GAST Automotive Industry & Technology Research Report
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Subject: The Latest Development Trends of ICVs

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Contents

In the Era of Software-Defined Vehicles (SDVs), OEMs Lead the Way in Building Open Ecosystems to Access External Resources

Automakers will continue to play a leading role in the era of SDV and will certainly hold the core value of vehicle development firmly in their hands

- **Hardware:** as hardware starts to resemble on a large scale, more automakers delegate power to their suppliers, continue to keep their supply chains open, and adopt modular supplying

➢ Hardware should be pluggable, convenient for software portability, and scalable by module, while also meeting regulatory requirements

- **Software:** automakers generally expect to have the autonomy, but choose to cooperate with supply chain partners in the initial phase, in order to maximize the possibility of mastering the core link

➢ Software forms plenty of subscription services based on a standardized architecture and interfaces, and an open-source software community will be gradually built

Automakers should fully access external open resources, integrate all kinds of ecosystem data, and take the initiative to provide accurate services for all scenarios → build new mobility service ecosystems integrating "connection + experience + value" and transform vehicles into smart mobility platforms in a real sense

Internet ecosystem	Technology ecosystem	Content ecosystem	Vehicle-road-city digital society
ByteDance, iQiyi, NetEase Cloud, etc.	Microsoft, Qualcomm, NXP, etc.	We-Media, user co-creation, AI creation, etc.	Efficiency, safety, life, management, etc.

New vehicle development drives the core competitiveness of the industrial chain to shift to hardware + software + content + services, with the development of flat and reticular supply networks and continuously reshaping division of duties and boundaries between automakers and suppliers

Automakers Build Open Frameworks to Encourage Users to Participate in Product Innovation

■ It is quite necessary for users to participate in product innovation, but the threshold for developing automotive application software is high: involve personal and vehicle safety → users should participate in the innovation of vehicle products within the frameworks defined by automakers

Prerequisites for users to participate in automotive application development

① Automakers should provide an open architecture platform and related capabilities as strong support
② Users' participation in application development should be achieved by smarter and more convenient human-vehicle/computer interaction
- Not deeply involve users in software programming and development, but ensure the feasibility as much as possible

Automakers should ensure convenience and safety for users to participate in the customization of functions

➢ Automakers should interact with users and allow users to make their own choices
- Open the controlled part to users so that they can make choices (e.g., function combinations in specific scenarios)

➢ Automakers should complete development and provide most functions expected by users
- The combination of functions allowed to be defined by users must be proven to be free of functional safety risks

Business cases

① **HiPhi:** build HiPhi Play & HiPhi Show based on H-SOA (HiPhi Service Oriented Architecture) to allow for co-creation
② **WM Motor:** allow users to freely combine function modules of vehicles through the smartphone App to create exclusive scenarios and functions

□ **Freewheeling customization of automotive applications is not advisable and automakers should carve out space from the architectures that they dominate for users to define the combination of functions: improve user experience in scenarios as much as possible on the precondition of safety**

Business Cases: HiPhi Relies on a New Architecture to Transform the Way of Developing Automotive Applications

- The intelligent transformation of automobiles will be reflected in transforming vehicles with intelligent technologies based on scenarios, rather than piling up intelligent functions → HiPhi created H-SOA and introduced co-creation initiatives to spur the creativity of ecosystems and collaborative innovation capabilities

- **OEMs and suppliers:** continuous evolution of vehicle performance and maneuverability, customized riding experience, optimization of tailored entertainment systems, voice control and emotional partners
- **Car owners:** customize personalized patterns of manifestation, and upload and download desired Apps
- **Third-party developers:** build an open programming platform based on financial-grade security architectures and content → form a new business model in the car owner ecosystem

HiPhi Play
- 140+ atomic capabilities (able to invoke 30+ modules, 500+ body sensors, and 300+ actuators)
- The atomic capabilities can be combined in a customized manner to form scenario cards → improved efficiency, rich experience, and creative brainstorming

Intelligent open platform

Scenario-defined design
- Rapid iteration of software
- Rapid deployment of software
- Rapid access of hardware

Co-creation-defined value
- Standardization of software interfaces
- Easy development of software
- Data-driven evolution of scenarios

SDVs (technology cornerstone)
Reservation of hardware computing power + decoupling of software and hardware + layered design of SOA + AI computing framework

HiPhi Show
- Graphical programming → low-code development
- Abundant official templates → fast creation
- Online simulation test environment → what you see is what you get

Features that used to take months to develop in coordination with multiple suppliers can now be developed and debugged by a person with basic programming experience within a day

Now used by **70%** of its users, **5,000+** scenario cards created, **35%** of its scenarios using more than 5 atomic functions, over **1.7 million** executions, **14,000** hours of development time saved

Under service-oriented architectures, 100 functions are no match for the ultimate experience in one scenario → it is necessary for automakers to radically alter their approaches

Business Cases: WM Motor Allows Users to Build Intelligent and Exclusive Scenarios Through the Combination of Functions

- Supported by the 8155 chip, users can set five types of trigger conditions via the smartphone App and invoke over 25 function modules and more than 200 automotive functions at will, which can be combined to deliver the ultimate experience in specific scenarios

Five types of trigger conditions

- Car door
- Vehicle speed
- Power capacity
- Driving mode
- Time

25+ function modules / 200+ automotive functions

- Function modules available: A/C, vehicle control (seats, door locks, etc.), navigation, system facilities, timing, multimedia, etc.
- Function modules to be available: autonomous driving, parking, panoramic view, telephone, horn, ambient lights, etc.

