TEAM - 83

INTER IIT JLR HIGH PREP

CHIPLET CHALLENGE

FINAL REPORT

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JLR

Current Industry Trends

Many OEMs are increasingly coming up with vehicles that manage their operations, add functionality, and enable new features primarily or entirely through software.

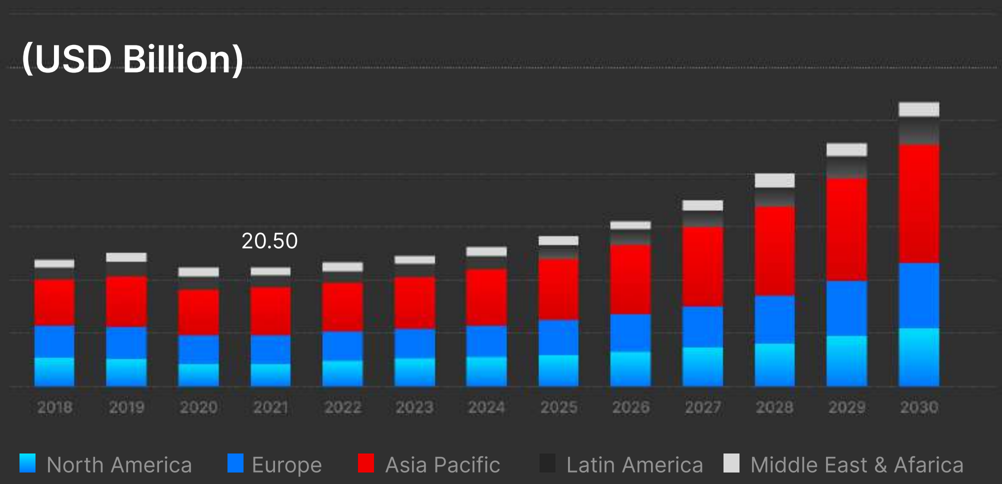
Not only this, this trend is forecasted to grow from a 2022 Market Size of $35.8 Billion to a 2032 Market Size of

$ 249.8B

a percentage growth of about 600%. (Wadhwani). To date, over 30 top OEMs have taken the initiative to develop their own versions of these SDVs. Another report by the Boston Consulting Group estimates that the auto industry will gain more than $650 billion in value by 2030 thanks to the advent of software-defined vehicles, constituting a significant portion, accounting for approximately 15% to 20% of the overall automotive value.

The User-Centric Revolution

Apart from the evolving tech used in meagre “operational” features, the automotive industry has shown great interest in packaging more and more software and hardware features that improve the driving experience for the users. AI-powered advancements, smooth incorporation of smartphones, advanced display technology, and a heightened emphasis on cybersecurity are shaping the future of in-car entertainment systems.



In-Vehicle Infotainment Market Size, By region (2018-30)

These developments are revolutionising thedriving experience, enhancing its enjoyment, efficiency, and safety for consumers around the globe.

In the new mobility paradigm, adding services over a vehicle's life span grows revenue

Sales/ Financing
- Direct-to-consumer sales, rental, and leasing

Over-the -air-Updates
- Temporary extra horsepower
- Activation of autonomous driving mode

Insurance
- Consumer specific insurance packages

Digital Services
- AI assistance
- Entertainment packages

Convinence Services
- Parking reservation fees
- Concierge sevices
- Vehicle swaps
- High speed charging
- Charging station reservations
- Call-out roadside recharging service

Aftermarket
- Quarterly automatic reading of vehicle's condition
- Convinient vehicle servicing

Recycling
- New vehicle, tailored according to consumer data

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0

Vehicles lifetime, in years

Market Analysis and Projection

The in-vehicle infotainment system market is expected to go from **$20.50B in 2021 to $48.62B in 2030**

Modern automobile consumers are embracing a new perspective as regular software updates that enhance services become the standard. They are not merely purchasing the latest car model expected to endure for approximately

5 yrs

instead, they are acquiring a connected, intelligent mobility device on wheels.

This smart vehicle enables them to work, socialize, and enjoy entertainment while continually evolving and improving over time.

The ERA of Hyper-Connected Intelligent Vehicles

Vehicles have become more connected than ever. This has given these vehicles the added ability to communicate with other software systems and collect data from their surroundings.

The global connected car market is roughly **$88.42B** in 2023 and is expected to grow to

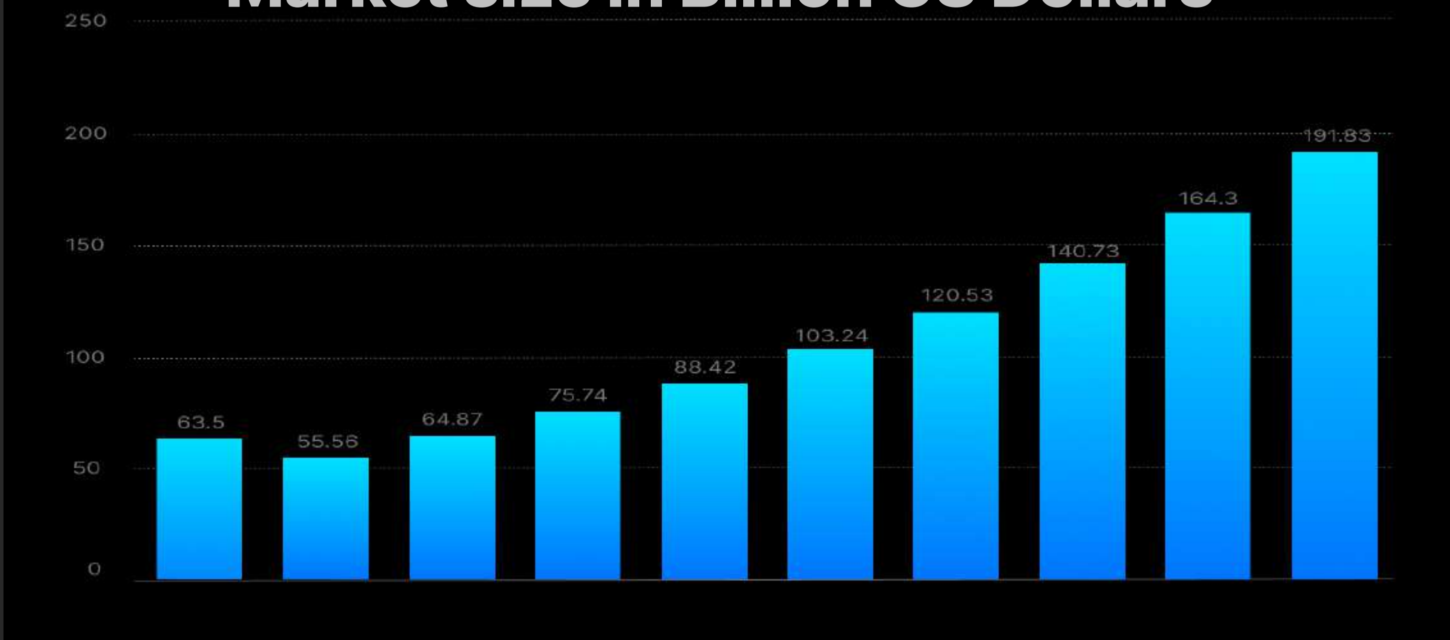
USD 191.83B

by 2028.

- 5G Connectivity
- Internet of Things (IoT)
- Vehicle-to-Vehicle (V2V)
- Vehicle-to-ability-Infrastructure (V2I)
- Vehicle-to-Cloud (V2C)
- Vehicle-to -Everything (V2X)

This has given these vehicles the added ability to communicate with other software systems and collect data from their surroundings.

Market size in Billion US Dollars



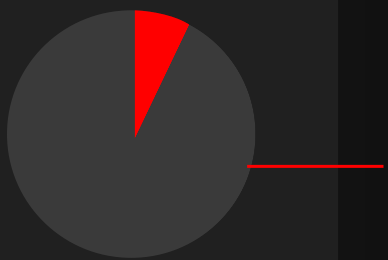
The Autonomous Vehicle Revolution

Passenger car advanced driver-assistance and autonomous-driving systems could create $300 billion to

$400.0B

in revenues by the end of year 2035.

OEMs are rolling out advanced vehicles with autonomous capabilities that are transforming the mobility scenario. With the aid of sensors, actuators, complex algorithms, machine learning systems, and powerful processors, autonomous vehicles are causing a revolution in the transportation sector. Though today, most cars only include basic ADAS features, major advancements in autonomous driving capabilities are on the horizon. Consumers want access to AD features and are willing to pay for them, according to a 2021 McKinsey consumer survey.



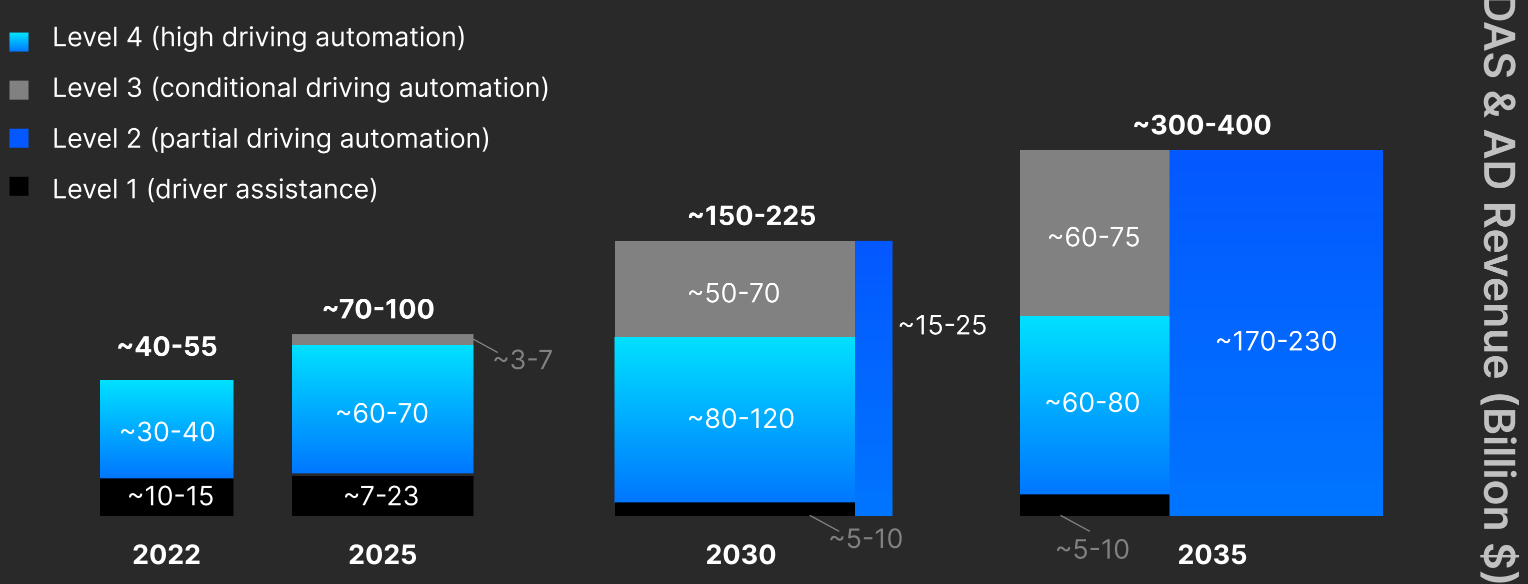
Autonomous vehicles promise to prevent about

90%

of the traffic deaths, according to a report by the Boston Consulting Group ("Rewriting the Rules of Software-Defined Vehicles").

