV?

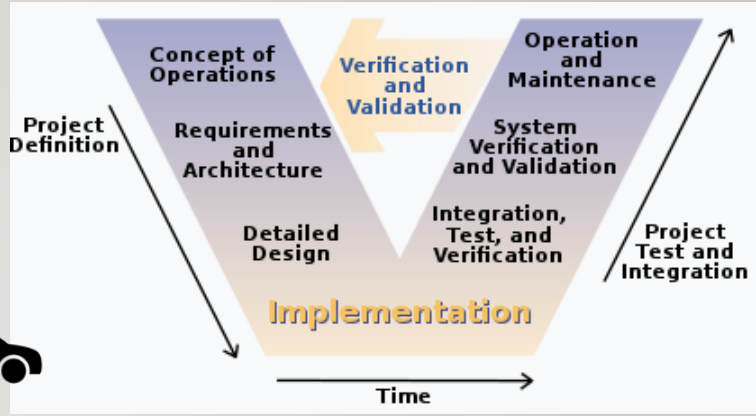
Upgradable Features & User Experience	• **Upgradability** • **New service/feature** • **Personalization**	**Consumers**
Faster Development Cycle	• **Higher reuse** of software • **More control** • **More flexibility**	**OEMs**
Power of the cloud & data analytics	• **New vehicle data** • **Faster design-test-development cycle** • **New data-driven business models**	**Consumers** + **OEMs**

New Product development Paradigm

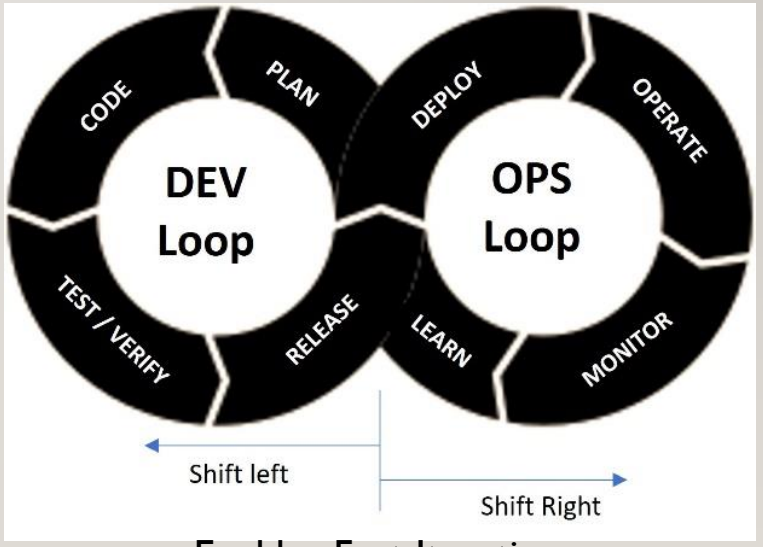
Fixed/Discrete Vs. Continuous Process

LINEAR TO A CONTINUOUS PARADIGM

- Current design-develop-test-validate-deploy process
  - Fixed, linear steps – defined by the **V-model**



- The new paradigm: "Continuous" framework
  - **CI**/**CD**/**CT**
  - Continuous Integration, Continuous Development, Continuous Testing