Without programming experience, users can add, manage, and enable the automotive OS to work together with their smartphones via the smartphone app

Login to "Weima Kuaijie" in the smartphone App → Select to modify/create a new scenario card → Edit function combinations → Synchronize in smartphones and head units → Voice/scenario/head unit/ smartphone trigger → Execution

Examples of use cases

Fresh air	Happy returning home	Party mode	Private space	Biochemical mode
Activate the negative ion air purification system (PM2.5/AQS)	Activate the comfortable driving mode + turn on the music/ambient light/navigation	Activate the trunk and loop multimedia + turn up the volume	Close the windows and sunshade + turn on the music and A/C	PM2.5 > 75 → close the windows + activate the purification/ internal circulation system

WM Motor enables users to customize functions to some extent through the combination of functions (not involving the functional safety of vehicles) → enhance user experience in use cases

Contents

NVIDIA's Chips and Platforms for Autonomous Vehicles

■ NVIDIA forges its full-stack AD service capability and highlights its strength via software

Goal

- Seize the $300 billion revenue opportunity in the automotive market (as the third business pillar of NVIDIA, following data centers and games)

Core: chips for autonomous vehicles

Orin SoC (production and sales are available) → Thor SoC (to launch in 2025)

- **Leading computing power:** 254TOPS per Orin SoC; 2,000TOPS per Thor SoC
- **Numerous customers:** more than 25 automakers & AD companies across the globe (20 ones from the global Top 30 automakers)

Four pillars → fuel the development of a chip ecosystem

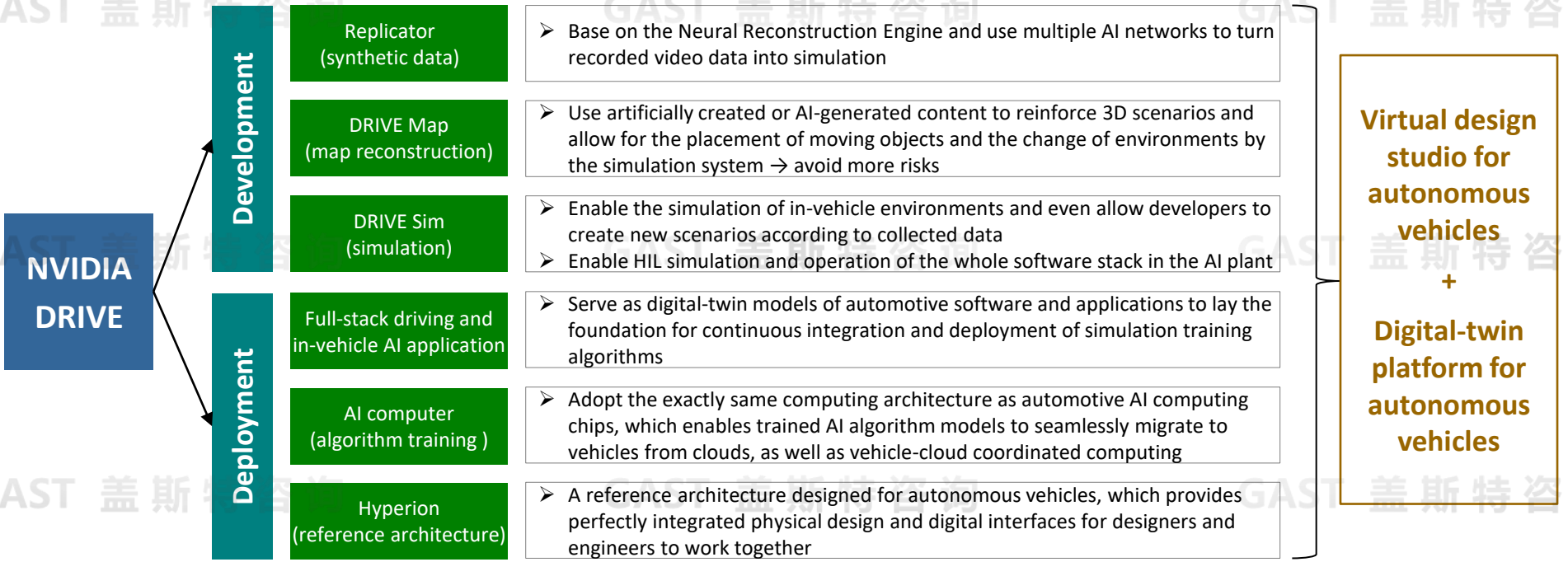
AD platform	AI training and reasoning	Simulation and digital twins	HP map
DRIVE Hyperion9 (a programmable architecture) • Built on multiple DRIVE Atlan computers (fewer chips) • Include a whole set of development tools, a data set, a data collection system, simulation tools, etc.	**Create NVIDIA DGX system** • Plug-and-play → provide the computing power required by large-scale training and optimization of deep neural network models	**Roll out Drive Sim & Drive Map based on the NVIDIA Omniverse** • Precisely reconstruct and modify real-world driving scenarios based on tools and platforms → accelerate the readiness of AD algorithms	**Acquire DeepMap** • Enable HD map updates and deeply integrate the computing platforms for perception & decision • Prowess: HP map, accurate and real-time positioning, and service infrastructure construction