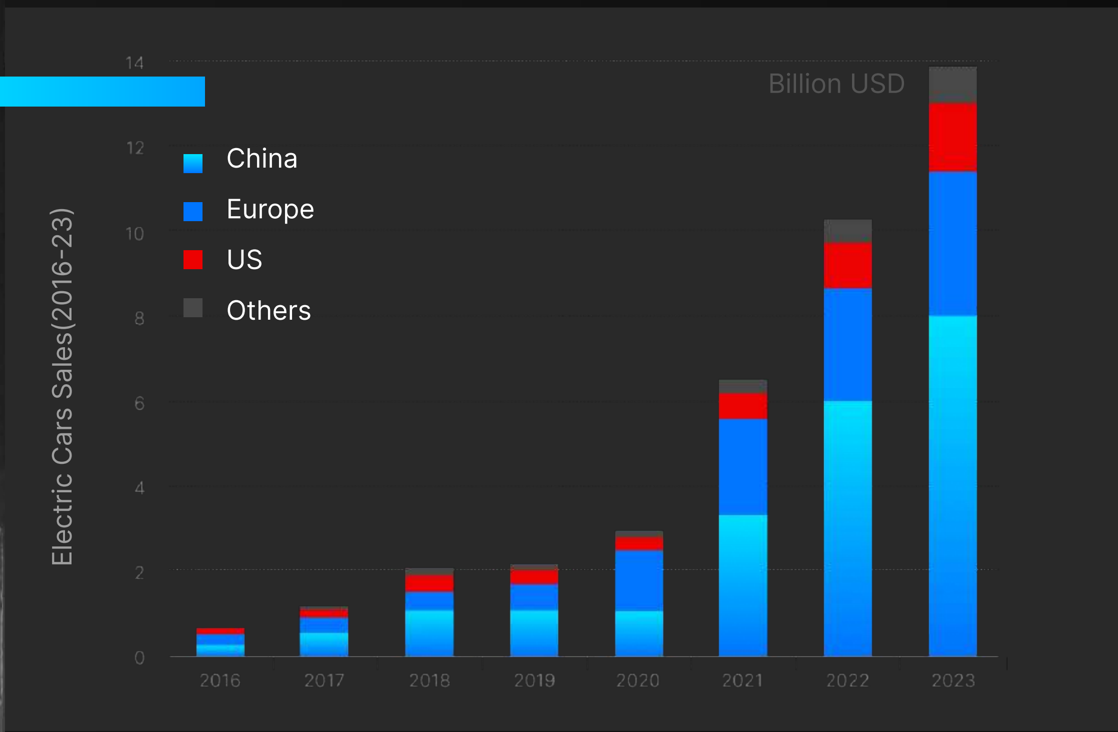
AD
AUTONOMOUS DRIVING

ADAS
ADVANCED DRIVER ASSITANCE SYSTEMS



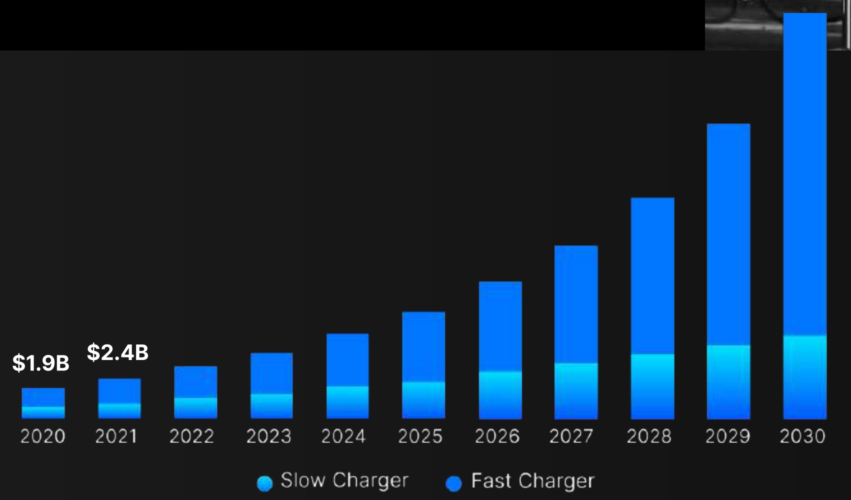
Source: McKinsey Center for Future Mobility

The Acceleration in Adoption of EVs



U.S. Electric Vehicle Charging Infrastructure Market

29.1% U.S. Market CAGR, 2023-2030



Source-Grand View Research

With the whole world moving towards a more environment-friendly world, the increasing awareness has influenced the people to buy more electric vehicles and hybrid electric vehicles. The transition to electric vehicles will likely have gained even more momentum, with a broader range of affordable EV models, increased charging infrastructure, and continued government incentives to promote electric mobility.

Electric car markets are growing exponentially as sales exceed USD

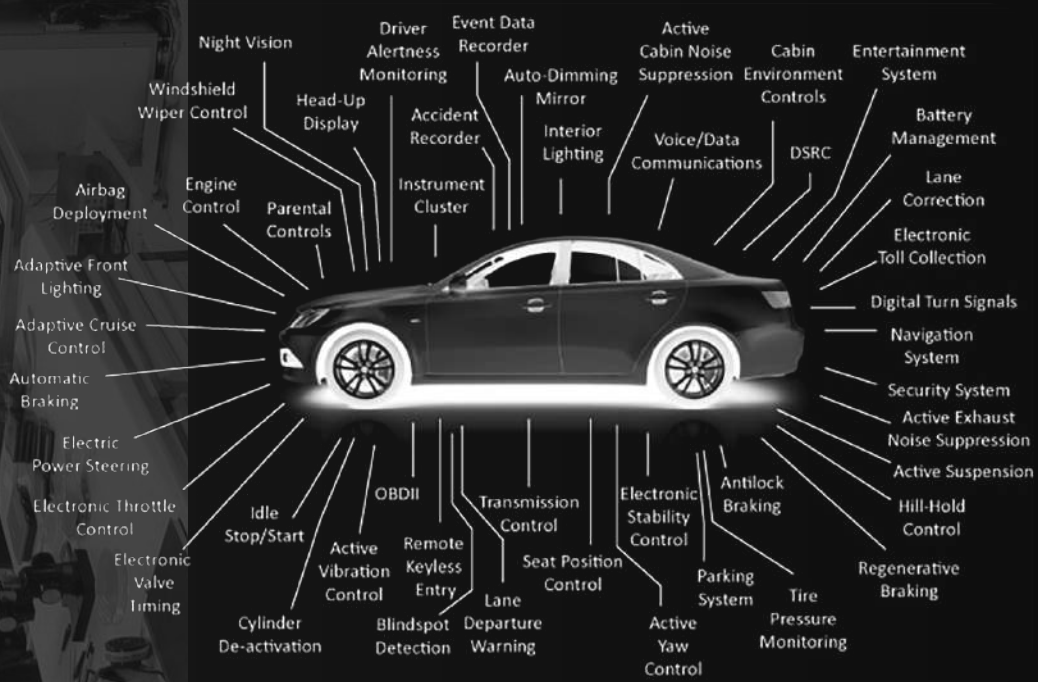
10M

in 2022. The share of electric cars in total sales has more than tripled in three years, from around **4%** in 2020 to **14%** in 2022. ("Electric vehicles - IEA")

The problem

Increasingly Complex Systems

Today's vehicles are equipped with a multitude of advanced technologies that enhance safety, comfort, and performance. These systems encompass everything from intricate computerized infotainment systems to intelligent connectivity features.



Complex sensor arrays and artificial intelligence algorithms enable modern cars to autonomously navigate, making self driving vehicles a reality, significantly improving safety on the road.

Moreover, electric and hybrid powertrains, which are highly intricate, have gained popularity, reducing emissions and fuel consumption.

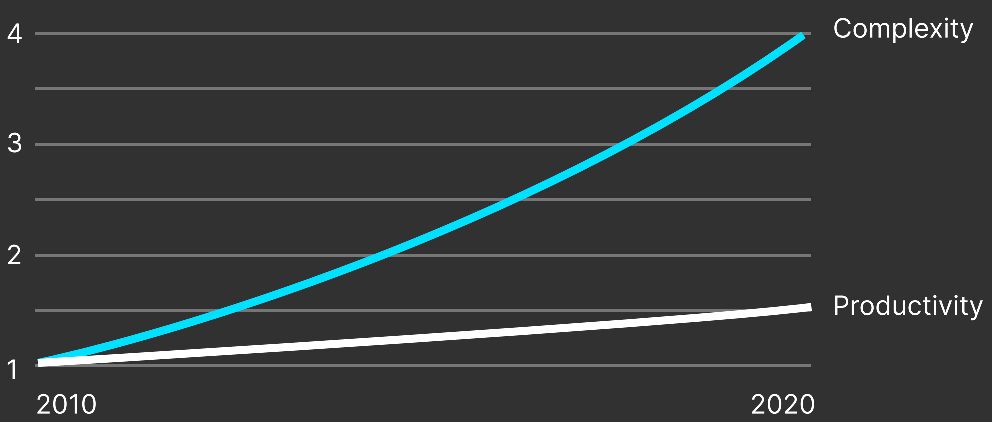
Modern vehicles implement over 150 electronic control units (ECUs) and nearly **100M** lines of code in order to achieve this.

This not only increases the overall cost of the vehicle but also puts a large strain on the hardware and communication systems. The average complexity of individual software projects in the automotive industry ,over the past decade has grown by

300%

(Marks and Moseley)

Growth of Software Complexity and Productivity in automotive systems, relative and indexed



Enormous Computational Workloads

Standard compute power inside the electronic control unit (ECU) will not be able to process the enormous workloads that come with the ADAS, communication, and entertainment functions of tomorrow's vehicles. These systems must process a vast amount of data from various sensors, cameras, and radars, all in real-time .