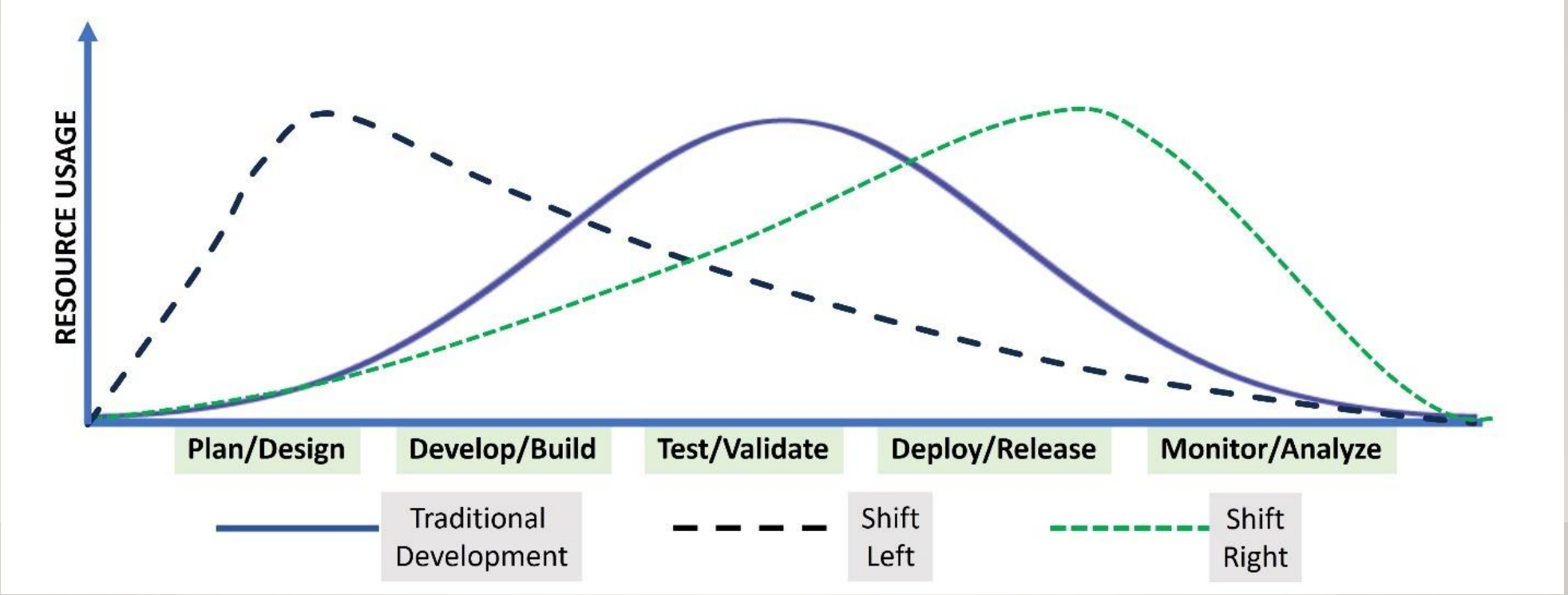
Enables Fast Iteration

SORP: Start of regular production
aka **SOP** - Start of Production
aka Series Production or **Job 1**

◆ =Test Hardware (Prototypes)

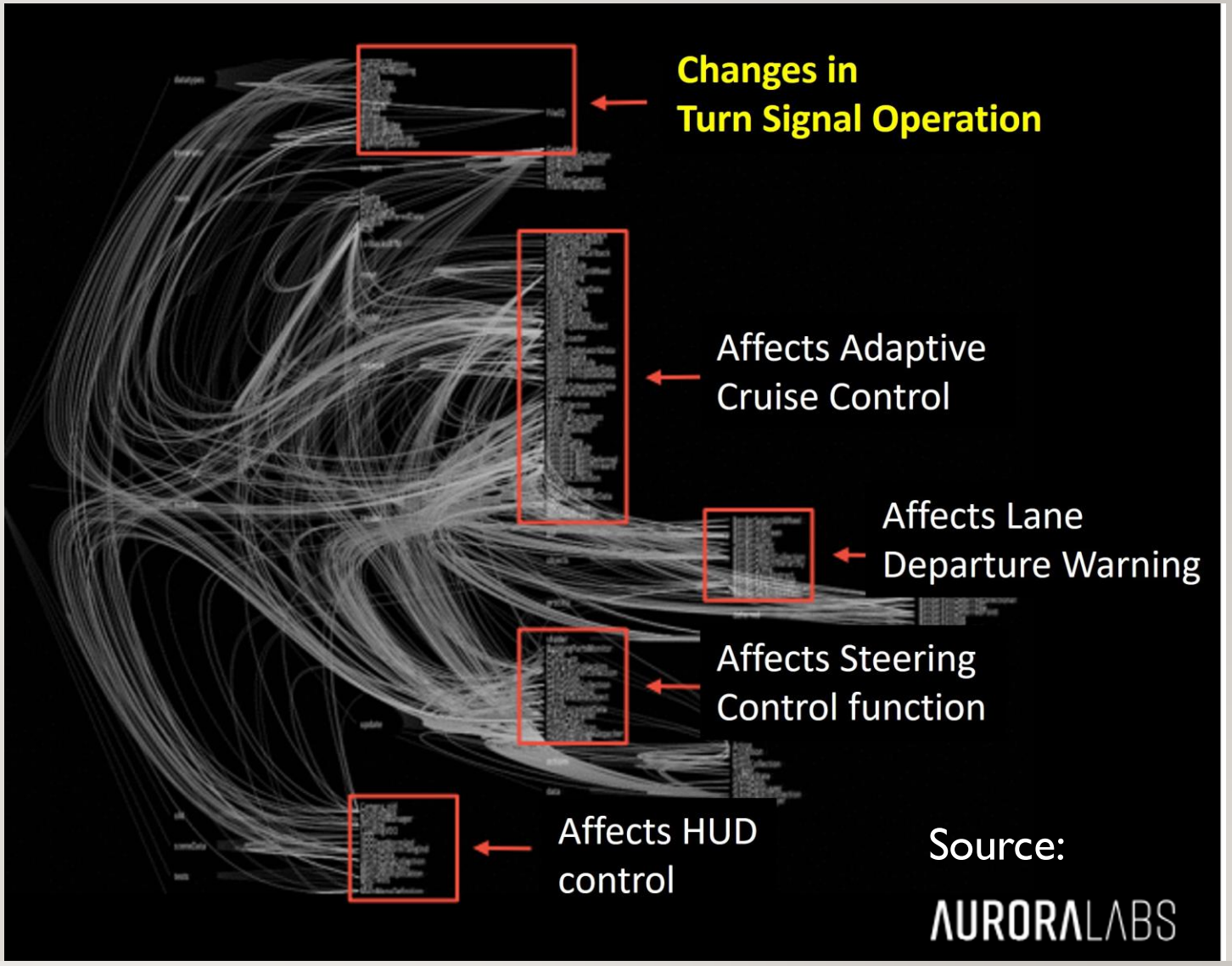
IMPLICATIONS - SHIFT-LEFT/SHIFT-RIGHT

- CI/CD/CT → Different resources usage
  - **Shift Left** – Test/evaluate early in the dev cycle → **Faster time to market**
  - **Shift Right** – Continuous testing in post-production → **Catch difficult to anticipate issues before customers do**