*Notes: NVIDIA DRIVE Sim (high-fidelity simulation); NVIDIA Omniverse (a platform for collaborative efforts); NVIDIA DRIVE Map (HD map)

□ **NVIDIA leverages its high-performance chips for autonomous vehicles as the core pivot to build its "moat" in a systematic manner**

NVIDIA's Complete Tool Ecosystem for Development and Deployment of AD

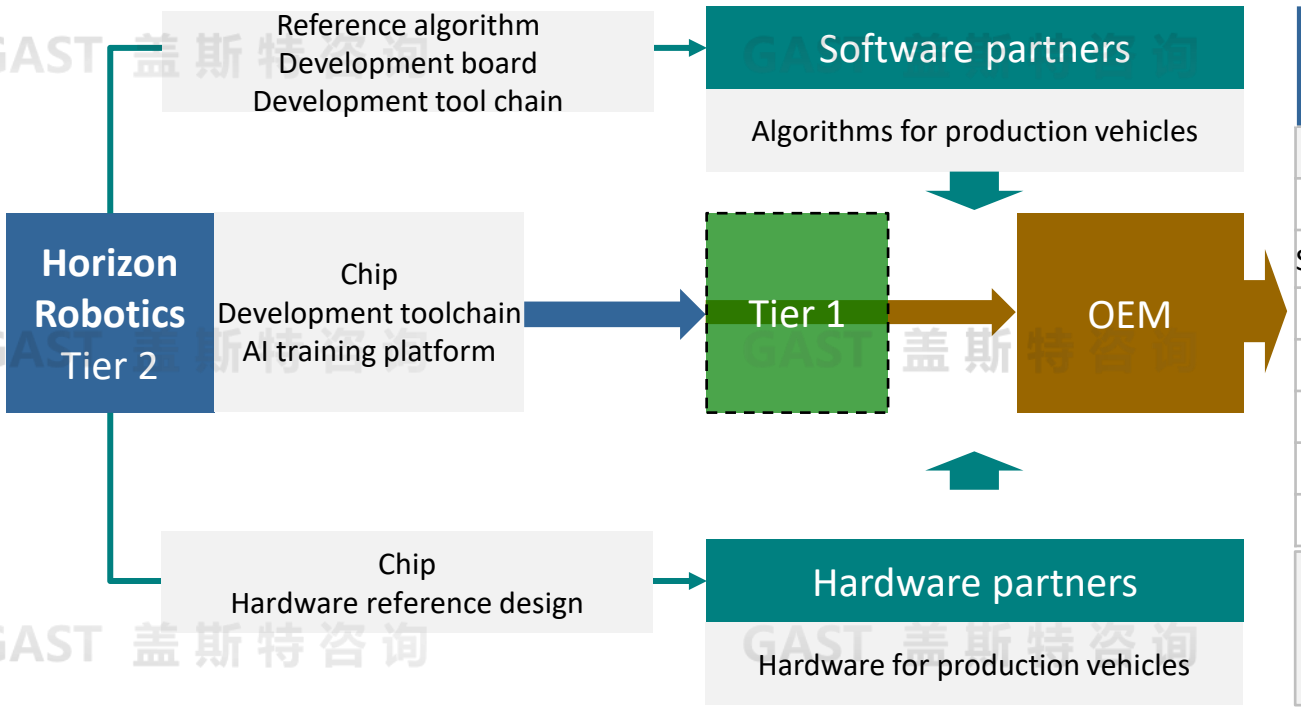
- In addition to onboard computing devices, AI plants located in data centers are also required to bring autonomous driving into reality, which can be used for data processing, AI training, digital-twin technology, and mapping → that's why NVIDIA DRIVE is developed



- **NVIDIA DRIVE can not only expedite the development of AD and smart cockpit but also improve the availability of autonomous driving systems by testing the corresponding digital-twins models → build a robust toolchain ecosystem**

Horizon Robotics Creates an Open and Altruistic Cooperation Model

- Positioned as a T2 supplier, Horizon Robotics has created an open and win-win cooperation ecosystem through the empowerment of chips and development tool chains



Horizon Robotics' OEM partners (intelligent driving domain control)

OEM	Progress
BYD	Under development
SAIC Passenger Vehicle	Under development
SAIC MAXUS	Under production
FAW Hongqi	Under development
Li Auto	Under production
NIUTRON	Under development
Changan	Under production

Create an upgradable development platform based on chips to empower OEMs' NOX functions (highways & urban roads) (L2~L2++)

- **Although positioned as a Tier 2 supplier, Horizon Robotics has direct interactions with automakers like Li Auto on the development of vehicles, in addition to cooperation with software and hardware partners → it is practically turning a reticular ecosystem for the auto industry into a reality**

Horizon Robotics Offers a Full Range of Product Packages Enabling Vehicle Mass Production Development

Development tools and infrastructure

Horizon OpenExplorer™ platform chip algorithms and toolchain
(for production and development)
→ quantification of AI algorithm models; performance simulation and analysis

Eddy AI development platform
(for R&D and training)
→ efficient AI training, testing, and management tool platform

AI chip and software stack

App
- Production algorithm (perception)
- Customer algorithm
- Reference algorithm

Middleware
- Sensor service center
- Vehicle control input/output
- Computer vision
- Deep neural network
- Framework for deterministic runtime
- Data processing tool
- Communication framework
- Data stream management
- Basic algorithm tools