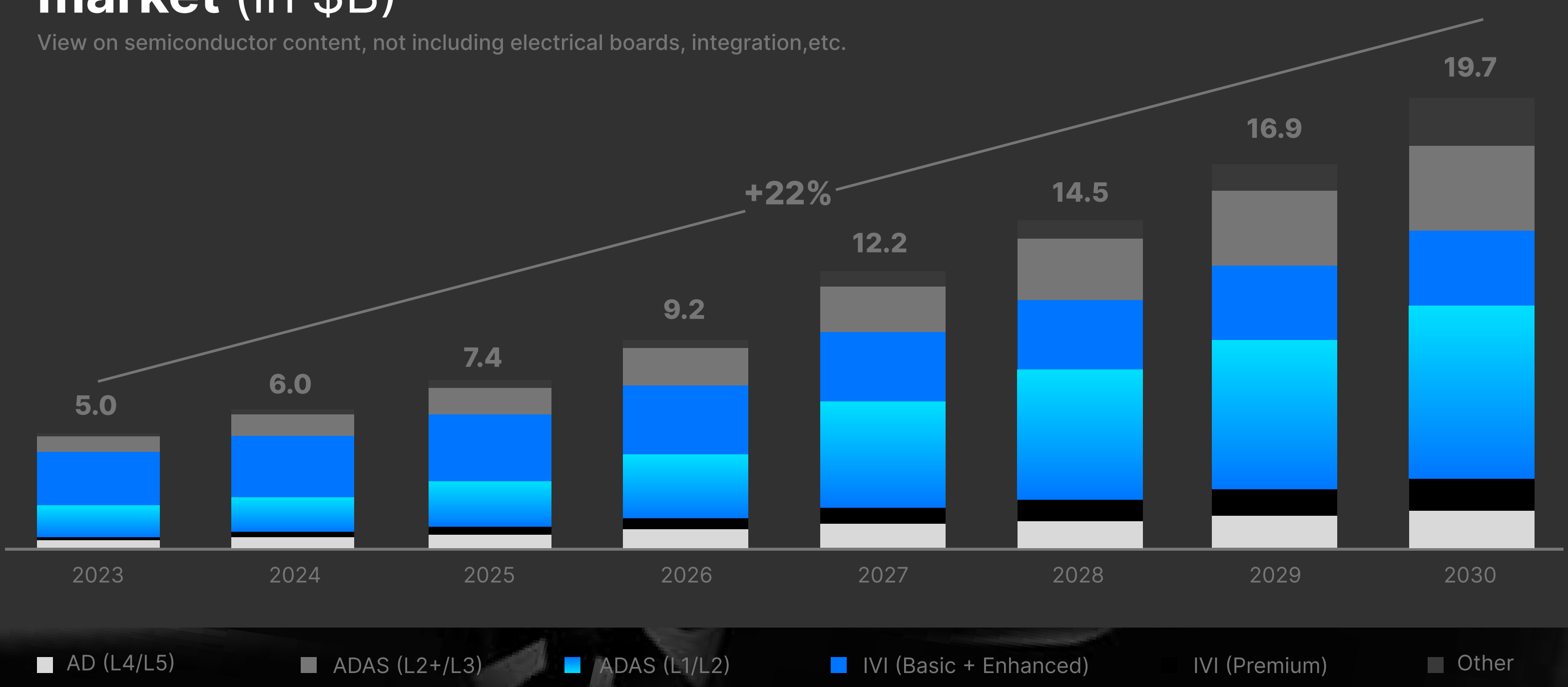
Anticipated developments suggest that the proportion of light vehicle sales incorporating ADAS functionalities at Level 2 or above is poised to double from the **2022** levels and potentially reach approximately 50% by the year 2030.

The driving force behind this trend is undeniably software, that fuels innovation and also serves as a key differentiator for Original Equipment Manufacturers (OEMs), significantly influencing consumers' purchasing choices. Facilitating the implementation of these intricate software functionalities demands increasingly powerful chips, consequently driving substantial growth.

It is projected that the automotive compute semiconductor market will experience robust expansion, with an anticipated Compound Annual Growth Rate (CAGR) of **22%** from 2023 to 2030.

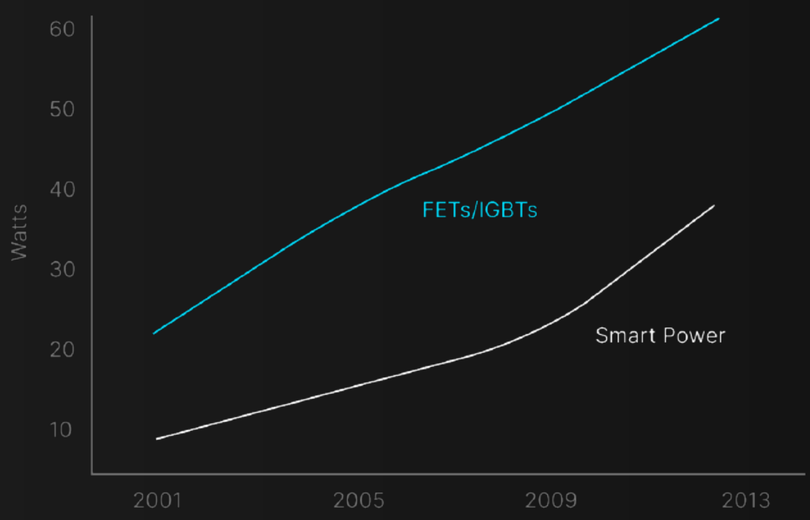
Automotive compute semiconductor market (in $B)

View on semiconductor content, not including electrical boards, integration,etc.



Heat Management Challenges

Maximum Steady State Thermal Power Per Chip



In semiconductor devices, the component gates have been shrunk down to nanometer sizes, and a single die can now contain millions of gates formed from billions of transistors.

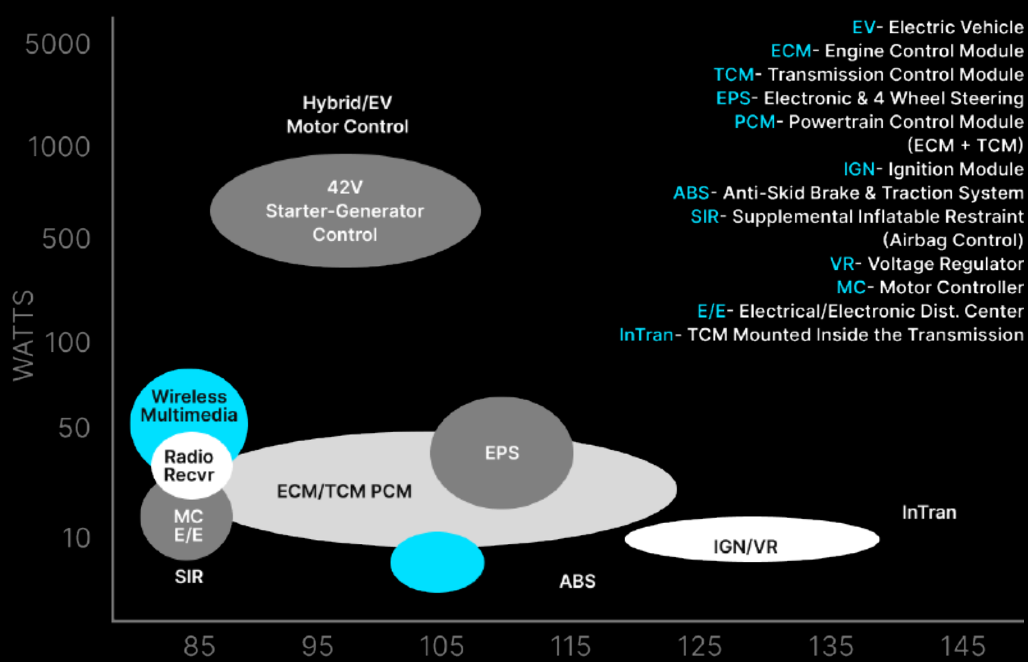
Moore's Law has marked this progressive miniaturization and predicts it will continue into the near future until a shift change in the underlying technology.

While each new generation of smaller, faster devices offers the designer more features to play with, they generate more heat in the same component footprint. Furthermore, the increased computational performance requirements of the hardware results in much more heat generation, eventually leading to several problems.

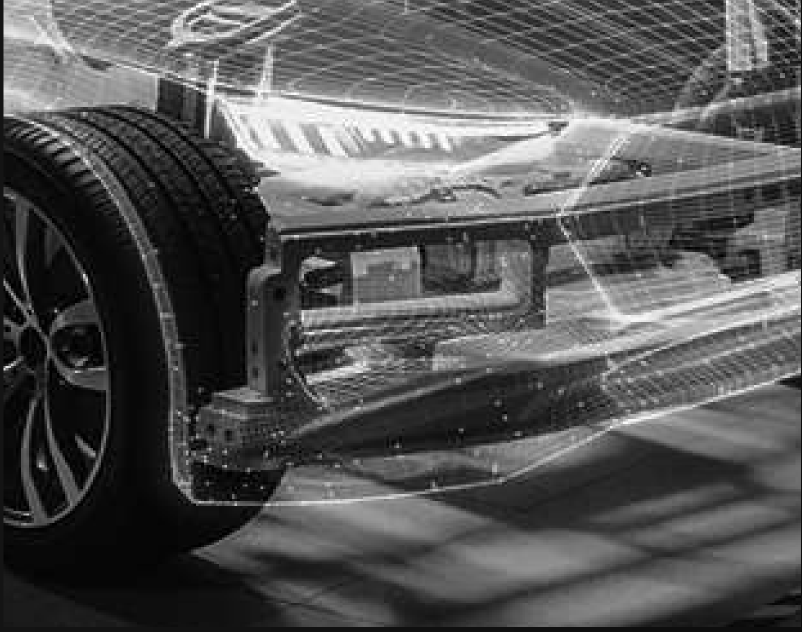
The properties of the semiconducting material itself change with temperature due to electromigration effects. Outside of the device's temperature limits, the device's performance may not adhere to its specification and produce unexpected behaviors.

The challenge is to extract the heat energy from the semiconducting material and dump it into the ambient environment as quickly and efficiently as possible to maintain the device's reliability