CROSS-FUNCTIONAL/INTER-DISCIPLINARY DEVELOPMENT

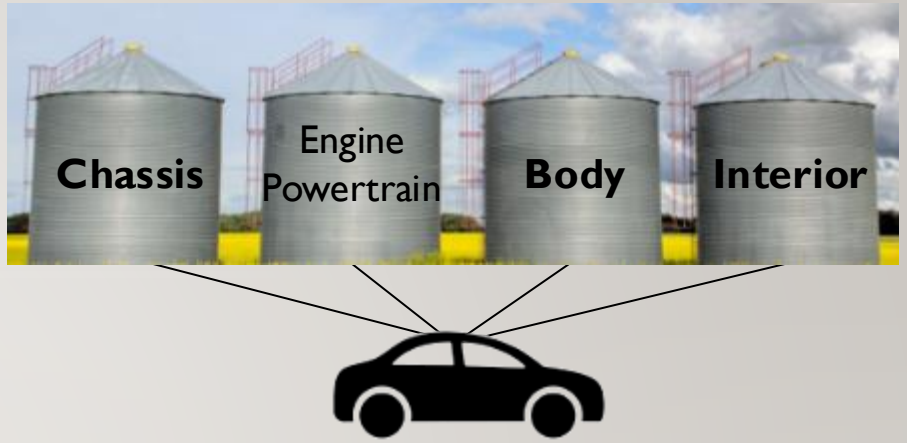
- SDV demands Upstream thinking
  - **Cross functional & inter-disciplinary** development
  - **Interrelation** with multitude of functions
    - Create new vulnerabilities
  - **Do No Harm:** One software update must not adversely impact other software elsewhere in the vehicle.



Impact of a recoding for changes in turn signal can impact multiple functions

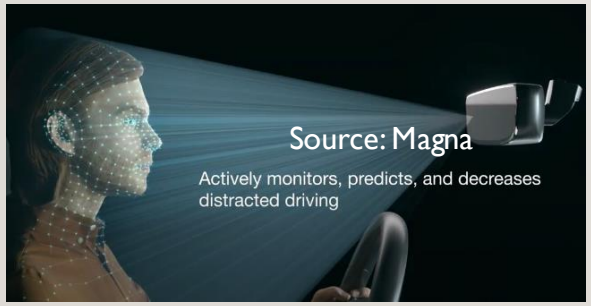
PARALLEL VS. CONCURRENT

- **Current** product development
  - Independent/Parallel development
  - Downstream integration



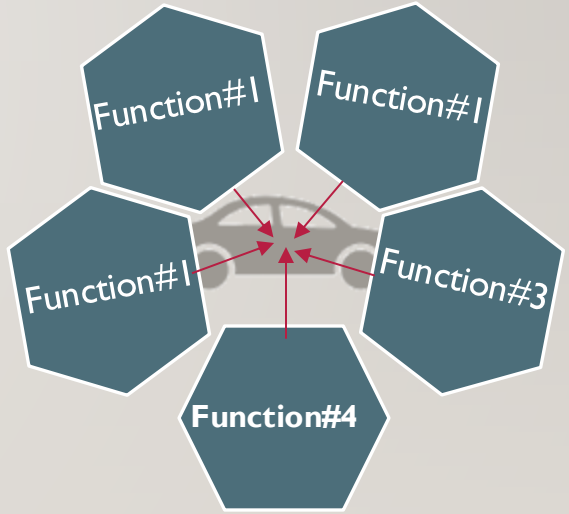
- **SDV: Interdisciplinary, Cross-functional & Concurrent**
  - Driver monitoring camera/GM SuperCruise*

Example



Potential concurrent functions

  - Occupant location or size, Driver intent, Fatigue



Holistic mindset

ADAS: Advanced Driver Assist System

*Hands-free driving (Level 2 autonomous driving) – Safety/ADAS function

HARMONIZATION **Process, Method, Tools**

1. Harmonization between systems

- **Example – Calibration**

Old
- Independent system calibration & **module-specific tools and processes**

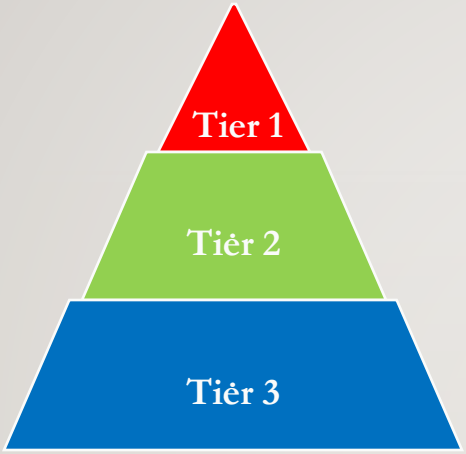
New
- Synchronize between modules, with **coherent methods, tools & processes**