Basic OS
- Basic middleware
- Hardware abstraction library
- Development tool chain
- Linux, QNX and other mainstream OS kernel
- Board support package (BSP)

Hardware

Development kit and reference design

AI chip → Development & experimental evaluation board → Pre-production of printed circuit boards → Hardware upgrade and expansion → Computing platform reference and design

Ecosystem/production

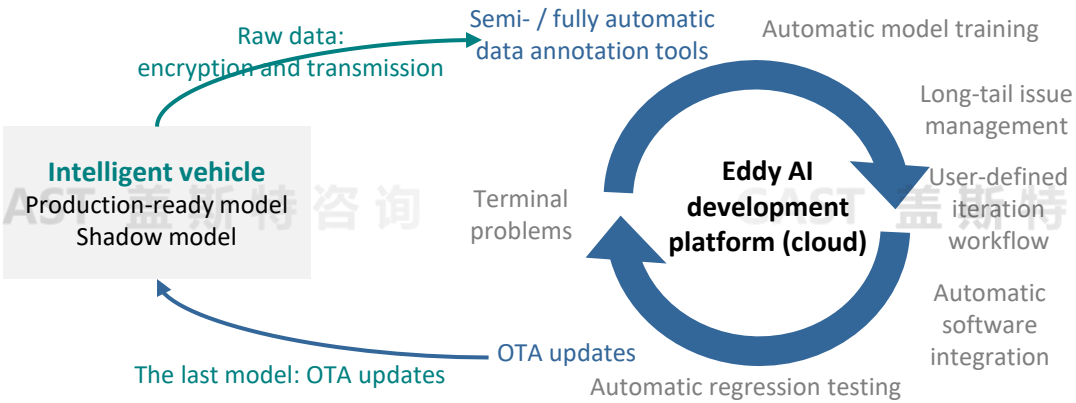
Strong basic software
Unified infrastructure
+
Sound development toolchain
↓
Enable flexible upgrade and expansion of upper-layer applications

Support chip upgrade
Clear technology path
(enhanced perception + improved security)

- **Horizon Robotics builds an upgradable development platform based on chips to provide complete, proven and user-friendly product packages → better enable customers to rapidly apply chips to the development and production of vehicles**

Horizon Robotics Drives Closed-Loop Management for Vehicle Data with Development Tools and Infrastructure

- Horizon OpenExplorer™ platform provides a complete development toolchain that ranges from models to real-time operation environment → build data-driven, proven development environment based on the "Eddy" platform, helping ecosystem partners' innovation activities



Closed loop of data from terminals and cloud

Chip algorithm and toolchain based on the Horizon OpenExplorer™ platform

Training	Optimization & transformation	Deployment
Compatible with the major AI frameworks TensorFlow, Pytorch, Caffe, etc.	**Optimization & Compilation toolkits** Detector + Analyzer + Compiler + Simulator	**Embedded reasoning toolkits** ↓ Real-time runtime environment
Training toolkits Model Zoo Quantitative training add-in programs		

Built-in

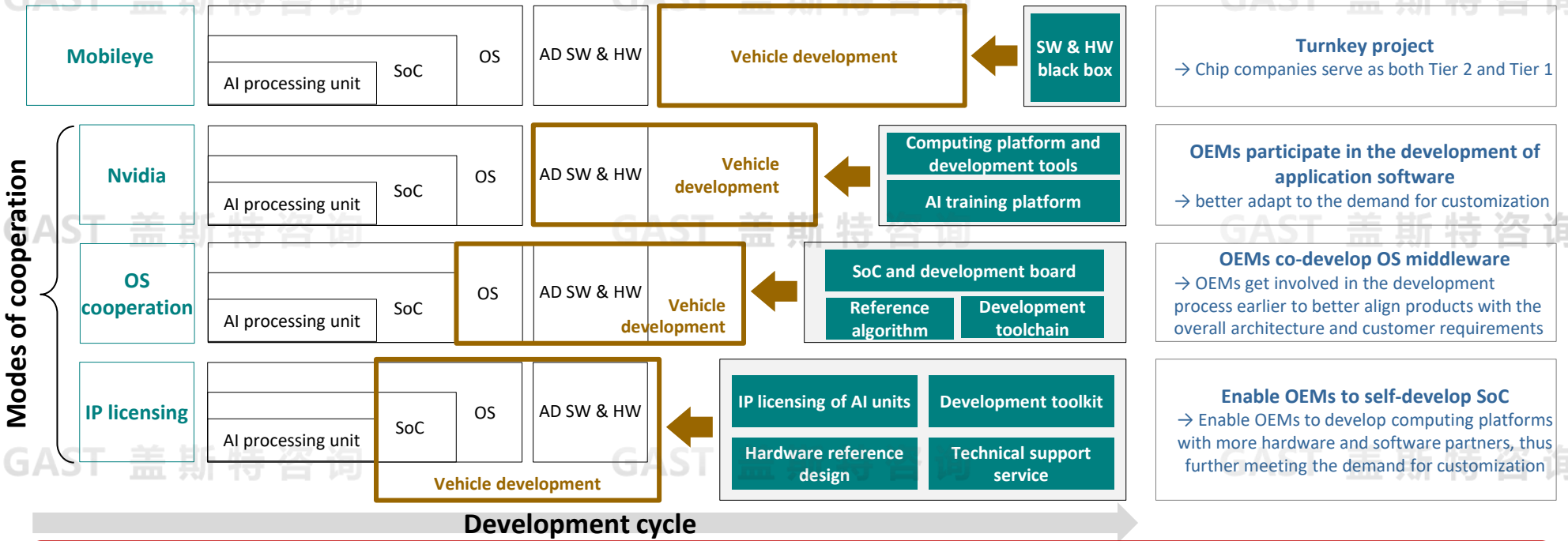
User-friendly, efficient, and precise → convergence of long-tail issues + improvement of performance