Thermal Power Dissipation & Operating Ambient Temperature



Issues with Scalability



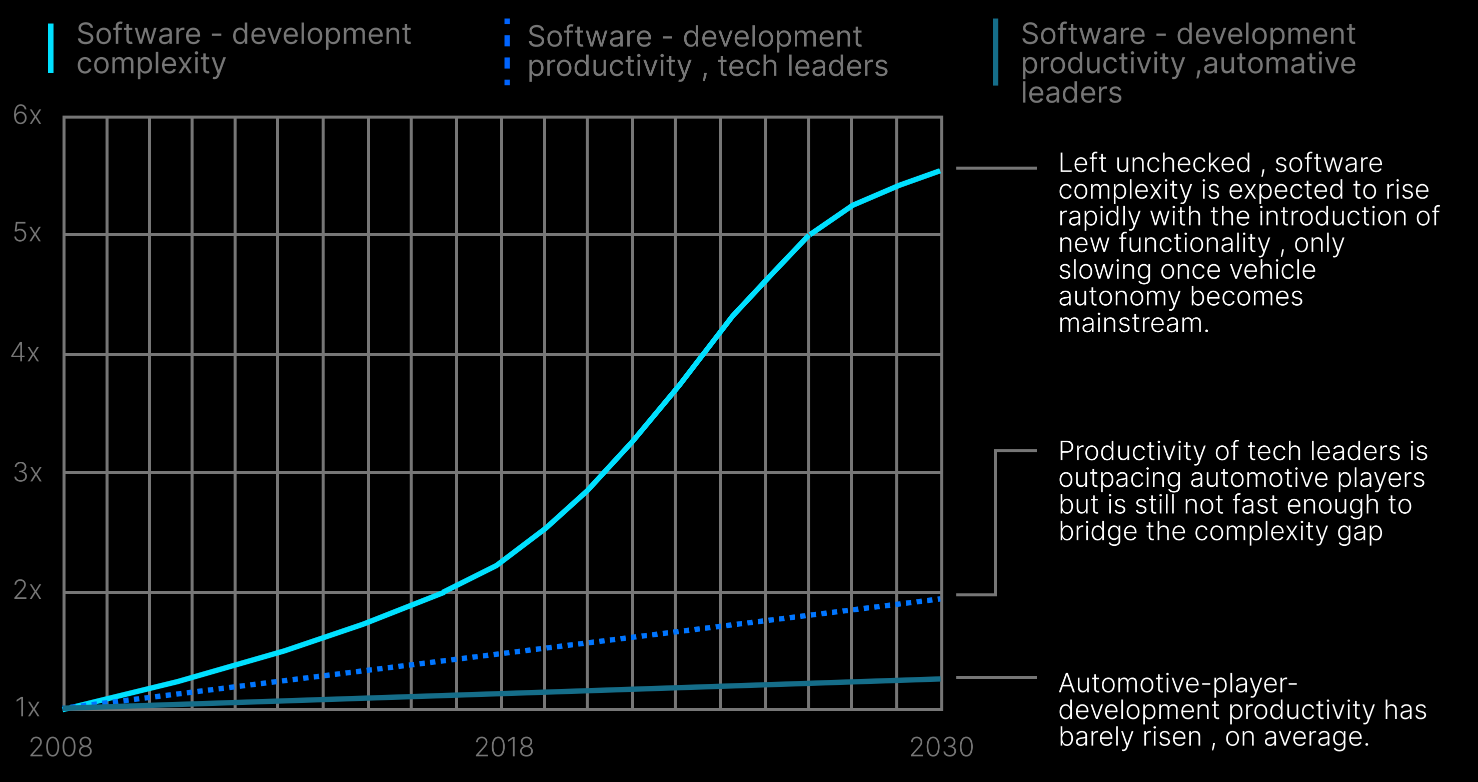
Scalability is a fundamental concern when it comes to the design and development of automobiles. With all the fast-paced updates and technological upgrades coming up in the industry, it is becoming increasingly important to ensure that the hardware technology is scalable to accommodate future advancements and that vehicles can be upgraded without significant hardware replacements. A modern vehicle is a **cyber-physical** that combine hardware and software components with varying innovation life-cycles, resulting in the challenge of controlling complexity and innovations throughout an electrics/ electronics platforms life.

The reliable implementation of over-the-air updates is increasingly impacting customer satisfaction. Thus, electrics/ electronics platforms face the .challenge of technically and structurally enabling software updates over-the-air, while also considering variability

As the volume of software integrated into various aspects of the vehicle continues to grow, so does the complexity of ensuring that different systems function cohesively.

Automotive

industry participants face significant difficulties in keeping pace with this trend. For example, contemporary infotainment systems now demand a development period of more than three years, with the contributions of numerous software engineers in each iteration. Implementing changes to any individual software module often necessitates extensive reworking.



Energy Efficiency and Power Consumption

Day by day, manufacturers strive to increase the range and performance of their vehicles. This leads to larger batteries and motors, which are controlled by increasingly complex control circuits. Additionally, energy-draining systems such as larger infotainment systems, and power hungry autonomous driving units further increase the already large amount of energy being consumed. On the other hand, as most are not optimized properly, these extremely power-intensive systems also tend to see a decline in efficiency as performance is pushed to its limits.

A study from MIT researchers reveals, **90%** of vehicles must limit their power consumptions to **1.2kW per vehicle** to prevent emissions

Recognizing the need to consider the environmental impact of autonomous vehicles, MIT researchers constructed a statistical model.
Their findings indicate that a billion autonomous vehicles, each operating for an hour daily with a computer using 840 watts, would generate emissions on par with current data centers.

Maximizing energy efficiency is essential, especially in electric vehicles, where hardware components like electric motors and power electronics directly affect range and battery life. Additionally, with the increasing processing requirements and advanced algorithms, significant amounts of energy are consumed just to perform these tasks, raising the need for computationally efficient hardware solutions. Data centers, which house the physical infrastructure for running applications, are notorious for their substantial carbon emissions, responsible for approximately

0.3%

of global greenhouse gas emissions, equivalent to Argentina's annual carbon production.

Achieving this would require more efficient hardware. In a specific scenario where 95% of the global vehicle fleet is autonomous by 2050, computational workloads double every three years, and current decarbonization rates continue, hardware efficiency would need to double even faster, every

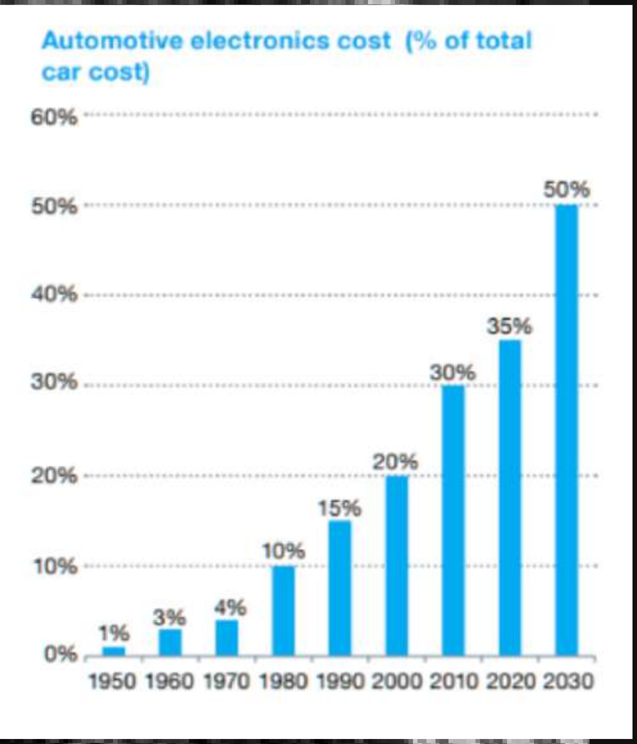
1.1years

to keep emissions in check. The study underscores the need to proactively design energy-efficient autonomous vehicles to mitigate their carbon footprint. Another article from 2018 highlighted that modern production cars equipped with cameras and radar generate approximately 6 gigabytes of data every 30 seconds, a figure that escalates even further for self-driving vehicles featuring additional sensors like LIDAR.

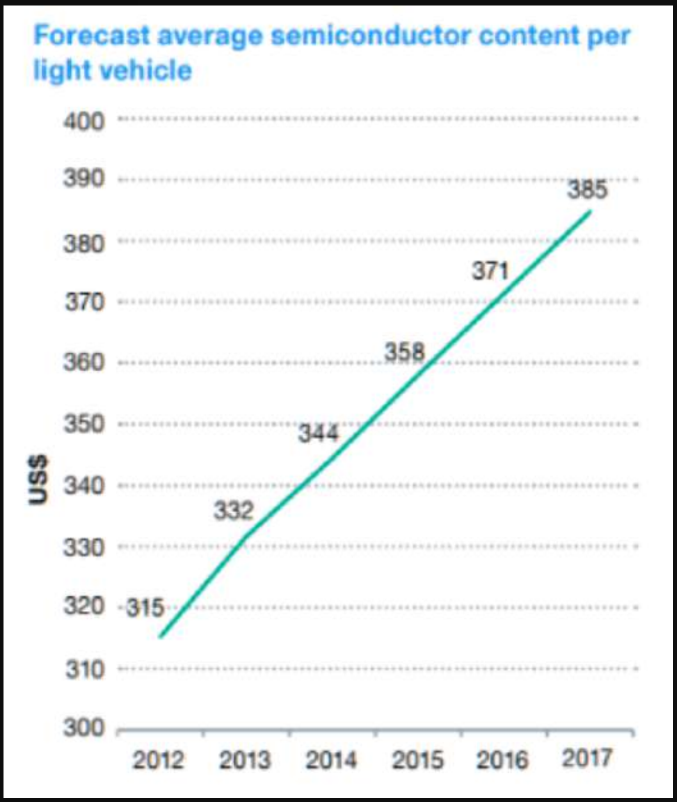
This immense volume of data necessitates complex processing to create a comprehensible depiction of the world for autonomous driving, along with instructions on how to navigate through it. Such processing requires substantial computing power, resulting in high electricity demands. **Prototypes typically consume around 2,500 watts, which is enough to power 40 incandescent light bulbs.** Embedding such a system into a traditional combustion-engine vehicle is impractical due to the substantial increase in fuel consumption it would entail. This is because the energy required for computing would significantly reduce the vehicle's fuel efficiency. In the context of electric cars, the electricity drawn by these computing systems results in reduced driving range, as a significant portion of the available battery power is allocated to the computers instead of driving the vehicle.

Cost Pressures on Hardware

Meeting the demands of advanced hardware technology can be expensive, and automakers face the challenge of balancing cost-effectiveness while delivering high-quality hardware in their vehicles. An analysis by PwC reports that the percentage of the cost of electronics out of the total car cost is expected to reach about 50% by the year 2030



Yield refers to the percentage of semiconductor chips that meet quality and performance specifications out of the total chips produced in a manufacturing run. When semiconductor manufacturing processes yield a lower percentage of usable chips, it can result in increased costs, slower production,and limited availability. Low yield can be a significant issue during a semiconductor shortage, as it directly impacts the number of functional chips available for automotive electronics