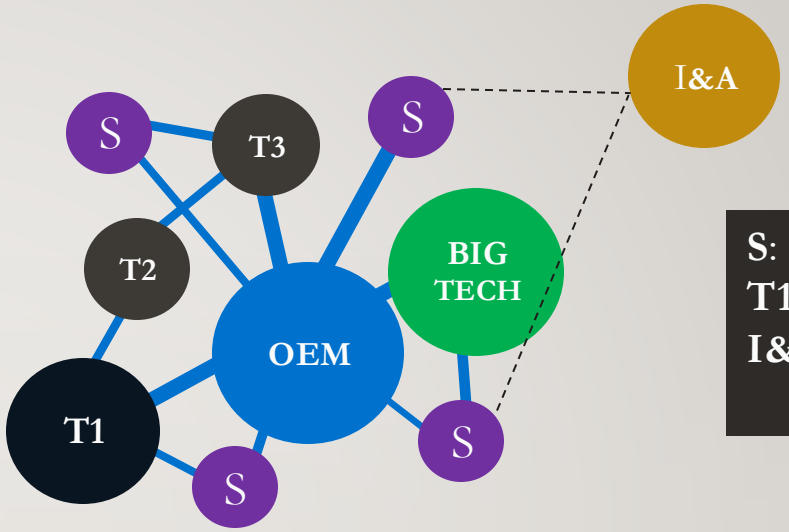
2. Harmonization between Vehicle and cloud

- Reusing existing cloud-native methods, standards and workflows to accelerate the SDV development.

MORE CONTROL IN A NEW VALUE CHAIN

Shift from Pyramid to Network





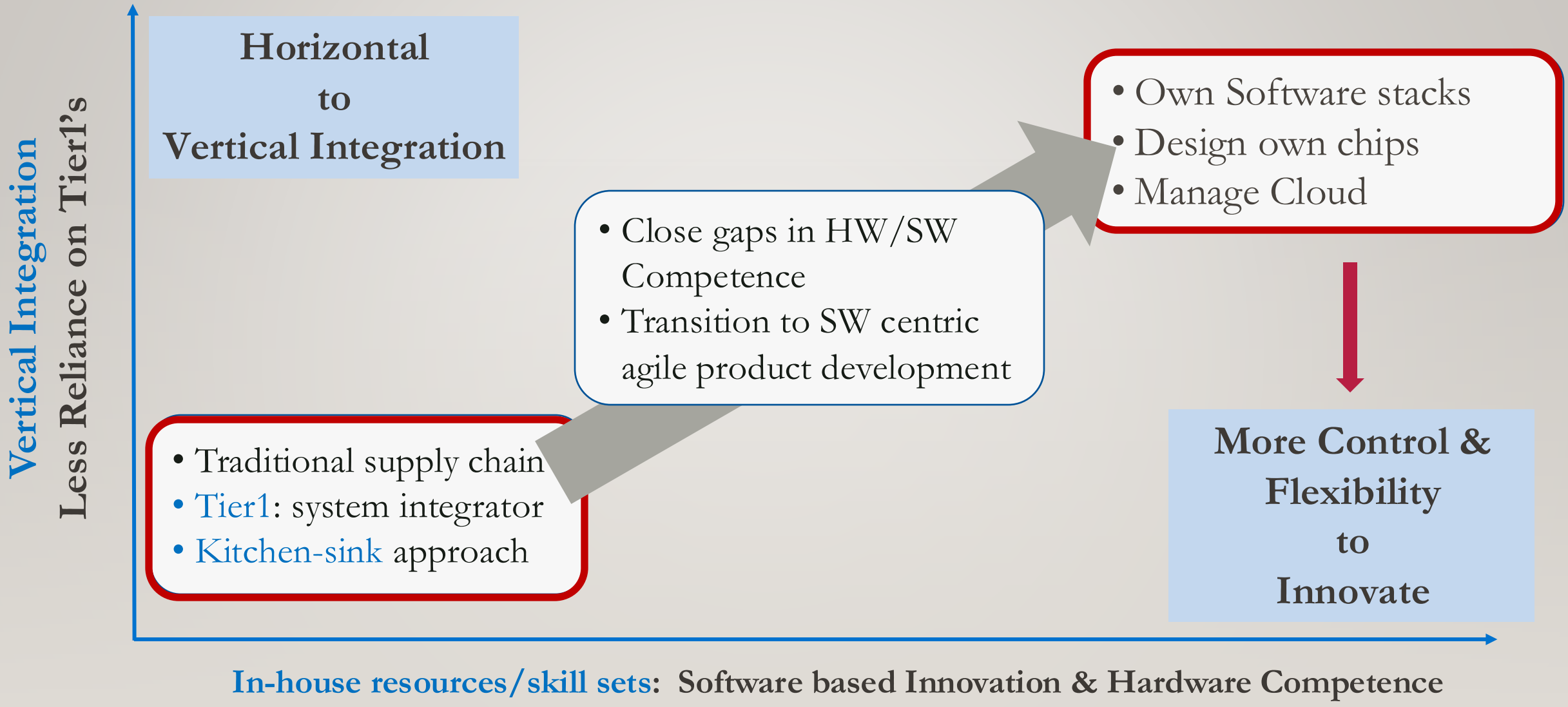
S: Startup
T1,2,3: Tier 1,2 or 3
I&A: Incubators & Accelerators

- **OEMs** take a bigger role in integration
- **Startups** & **Technology industry** engage more directly with the OEMs