- Explore problems in key scenarios: the success rate of precision optimization ≈ 100%
- Full-process automation of model iteration: the success rate of the first model migration = 80%
- Greatly improve the efficiency of developing algorithms: the development cycle of an operator is reduced by 30% on average
- Open the access to all terminals: halve the investment in customer traffic on average

- Perception training of model quantization: completely consistent with the accuracy of chip deployment, with no loss of accuracy
- Post-training model quantization: accuracy loss < 1%; rich experience in engineering tuning; instrumentalization and automation
- Optimization of model compilers: improve the output of real AI performance
- Customer-friendly: hundreds of customers + reference samples and reference algorithms + rich documents and communities

Horizon Robotics Opens Chip BPU IP Licensing to Promote the Reform of Vehicle Development

- Positioned as a Tier 2 supplier, Horizon Robotics can provide different modes of cooperation according to the level of coordination, proactivity, and leadership of OEMs in intelligent driving



- **Flexible modes of cooperation and comprehensive service capabilities can not only meet OEMs' requirements for customization and shorten the development cycle but also make Horizon Robotics more competitive in the future automotive industry**

Contents

Opportunities and Challenges to Security Brought by Digital Transformation of the Automotive Industry

- The comprehensive digital transformation of the auto industry brought by the Internet of Things (IoT) makes the Internet of Everything (IoE) become an inevitable trend, ensuing unavoidable opportunities and challenges for the industry. However, opportunities would outnumber challenges

Essential characteristics of digital transformation: define the basis of the world with software

① everything is programmable ② everything is connected ③ big data drives business

Opportunities (transformation of traditional industries + national development strategy)	VS.	Challenges (connectors and data surge → more complex problems of data security)
① Digital economy is not the virtual economy and can empower the real economy • Better allocation of resources + high-quality development of industries → create greater value ② The greatest value of digital transformation is to perform the digital transformation of industries • Fully transform the traditional economic pattern and create new ones ③ Digital transformation strategy is of important significance to China • China has a chance to play a leading role → developing digital economy has been lifted to the height of the national development agenda	>	① Software vulnerabilities are inevitable and the risk of hacking exists • Hacking is hidden and uncertain → impossible to defend effectively ② Attacks from the virtual space can be translated into damage in the physical world ③ If the big data system is under attack, there would be serious social security issues

Digital transformation of industries is the core lever to navigate this round of scientific and technological evolution and to seize opportunities during the industrial restructuring → standstill is unadvisable for the sake of potential safety risks. Players should address digital security issues and maximize the value of digital transformations

Digital Transformation Empowers Auto Industry: Address Three Challenges for the Design and Development of Smart Vehicles

- Challenges to the development of vehicles: ① inadequate integration/verification of needs; ② hard to coordinate software and hardware; ③ high cost of integration/test

① Requirement engineering & architecture
↓
How to integrate the requirements of the stakeholders and propose the optimal solutions as soon as possible?

Synergize SW & HW via DC* tools

SW
- Weave software codes into product life-cycle management (e.g., integrated software release management tools)

Electronic
- Provide software components in line with the AUTOSAR standards (e.g., embedded software development tools)

HW
- Accelerate parallel and collaborative development of electronic systems and hardware (e.g., electronic design integration tools)

Electrical
- Integrate wiring harness from the schematic diagram to the layout and processes (e.g., electric design tools for wiring harness)

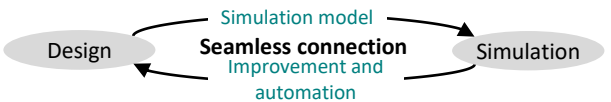
③ Integration + verification + validation
↓
How to reduce the time and cost of integration and verification?

Adopt the systems engineering method

- Modeling, simulation, and evaluation of candidate product solutions + decision at the **concept stage** → define needs and architectures
- Verify the **feasibility of the solution** as soon as possible to reduce the risk of introducing new technologies → cooperate across business units (e.g., market, product) to verify solutions centric to user experience
- Make higher demands on the **integrity and quality** of the solution before in-depth development of the product → study, weigh up, and improve the combination of solutions

② Specific design of SW & HW
↓
How can OEMs and suppliers cooperate to integrate software and hardware?

Perform design: seamless virtual testing



- Realize seamless connection of data between design and simulation to promote the verification and improvement of timely coordination and virtual prototypes
- Virtual integration of multiple fields and numerous physical scenarios **(e.g., man-vehicle-road-cloud integrated simulation) to reduce the cost of physical testing**

90% of innovating functions of smart vehicles will be dominated by software and realized via the SW & HW synergy → substantially intensified complexity of product development. Empowering product design via digital approaches can markedly increase development efficiency and reduce cost

*Note: DC (Digital Continuity) means data flow and model sharing across product life cycle, avoiding information silo

Digital Transformation Empowers Auto Industry: Develop Products that Integrate Vehicles, Roads and Cloud

- The deep integration of vehicles, roads and clouds requires vehicles to be designed based on integrated architectures → digital transformation is the precondition

Typical application of V2X-enabled safety/efficiency functions

- Share the information of vehicles, roads and cloud + utilize auxiliary information to help improve driving safety and road traffic efficiency

Application scenarios for V2X-enabled data sharing

- Share perception data, protect the safety of vulnerable traffic participants, etc. → continue to improve the whole performance

Application of V2X-enabled coordinative functions

- The functions beyond the capability of intelligent vehicles like coordinative traffic, merge-in, lane change, etc.