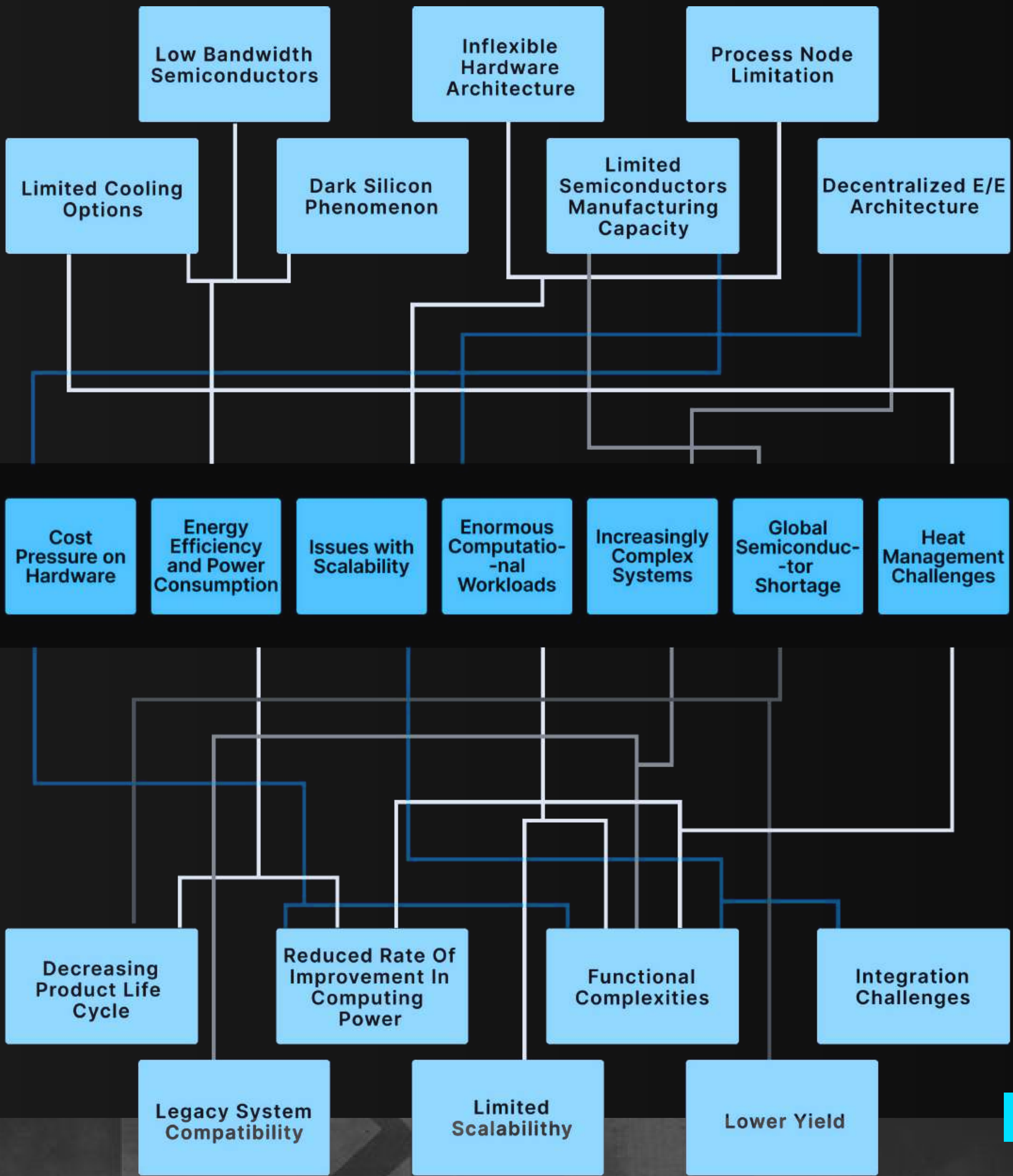


With the current system on chip (SoC) requirements, the die sizes must increase in order to accommodate the required IPs. However, as the die size increases, the yield decreases, leading to lesser functional chips and more wastage, ultimately contributing to the semiconductor shortage. The majority of highly advanced semiconductor chips are initially developed for the consumer market, whereas failure rate of one in a million and a lifespan of two to five years are considered sufficient. However, attaining the essential automotive standard of one in a billion failure rate over a 15-year lifespan demands a distinct methodology

If automotive OEMs are not able to keep all these issues under check, the public might not buy anymore, resulting in the decline of the whole automotive industry

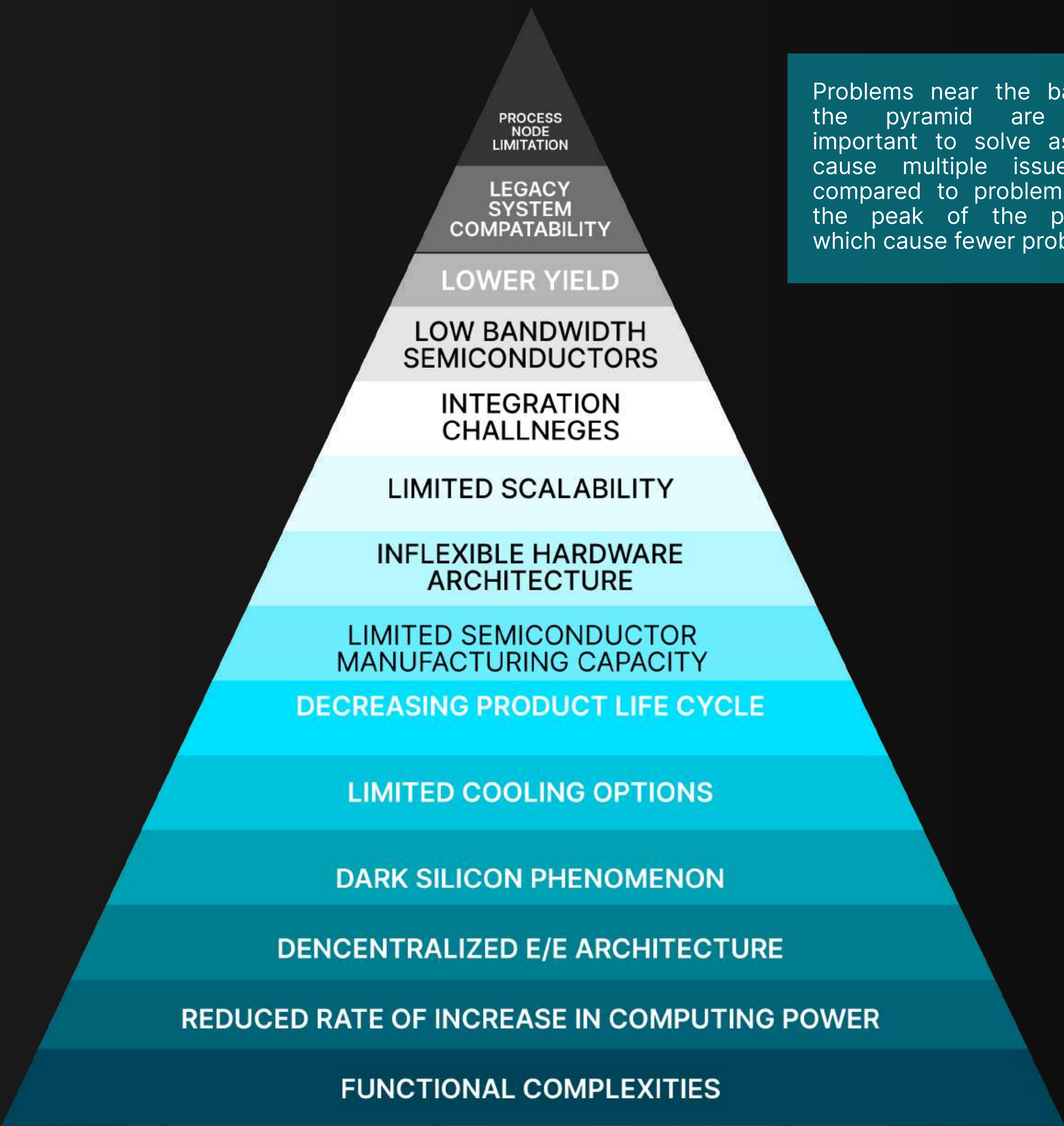
Root Cause Analysis- Fault Tree

Based on the fault tree, we can identify the root causes and easily see which causes occur more commonly and prioritize to tackle those specific problems.



Root Cause Analysis- Pyramid

The pyramid below depicts the root causes and the number of large-scale issues that they cause.



Problems near the base of the pyramid are more important to solve as they cause multiple issues, as compared to problems near the peak of the pyramid which cause fewer problems.

Identifying Alternatives

Now that the underlying root causes have been identified, we explore different alternative semiconductor technologies that can provide suitable solutions to the discussed problems. These are as follows:

1

System-on-Chip (SoCs)

”System on a Chip” (SoC) is a revolutionary electronic component found in modern devices like smartphones and tablets. It stands out for its ability to **consolidate numerous essential hardware elements into a single, compact chip**. Typically, an SoC includes a Central Processing Unit (CPU) for general computation and a Graphics Processing Unit (GPU) for **efficient graphics rendering**, memory components (RAM and storage) for swift data access, reducing the reliance on external memory modules. Furthermore, SoCs can house additional components like audio processors, hardware accelerators, and connectivity modules. SoCs **enable smaller, more energy-efficient devices** with diverse capabilities, all within a single chip

2

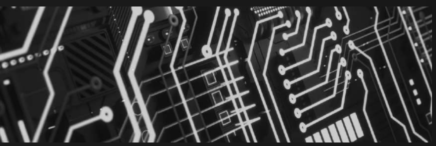
Chiplets

Chiplets are a novel paradigm in semiconductor design, where complex ICs are disassembled into separate, specialized components. These chiplets are then interconnected, allowing for modular and scalable system design. This specialization optimizes performance and power efficiency, and **heterogeneous integration** enables custom solutions. Chiplet manufacturing can improve yield and time-to-market by reducing waste, and upgrades become easier. Customization offers tailored solutions.

3

Field-Programmable Gate Arrays (FPGAs)

Field-Programmable Gate Arrays (FPGAs) are user-configurable ICs with hardware-level performance and software-like adaptability. They feature configurable logic blocks and programmable interconnects, allowing **custom digital logic creation** using hardware description languages. FPGAs excel in **rapid prototyping, custom logic deployment, and digital signal processing, serving industries from aerospace to telecommunications.** Valued in education and research, FPGAs aid digital design education and experimentation.



4

Application-Specific Integrated Circuit (ASIC)

An ASIC, or Application-Specific Integrated Circuit, is a custom-designed integrated circuit optimized for a specific task. It offers **efficiency and high performance** tailored to its intended application, be it in consumer electronics, telecommunications, or industrial settings. ASICs are non-programmable, unlike FPGAs, and their design complexity demands specialized expertise and tools. While development can be costly, ASICs become **cost-effective in high-volume production** due to their task-specific efficiency. Surpassing the capabilities of general-purpose processors or FPGAs, ASICs are invaluable when it comes to efficiency for a specific application.

Assessing the Alternate Technology

In order to identify the regions in which these alternatives can be put to use, we perform a **SWOT analysis** to ascertain areas in which these alternatives can provide fruitful solutions while simultaneously steering away from the applications where their use would be disadvantageous. This way, we get a qualitative idea of the relative strengths and weaknesses of the solutions along with their possible applications.

Further, we prepared a **quality factor determination matrix**

QFD in order to quantitatively analyze each alternative. If multiple alternatives could be considered for a single application, the quality factor determination matrix helps us identify which alternative would be the better choice by quantifying the benefits.

In order to do this, the alternative solutions are listed against the root causes identified, and they are rated accordingly. A weightage is assigned to each root cause in proportion to the number of large-scale issues it leads up to.

Through both these exercises, we can ultimately come to an informed and elaborate conclusion as to where and why each alternative should be implemented. This would help us identify potential areas of application of chiplets

SoCs SWOT Analysis

	Helpful	Harmful
Internal origin	Reduced Latency Reduced system complexity Improved Safety and Security High Performance Capability Increased System Efficiency	High Costs Limited Mnaufacturing Technology Issues with Overheating Lack of Scalability and Flexibility Customisation Limitations Long Development Cycles Power Hungry High Performance Compute SoC's Lower Yeild Decreased Life Cycles
External origin	ADAS and Autonomous Driving Connected Vehicles Advanced Informant Systems	Lack of Feature Differentiation Upgradability Issues Slowing Down of Moore's Law Supply Chain Issues and Market Oligopoly

Assessing the Alternate Technology

Chiplets SWOT Analysis

	Helpful	Harmful
Internal origin	High scalability and modularity Specific functionality and enhanced preformance reduced development time high cost efficiency higher yields than monolithic ICs Energy efficient Scalability for mass production	Interconnects complexity Lack of standardization and regulatory compliances Intellectual property concerns Thermal design issues Multiple chiplet control challanges
External origin	AI and edge computing ADAS and autonomous driving connected vehicles Advanced infotainment system Innovation and feature differentiation Vendor ecosystem development Enhanced processing capabilities	Cyberattacks and security concerns Legacy system compatibility Competitive pressure Long regulatory approval process

FPGA'S SWOT Analysis

	Helpful	Harmful
Internal origin	Flexibility and Customisation Real time processing Reliability and safety Long lifecycle support Low latency	Higher costs Higher power consumption Complex Designs Larger size and packaging issues Issues will supply chain availability
External origin	ADAS and autonomous driving Connected vehicles Advanced infotainment systems cybersecurity Communication systems	Packaging constraints Cybersecurity vulnerabilities Supply chain issues

ASIC SWOT Analysis

	Helpful	Harmful
Internal origin	Optimized Performance Low power consumption Space efficiency Safety and reliability Long Product Lifecycle	Lack of flexibility High upfront development costs Limited reusability Design complexity
External origin	ADAS and autonomous driving Power efficiency and EVs Better packaging	Technological obsolescence Cybersecurity concerns

Quality Factor Determination (QFD) Matrix

As it is evident from the matrix, chiplets seem to be the best option out of the lot, followed by ASICs, and SoCs, with FPGAs at the bottom of the table. Not only this, through this table we can also get an understanding of how these compare for individual issues, which will help us choose applications accordingly.