BIG TECH
Qualcomm aws
intel Microsoft
Google
NVIDIA

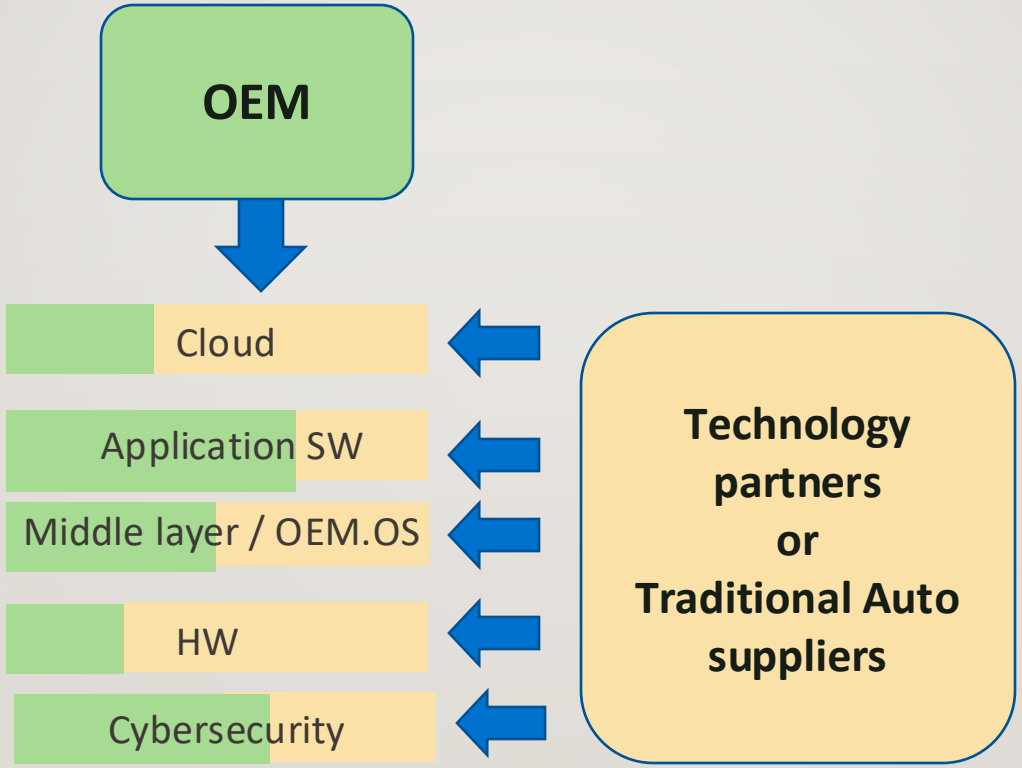
More flexibility and control

HORIZONTAL TO VERTICAL INTEGRATION



INTERACTION WITH THE SUPPLY CHAIN

LESS TRANSACTIONAL ⇨ MORE PARTNERSHIPS



A Generic Scenario – For Illustration Only

[Collaboration vs. In-house Skills]

The Journey to SDV

Key Challenges

STRATEGIC SHIFTS

- Software-centric product development process

Organizational Structure:

  - **People – New Talent**
  - **Culture – Align with "continuous" development**
  - **Mindset – Agile project management philosophy**
    - **Flexible and fast short iterative cycle**

- **Software as an economic asset**: SW in the auto industry is not usually perceived or handled as an economic asset, unlike in the technology sector

The Industry has to "Unlearn", Learn and implement at the same time.

STANDARDIZED VS. PROPRIETARY

- Standardization limited to physical components

- Now OEMs have to focus on
  - Leveraging common standards for "non-differentiated" software, tools, and processes
  - While building their own software that differentiate the brand

2003 – AUTOSAR
2004 – Eclipse Foundation
2009 – GENIVI

2021 – COVESA
2021 – SOAFEE
2022 – Eclipse SDV Working group

2024 – SDV Alliance

COVESA: Connected vehicle system alliance, SOAFEE: Scalable Open architecture for the embedded edge; AUTOSAR: Automotive Open System Architecture

SW CERTIFICATION

- Currently, ASIL (A-D) provides certification of safety assurance

- However -
  - No overarching structure exists for SW certification by an independent agency
    - OEMs and the software supply chain – can work with organizations, such as TÜV, Exida, SAE, ISO to establish such certification

ASIL
Automotive Safety Integrity Level*
(**For Functional Safety**)

Exposure Probability + Controllability by Driver + Severity of Failure

* For risks associated with failure

SW MAINTENANCE – PROCESS UNDEFINED

- **Consistency** – Maintain compatibility between software between generations of vehicles
- **Long term vehicle support** - Software deployed a decade back continues to run as intended,
  - Regardless of the change in tool chain or testing environment or cloud server over the years
- **Traceability** – Maintain trail of SW builds, updates, bug fixes over time

MY32

- **Archival** of "fully functional' Version of old SW
- **Maintain** Digital Twins