Continuous integration of vehicles, roads, and cloud make automotive systems more complex, entailing faster iterations of automotive products → accelerate the digital transformation of product development

Base on software and algorithms to realize digital transformation of some hardware, complete virtual integration between software and hardware, and build a closed loop covering product design, trial-production and testing in the digital space

Flexible development and rapid iteration

- Digital parts and components → digital products → digital automobiles: rapidly change parameters and digital models

Virtual verification

- Perform integration, simulation, testing and verification in digital environments to increase the coverage and efficiency of tests

Virtual software development environment

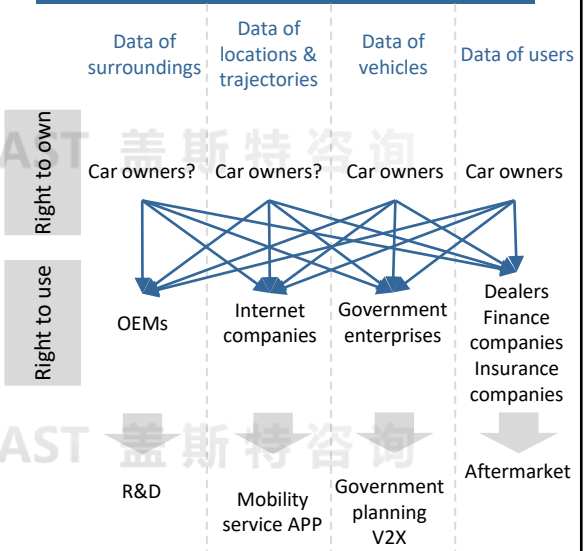
- Enable software development, integration, simulation & testing under collaborative efforts

Develop products that enable the integration between vehicles, roads, and clouds based on digital technologies: halve the demand for physical prototype vehicles, shorten the development cycle by 30%, and cut the development cost by 40% → realize rapid automotive-grade iterations

Three Challenges Brought by Digital Transformation to the Application of Data from Smart Vehicles

- No consensus has been reached on determining the right to own and use data, hindering the extraction of data value; Data security faces huge challenges, requiring improved regulations and technologies; data ecosystems involve multitudinous links, as a complex engineering system

① Right to own and use data



Require a third party to secure the compliance → government supervision + formulation of standards

② Data security

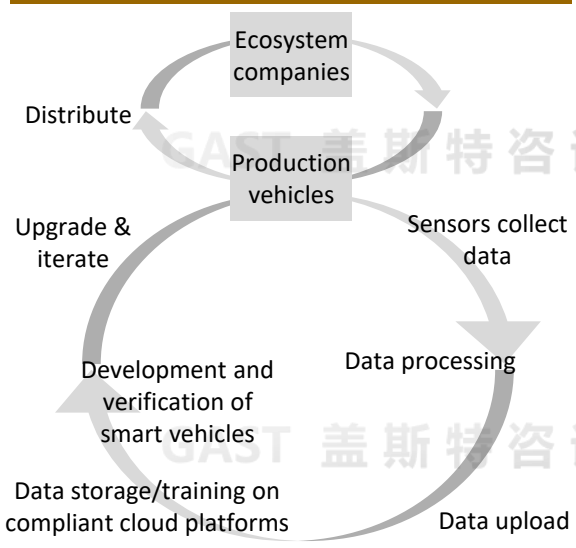
Personal privacy
- Identity information: check information of other car owners via applications
- Image information: real-time images from the dashcam

Public security
- Vehicle safety: unlock vehicles via the Bluetooth key
- Traffic safety: safety accidents caused by remote control of vehicles

National security
- Illegal collection: some units deny the access of specific vehicles
- Cross-border transfer of data: information and data of national key infrastructure

Large-scale automotive sensors + multiple types of data to be collected → data security is crucial