Technology	Weightage	SoCs	Chiplets	FPGA	ASIC
Computing Power	4	9	7	6	5
Ease Of Cooling	3	5	5	4	7
Product Life Cycle	4	5	9	7	6
Hardware Flexibility	2	4	8	9	6
Scalability	3	5	9	6	7
Yield	4	5	8	4	6
Ease Of Integration	2	6	8	7	9
Power Efficiency	5	8	8	6	9
Cost	5	8	6	5	9
Total Score		206	240	185	230

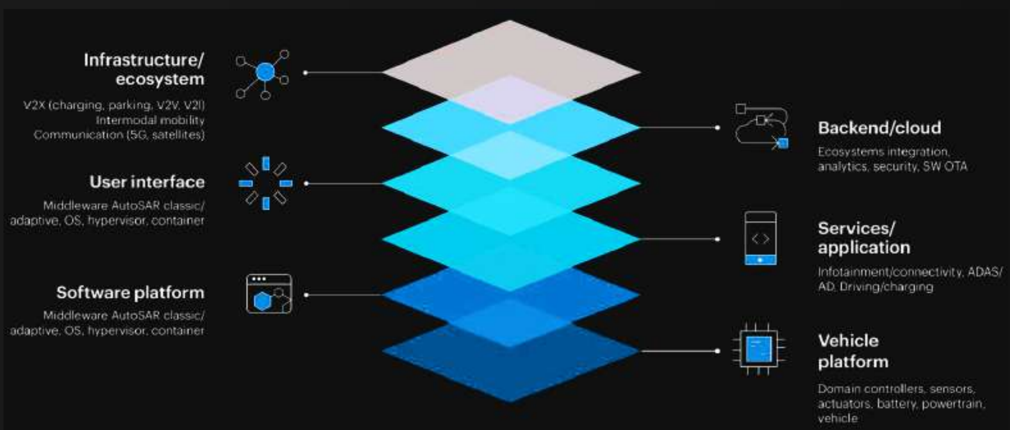
Traceability Matrix

The Traceability Matrix below maps the electronics requirements to mitigate the root causes of the current industry trends. This helps us identify the areas in which chiplets can find specific solutions.

	SOFTWARE DEFINED VEHICLES	USER FEATURE DIFFERENTIATION	INTELLIGENT CONNECTED VEHICLES	AUTONOMOUS VEHICLES	ELECTRIC VEHICLES
COMPUTING POWER	SoC	Chiplets	FPGA	SoC	ASIC
COOLING OPTIONS	ASIC	ASIC	ASIC	ASIC	ASIC
PRODUCT LIFE CYCLE	Chiplets	Chiplets	FPGA	Chiplets	Chiplets
HARDWARE FLEXIBILITY	FPGA	FPGA	FPGA	FPGA	Chiplets
SCALABILITY	Chiplets	Chiplets	Chiplets	Chiplets	ASIC
YIELD	Chiplets	Chiplets	Chiplets	Chiplets	Chiplets
EASE OF INTEGRATION	ASIC	Chiplets	ASIC	ASIC	ASIC
POWER EFFICIENCY	Chiplets	Chiplets	SoC	ASIC	ASIC
COST	ASIC	ASIC	SoC	ASIC	ASIC

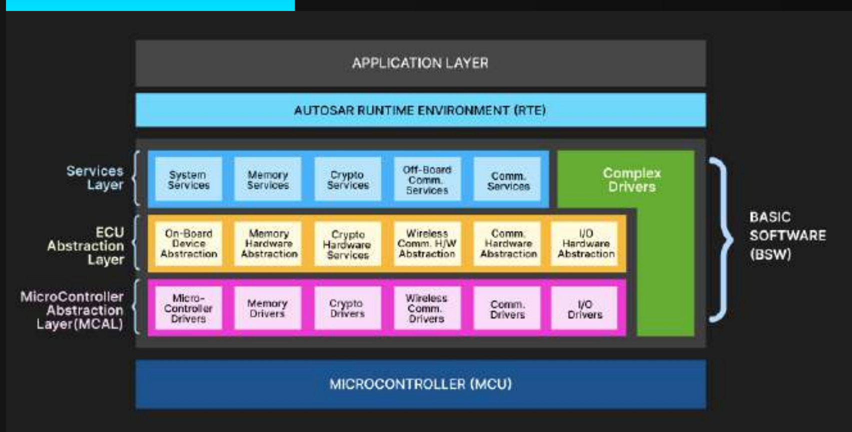
Applications of Chiplets in the Modern Automotive Industry

The automotive industry is undergoing a transformative shift as trends like connected vehicles, electric mobility, and autonomous driving drive increased digitization. While vehicles traditionally focused on hardware,there's a significant transition towards software-based features. This evolution, turning vehicles into software-centered cyber-physical systems, enables advanced functionalities like over-the-air updates and self-driving capabilities, necessitating seamless interactions between software, hardware, and the vehicle's environment. Scholars propose an electrics/electronics (E/E) platform as a solution, integrating hardware and software principles to establish a comprehensive vehicle architecture. This platform acts as a connection layer, facilitating the close integration of hardware and software within a cyber-physical system, aiming to enhance scalability, cost savings, and the overall effectiveness of vehicle engineering.



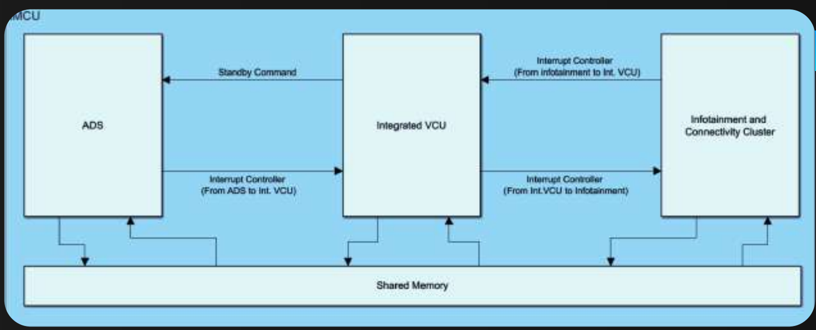
The E/E platform functions as a unified framework for efficient component reuse, introducing a new level of abstraction in structuring products. It integrates all software artifacts and their physical implementations within electric control units, forming an interconnected embedded system. This platform does not alter the existing platform strategy but introduces a cross-vehicle basis that increases the reuse and standardization of software-intensive components

Moreover, the current landscape of vehicle requirements necessitates over 100 Electronic Control Units (ECUs) with a one-to-one mapping to individual functions, resulting in a decentralized architecture. This decentralized approach significantly elevates the communication load on the vehicle network, leading to increased overall costs. The traditional use of networking technologies like Controller Area Network (CAN), FlexRay, LIN (Local Interconnect Network), and MOST (Media Oriented System Transport) has been adequate for traditional communication. However, with the growing implementation of software functionalities in modern cars, the "one function per ECU" model is proving impractical. The challenges include the expected surge in data volume and the escalating number of interconnections between different ECUs. Building vehicle variants for diverse market segments requires numerous software releases and may entail constructing multiple architectures, thereby limiting efficiency.



To address the drawbacks of decentralized architectures, the automotive industry is witnessing a shift to-wards centralized alternatives. Recent developments include domain-centralized (or domain-oriented), cross-domain centralized (or cross-domain-oriented), and vehicle-centralized (or zone-oriented) architectures.

Integrated Master Control Unit



In our approach, we intend to integrate all the major control units with the Vehicle Control Unit into a single chiplet based architecture, known as the **Integrated Master Control Unit (IMCU)**.

Innovating automotive architecture, the system incorporates several key features to enhance efficiency and functionality. The centralization of all control units into a unified hub forms a core aspect, streamlining the management of computational tasks. These tasks are efficiently handled by a pooled processor, ensuring optimal utilization for tasks of similar magnitude. The architecture consists of three sub-units, each based on distinct processing clusters.

- Integrated Vehicle Control Unit (VCU)
- Autonomous Driving System (ADS)
- Infotainment and Connectivity Cluster

To facilitate seamless data transfer, a Shared Memory Module is implemented, connecting all three systems. Notably, major sub-components like the motor control module and State of Charge (SoC) estimation for the battery pack are software-defined, providing flexibility and adaptability