MY24

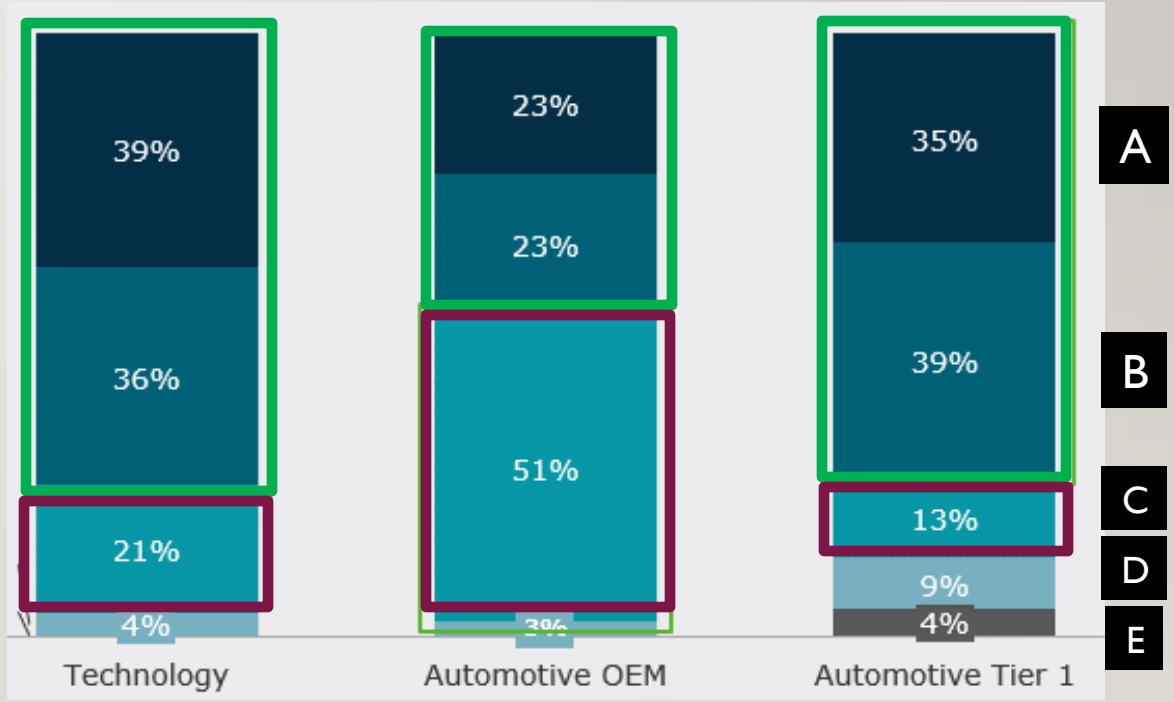
TRANSITION TO SDV : ALIX PARTNERS 2023 SURVEY*

- **Two-third** consider them **moderately prepared** for the transition & expect the first versions of their SDV to arrive no sooner than the next 3-4 years

On Proprietary vs. Open-source SW:

- **51%** of OEMs favor proprietary vs. only **21%** tech cos & **13%** Tier 1s.

- The numbers are opposite in favor of a mix of open-source and proprietary
  - **74%** Tier 1s, **75%** Tech companies & only **46%** of automakers



A Blend of Open source & proprietary

B Proprietary Only for core

C Proprietary

D Open Source

E Other

* Published Jan 2024 – Survey of OEMs, Tier 1s & Technology companies

Execution Headwinds

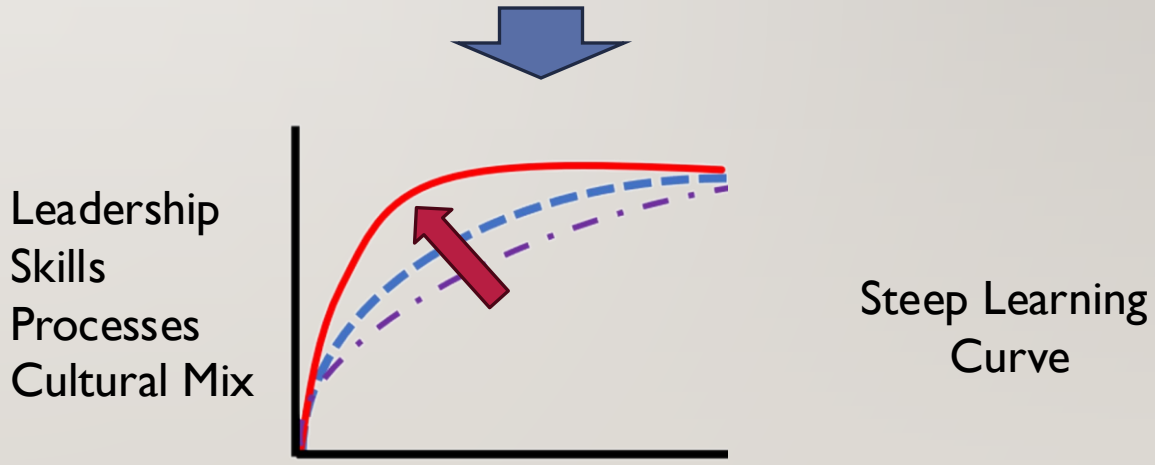
BUILDING GREENFIELD & BROWNFIELD TOGETHER

- OEMs are

Designing & Building Next-gen architecture + **Executing ongoing programs with traditional E/E architecture**

Brownfield	Greenfield
Software & hardware tightly coupled – Dedicated ECUs	Software decoupled from hardware
V-model of Design-Develop-Validate	Continuous Integration & Deployment (CI/CD)