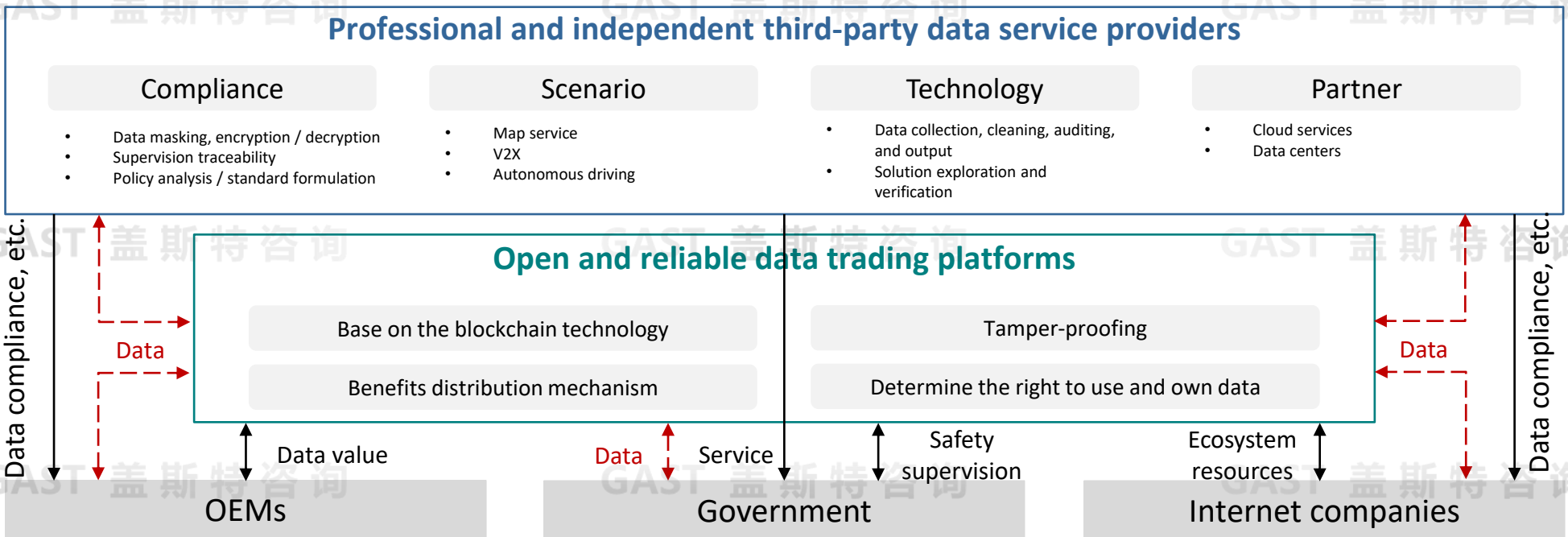
③ Complex data ecosystems



Masses of participants exist in every link → easy to trigger a raft of safety problems

Develop a Multi-Stakeholder Data Ecosystem for the Automotive Industry

- Data security has been lifted to the height of China's development agenda, with the supervision system under gradual improvement. However, the next priority for the government is to think about how to balance security and open innovation with proper supervision



- **With the supervision over data security tightening up, the automotive industry requires professional and open data security service providers and data trading platforms. All stakeholders can explore the business value of data together under the government supervision**

Business Cases: Microsoft Aims to Empower the Automotive Industry

- Microsoft is more apt to serve as a computer to empower every individual and organization on the planet, rather than leave its footprints in the car-making game → connect computing power, algorithm, and ecosystems for both vehicles and clouds

Microsoft provides future-oriented mobility services to empower the digital transformation of the automotive industry

Drive R&D innovation
- IoV platform
- AD development platform
- IVI system
- Automotive OS

Deliver differentiated experience
- Digital customer platform
- Digital marketing
- User experience & customer relationship
- Distributor management system

Improve operation resilience
- Inter-connected factories
- Integrated supply chain
- AI-based decision making
- Real-time inventory optimization

Enhance the productivity
- Modern office mode
- Product R&D management and high-performance computing
- Low-level code development
- SAP* deployment on the cloud

Empower smart vehicles

Vehicles
- Deliver all automotive software from the cloud in a dynamic manner

Vehicle-cloud collaboration
- Manage the two-way vehicle data channel to realize advanced, real-time digital and mobility services

Empower manufacturers/operators

Global operation
- Expand footprints across the world and comply with local safety requirements and regulations
- Expand overseas business and build marketing platforms to reshape digital trips for customers

Empower value chain

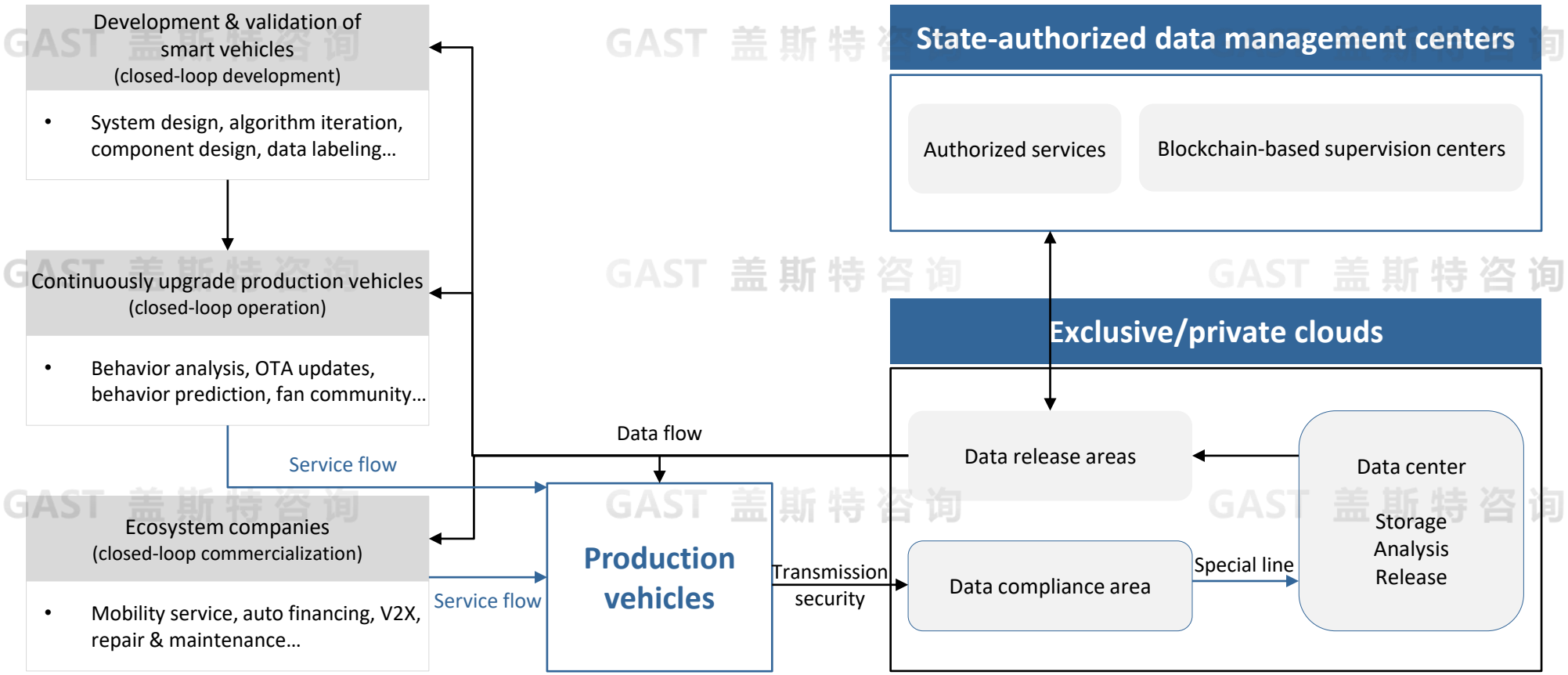
Data asset security
- Manage all business data, drive the insight, analysis, and decision mechanisms, and ensure data compliance