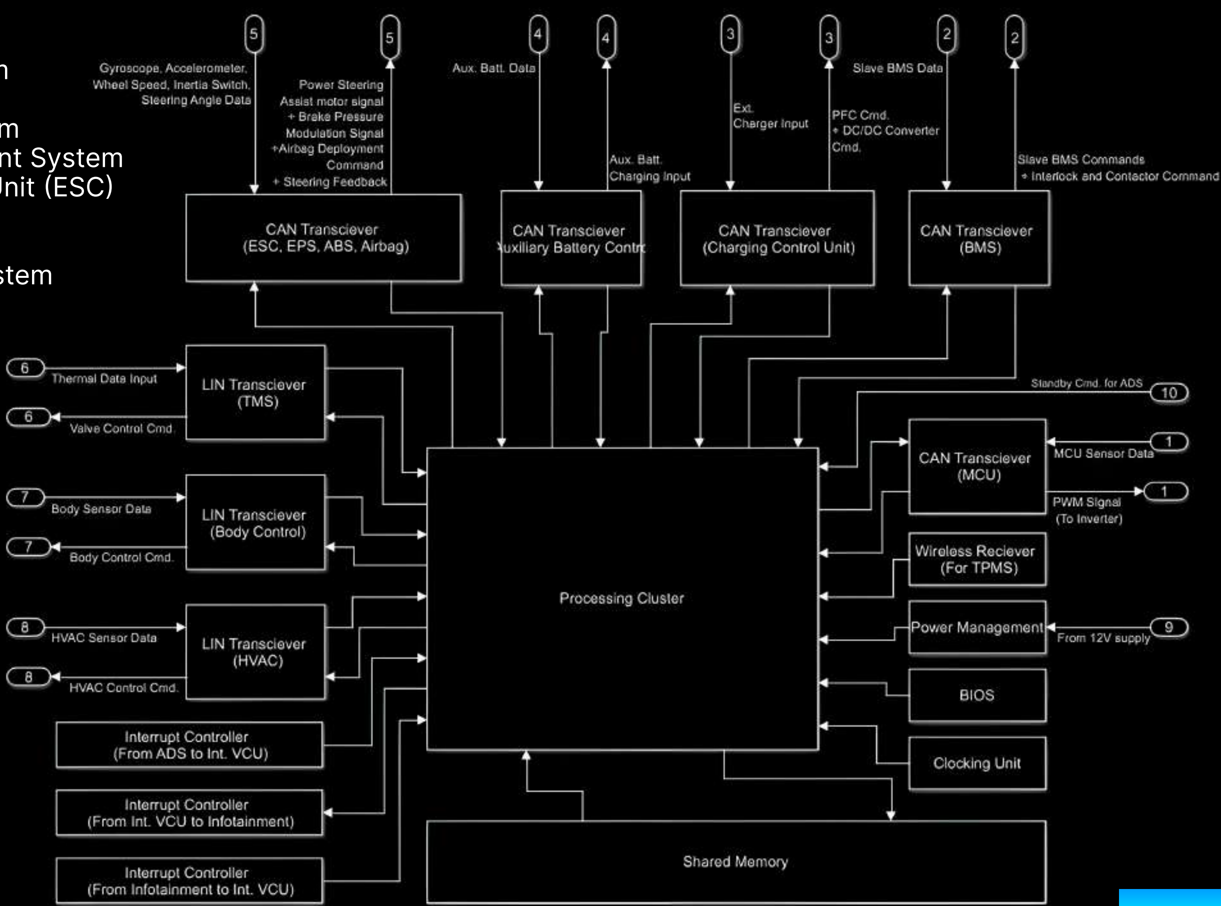
The architecture boasts far greater power efficiency compared to the prevailing use of multiple Electronic Control Units (ECUs), contributing to an environmentally conscious and energy-efficient design. Lastly,the hardware is customizable according to Original Equipment Manufacturer (OEM) requirements, offering adaptability and flexibility in addressing specific automotive needs.

Integrated VCU

The ”Integrated VCU” subsystem of the IMCU incorporates all the functions present in a traditional VCU and integrates it with all other related ECUs (except for those integrated into the ADS and Infotainment and Instruments Cluster).

The following are the ECUs integrated in this subsystem:

- Motor Control Module
- Transmission Control Unit
- Battery Management System
- Charging Control System
- Thermal Management System
- Auxiliary Battery Management System
- Electronic Stability Control Unit (ESC)
- Electric Power Steering Unit
- ABS Control Module
- Tire Pressure Monitoring System
- Body Control Module (BCM)
- HVAC Control Module



The computations done by the individual ECUs are now offloaded to the chiplet-based processing cluster shown in the diagram. Hence, these ECUs are now essentially software defined, rather than a hardware unit. The outputs generated from these computations from each (now software-defined) system is stored inthe shared memory unit. Any other system that needs the outputs of the computation or the data collected by the sensors, can access it from the shared memory.
In order to streamline data collection and transmission, we perform data-level sensor fusion for sensors that are physically close together, combining their raw data. This is then sent to the IMCU via a CAN bus.The IMCU receives the data, and the appropriate sensor data gets stored in the shared memory, from where all systems that require the data can access it. A more detailed explanation of the sensor fusion technique has been given later under the ADS subsystem section
For sensors that transmit non-critical data, LIN has been utilized instead of CAN. The memory module shown is shared by all the subsystems of the IMCU, ensuring any data collected by one is available for utilisation by the other. For the transmission of data, the same CAN buses that were used by the sensor sare used to transmit the required control signals to the appropriate actuators

Autonomous Driving System (ADS)

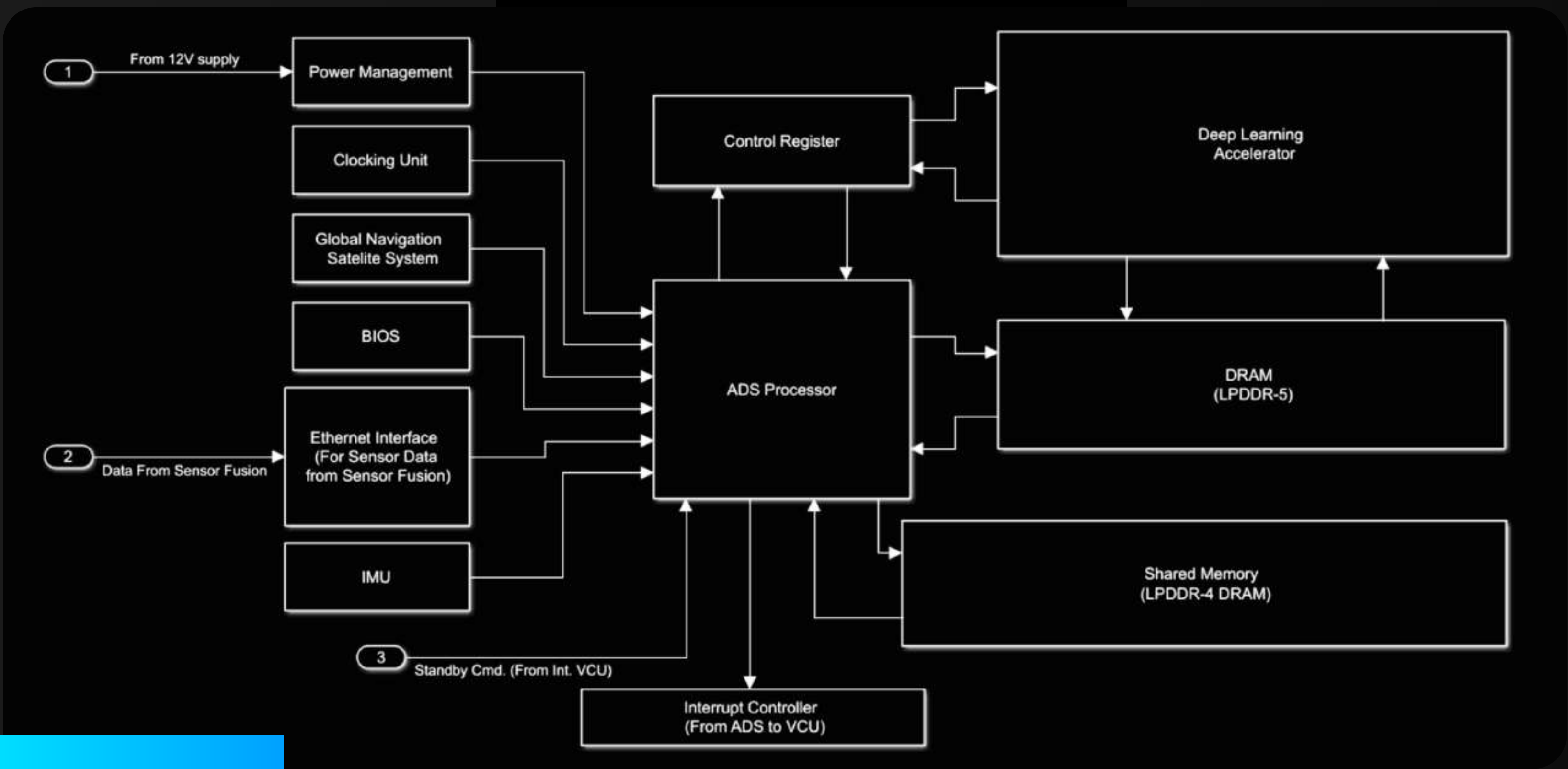
We aim to implement an Autonomous Driving System (ADS) into our system. Its purpose is to facilitate the autonomous driving of the car, with minimal human intervention. The ADS integrates the data from various sensors such as the LiDAR and RADAR, processes it, prepares a course of action, and executes it in collaboration with the Integrated VCU subsystem

The systems integrated into the ADS subsystem include:
- Perception Subsystem: Cameras, LiDAR, RADAR, etc.
- Localization Subsystem: GPS, Inertial Measurement Unit, etc.
- Planning Subsystem: Route Planning, Trajectory Planning, Maneuver Planning
- Control Subsystem: Steering Control, Acceleration/Deceleration Control .

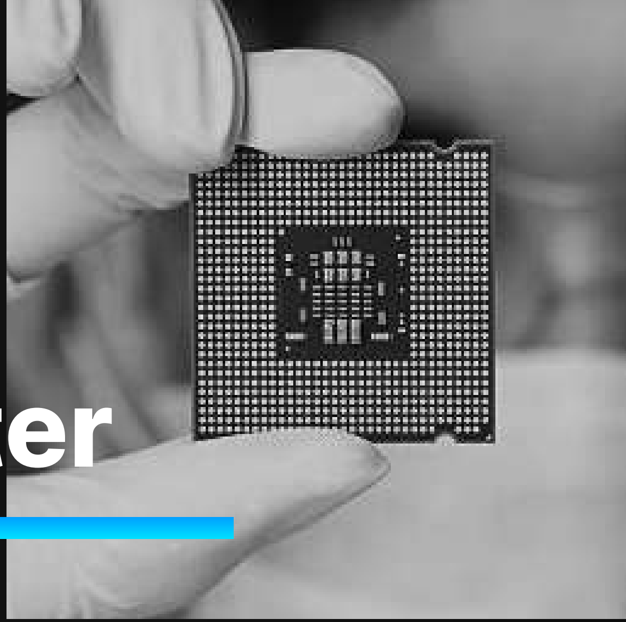
In our implementation, the data from various peripheral sensors such as camera modules, LiDAR and Radar are combined by data level sensor fusion. The combined data is transmitted to the ADS subsystem of the IMCU by using Ethernet. The ethernet interface receives the data and passes it onto the ADS processor.

The processor also receives data from various other sensors and systems such as the Inertial Measurement Unit (IMU) and the Global Navigation Satellite System that are directly connected to it.

It can also access data collected by the Integrated VCU and the Infotainment and Connectivity Cluster subsystems via the Shared Memory module (LPDDR-4 DRAM). The processing involving Deep Learning Agorithms is done by the Deep Learning Accelerator of the system.