- **Processes & tools**: Using old ones & adopting new ones
- **Supply chain management**: Two different modes

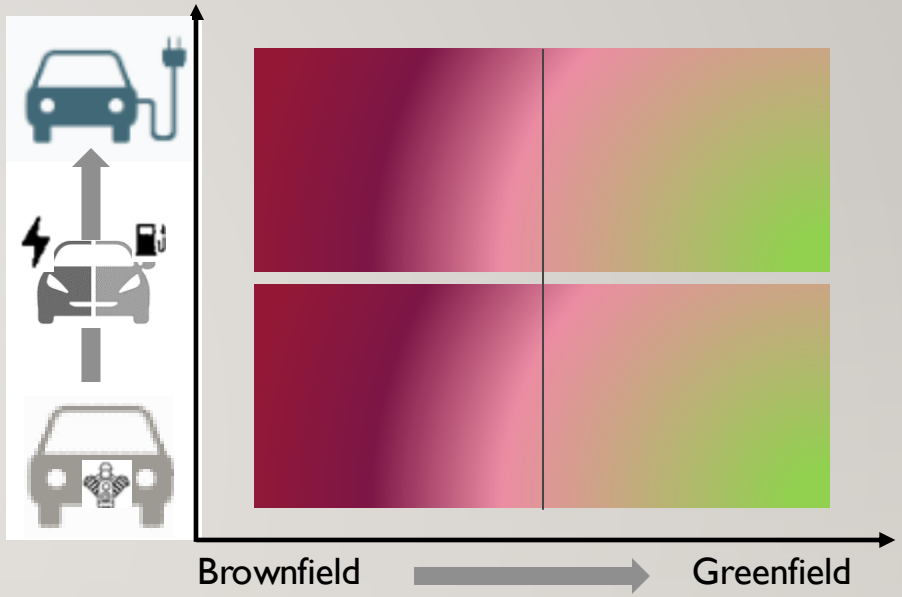


E/E = Electrical & Electronic

ELECTRIFICATION & SOFTWARE-FIRST TRANSPORTATION

Parallel Execution –

- Simultaneous investment
  1. EV transition
  2. SDV and software-centric product development



Architectural Changes
HW Centric to SW Centric

LIABILITY & SOFTWARE **FOR THE LONG HAUL**

Today

- Clear ownership between OEM and the system or sub-system integrator (e.g., Tier 1)

Future

- Liabilities spread across the supply chain - More difficult to sort out the owner.

30 years view

- Keep the software functioning into distant future – 15-30 years from now is an unexplored area.
- **OEM or supplier bankruptcies**: Who owns the software repair or maintenance problems?

The 2015 "Fixing America's Surface Transportation" or **FAST Act** requires automakers to repair safety defects for free for up to 15 years after a recall

WM

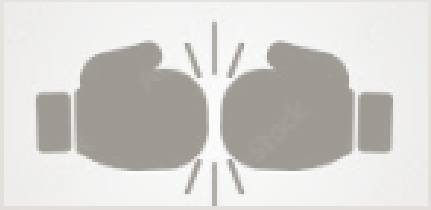
Over 100K vehicles form WM Motors have lost support for cloud services, remote control, or even in-car services

"Average" age of car ownership is now 12.6 years, with many vehicles twice as old as the average.

MESSY CULTURAL CHEMISTRY – SOFTWARE & AUTOMOTIVE

- Influx of software experts from the technology industry
- Both sides bring **complementary** skill sets
  - **Safety-first**: The software experts have to fully appreciate the complexity of an automobile as a safety-critical system, ISO 26262 compliance, ASIL-D level safety assurance
  - **Software-first**: Slow uphill journey for the legacy OEMs to institutionalize software-first mindset & continuous product development

X



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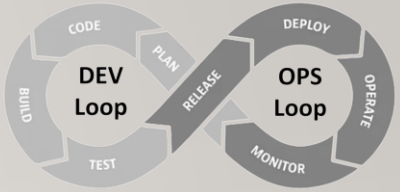
Takeaway

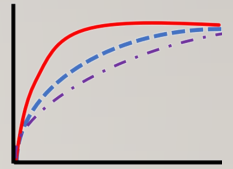
SUMMARY

- **Building SDV is a Total Paradigm shift**:
  - OEMs adapting at varying speeds as they build new skills, **new culture** and processes to be software centric

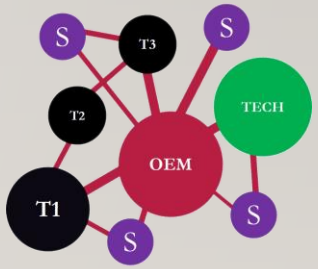


- **Methods & Process change**
  - **Linear to Continuous** – Product development, Test, Validation,

- **Steep learning curve**: Design of hardware, Software, security, testing and long term maintenance



- **Horizontal Vs. Vertical**: Balance between in-house control and partnerships, i.e., vertical and horizontal integration.



- **Value Chain Shift**: Tiered structure is yielding to a networked eco-system

- **Synergy between Auto &Tech**: A stronger cross-pollination of the best of both world will separate winners from others

Thank You!

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PG Mobility Analysis

New upcoming report on SDV Execution

SAE INTERNATIONAL EDGE Report

Software Defined Vehicle: Its Current Trajectory and Execution Challenges

Coming this fall

Partha Goswami

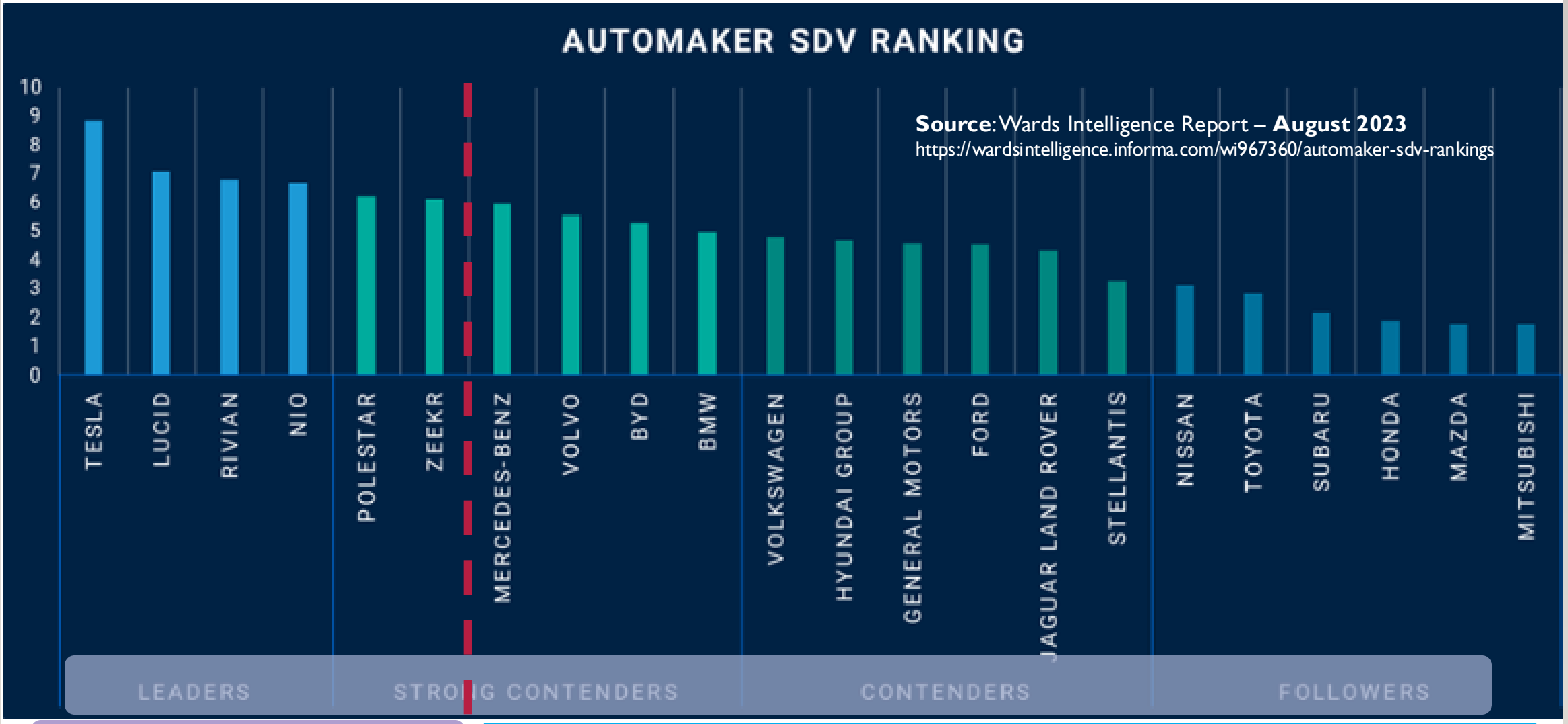
Collaborators

Brian Carlson	NXP Semiconductors
Martin Schleicher	Continental
Prathap Venugopal	General Motors
Fatih Tekin	Mbition GmbH

SDV LANDSCAPE – OEMS: 2020-2024

OEM	APPROACH
VW	Created CARIAD subsidiary with strategic goals, e.g., 60% in-house SW by 2025
GM	Launched in-house platform Ultifi, created an SDV team, then Software & Services team, hired extensively from Apple, Meta, Tesla etc.
Ford	FNV architecture (Fully Networked Vehicle), with the Goal of OTA for all key modules, intends to own SW stack (Blue Oval Intelligence tech stack)
Stellantis	Announced STLA platform (STLA Brain, STLA AutoDrive, STLA SmartCockpit), partnerships with Amazon
Toyota	Created 'Woven by Toyota' SW subsidiary; Acquired Renovo; Developing Arene vehicle OS → Goal: "Programmable Car"
Mercedes	Software subsidiary Mbition; Expanded MB.UX to build MB.OS on Mercedes Modular Arch (MMA)
Hyundai	Acquired 42Dot – to launch internal E/E architecture for SDV, with Samsung as partner
Honda	Ongoing internal development work to build its own OS, JV with Sony

RECENT WARDS AUTO RANKING OF OEMS ON SDV PROGRESS



Source: Wards Intelligence Report – **August 2023**
https://wardsintelligence.informa.com/wi967360/automaker-sdv-rankings

EV Only, Clean sheet

Traditional, Established ICE business, Evolving