Infotainment and Connectivity Cluster



This subsystem integrates the infotainment ECU and all other ECUs involved with data logging and telemetry. Its main purpose is to perform all Infotainment functions along with all V2X functions required by the car. It interacts with the user interface and conveys all the information that needs to be passed on to the driver and other passengers. It integrates various connectivity functions, such as WiFi, Bluetooth, etc, from entertainment systems and also supports smart connection technologies such as IoT integration and V2Xcommunication

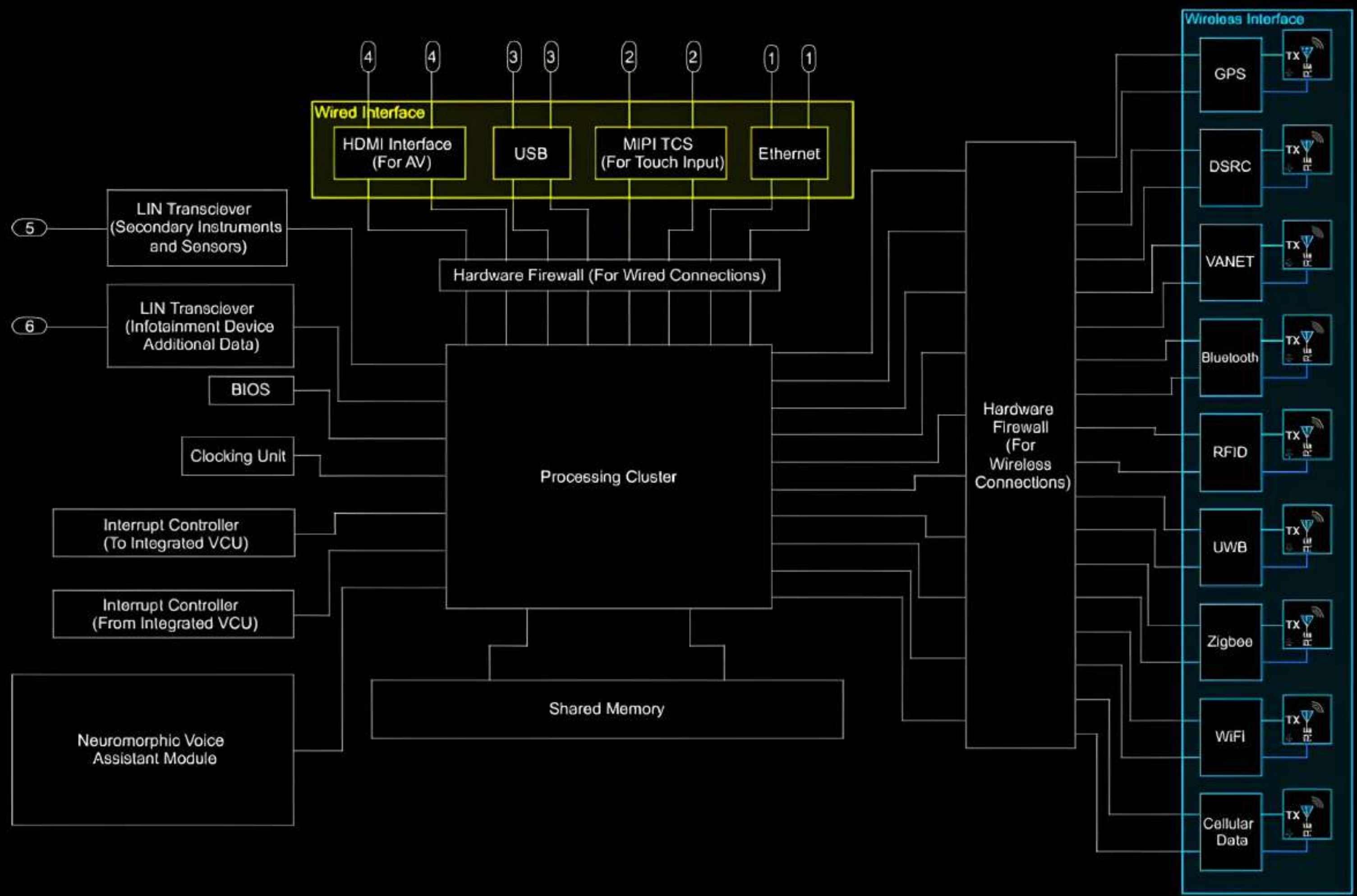
Infotainment Instrument Interfaces

Several wired interfaces such as HDMI, USB, and Ethernet connect with various infotainment instruments,including touchscreen displays. These interfaces convey critical data to the driver and enable features like radio playback and multimedia content from the internet or USB media devices

V2X Connectivity in Intelligent Transportation Systems

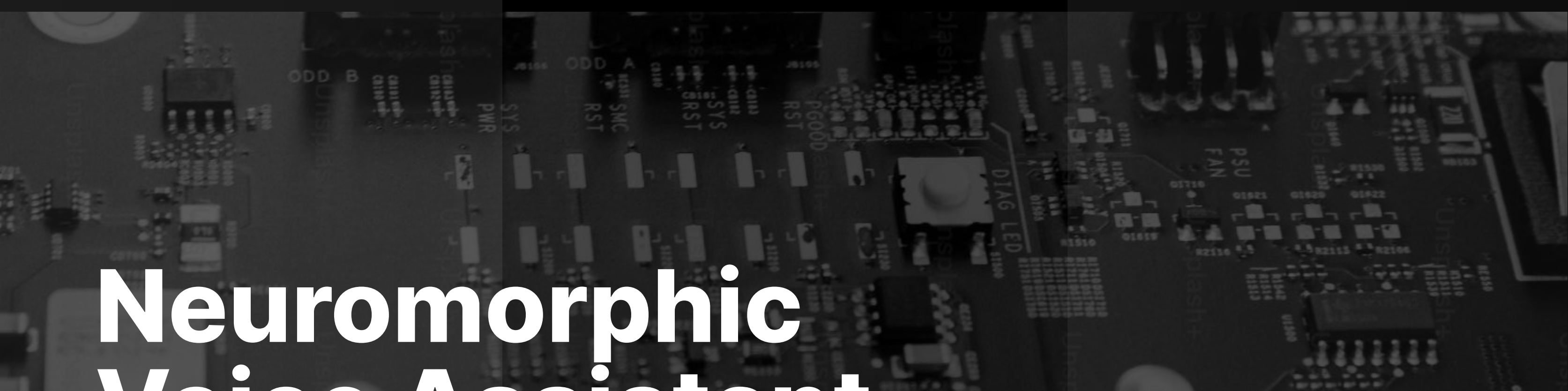
Vehicle-to-Everything (V2X) connectivity is crucial for Intelligent Transportation Systems (ITS), facilitating communication between vehicles, infrastructure, and elements within the transportation ecosystem. V2X includes Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Cloud (V2C), and Vehicle-to-Infrastructure/Internet of Things (V2IoT) communications.

These leverage wireless technologies like DSRC/VANETs, cellular networks (LTE and 5G), Zigbee, UWB, Wi-Fi, WiMAX, RFID, and Bluetooth to ensure secure data transfer between the car and the cloud, a Hardware Firewall is implemented. It monitors network traffic, allowing only legitimate connections and employing techniques such as Network Address Translation (NAT) and Virtual Private Networks (VPN) to enhance security.



Communication within Vehicle Subsystems

The Infotainment and Connectivity Cluster shares data and instructions with the Integrated Vehicle Control Unit (VCU) through a shared memory module accessible to all three subsystems. Two interrupt controllers facilitate the exchange of instructions between the Infotainment and Connectivity Cluster and the Integrated VCU subsystem.



Neuromorphic Voice Assistant

Speech recognition plays a pivotal role in the HMI of modern cars, enhancing user experience and safety.
It enables hands-free interaction, allowing drivers to control various functions through voice commands,such as making calls, sending messages, adjusting navigation settings, and managing multimedia playback. Advancements driven by natural language processing and machine learning algorithms contribute to better understanding diverse accents, languages, and commands

Speech recognition plays a pivotal role in the HMI of modern cars, enhancing user experience and safety.
Neuromorphic circuits can be implemented for speech recognition, offering varying degrees of functionality. One approach involves a wake-up module that triggers the main processing system upon detecting specific keywords, improving power efficiency. Another approach implements a complete neuromorphic system using a Spiking Neural Network (SNN) architecture for speech recognition, achieving energy efficiency compared to traditional processors
In the implementation of a keyword spotting model, a Loihi neuromorphic processor running speech2spikes demonstrated significantly lower energy usage compared to GPU and CPU alternatives. This efficiency extends beyond keyword spotting, with orders-of-magnitude improvements observed across various tasks.

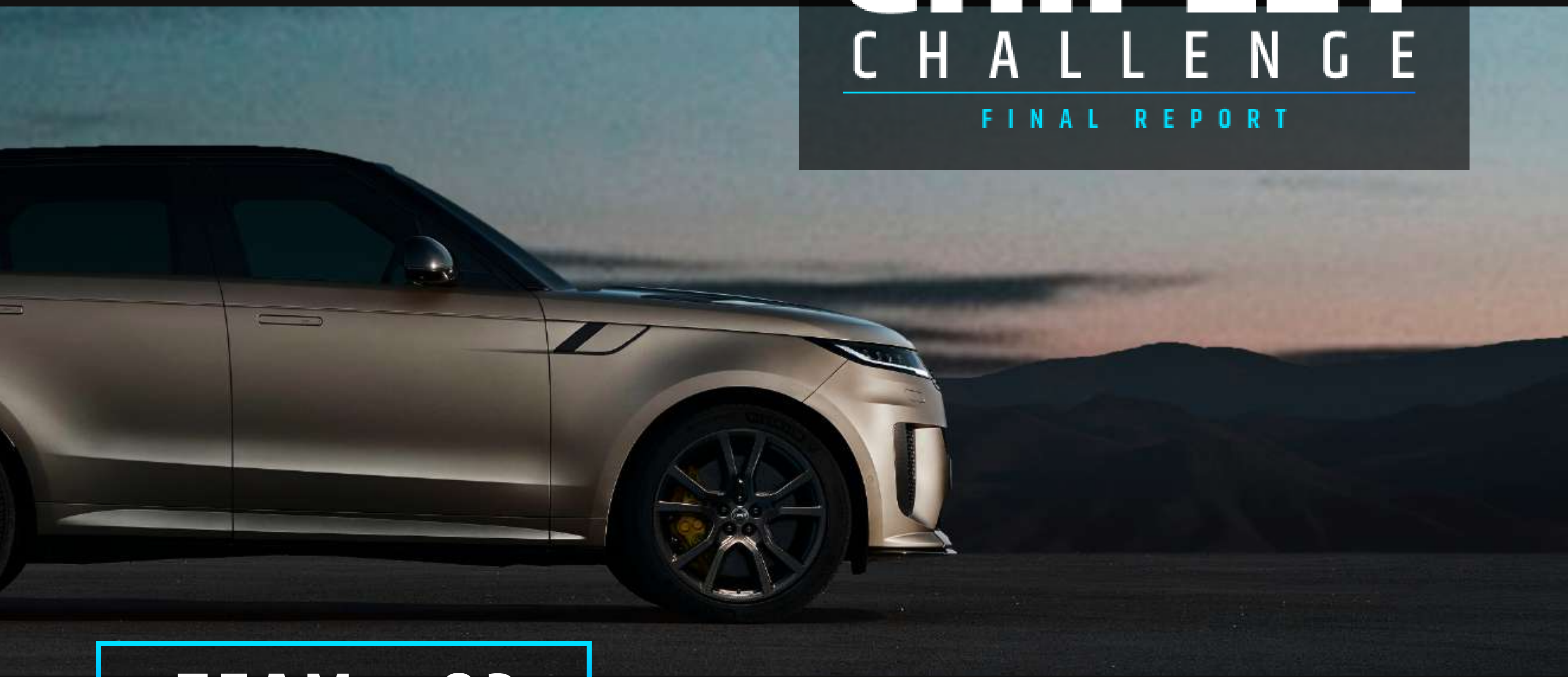
INTER IIT
TECH MEET
MADRAS

JLR

INTER IIT JLR HIGH PREP

CHIPLET CHALLENGE

FINAL REPORT



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