Based on the smart cloud, Microsoft taps edge technologies to drive innovation in the automotive industry: ① focus on AD and smart cockpit technologies; ② Serve as the best partner for players to develop business at home and abroad, driving China's auto industry to harmonize with the global one

*SAP: System Applications and Products

Business Cases: NavInfo's Closed-loop Data Security Solution

- Realize more efficient use of the data related to smart mobility on the precondition of safety and enable the development, test, verification, and large-scale application of smart vehicle functions



Summary

The Latest Development Trends of ICVs

☐ Automakers would continue their leadership in the SDV era and stakeholders will participate in the development of ecosystems on the platforms built by automakers

- ✓ The development of "new automobiles" drives the core competitiveness of the automotive industrial chain to shift to "hardware + software + content + services"; the division of duties between OEMs and suppliers will be reshaped
- ✓ Under the precondition of no functional safety problems, users can participate in the innovation of automotive functions under the architectures defined by automakers
- ✓ When participating in product innovation, users will pay more attention to extreme experience in different use cases than function development and combination
- ✓ Chip vendors should hold a mindset of "all-dimensional altruism" to provide different solutions for automakers → further empower the development of vehicles

☐ Leading chip players actively develop open ecosystems to fuel automakers' development of vehicles

- ✓ Chip companies not only provide chip products, but also sound development tools, training platforms, and diverse "one-stop" services
- ✓ While providing products and services, chip companies gradually further interactions with automakers, changing their role to T1 from T2
- ✓ Chip vendors gradually integrate various capabilities to pool strengths together → develop chip-centric small ecosystems to meet needs of different automakers

☐ Digital transformation will effectively empower the automotive industry and promote the innovation and transformation of automobile development, but the challenges arising from digital transformation should not be underestimated

- ✓ Digital approaches empower the design of automotive products, which can substantially increase development efficiency and cut costs
- ✓ Developing products that integrate vehicles, roads and cloud based on digital technologies can enable rapid automotive-grade iterations
- ✓ Data security involves personal privacy, public security, and national security, presenting complex and daunting challenges → require the collaborative efforts of all stakeholders
- ✓ Data security has been lifted to the height of China's development agenda and the supervision system is under gradual improvement. The next priority is to think about how to strike a balance between supervision and open innovation

Information Source (Non-Exhaustive)

- Title of the conference: *The Fourth World New Energy Vehicle Congress (WNEVC 2022)*
- Venue: Beijing/Hainan, China
- Organizers: China Association for Science and Technology, People's Government of Beijing Municipality, People's Government of Hainan Province, Ministry of Science and Technology, Ministry of Industry and Information Technology, Ministry of Ecology and Environment, Ministry of Housing and Urban-Rural Development, Ministry of Transport, State Administration for Market Regulation, and National Energy Administration

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Company Profile

Setting its foothold in China automotive industry, GAST Strategy Consulting, LLC is oriented to the globe to focus on the ecosystem of the whole automotive industry and starts from three dimensions (industry, enterprise and technology) to carry out in-depth study on strategy design, business positioning, management improvement, system building, business process reengineering, product planning, technology choices and business models. It is dedicated to providing governments at all levels with decision-making support and implementation advice and enterprises in the automotive industry chain and relevant industries with all-dimensional high-level professional consulting services in strategies, management and technologies. Since the establishment, GAST is dedicated to becoming a world top auto think tank as the vision and sharing wisdom as the mission. Adhering to creating value for clients and focusing on actual effects, GAST commits itself to forging long-term partnership and providing guidance service. It has fostered strategic partnership with and is providing services for nearly 100 domestic and international enterprises, organizations in the automotive industry and governments at all levels by virtue of comprehensive, systematic, advanced and pragmatic consulting methods.

Range of Service

Provide diversified and open services and flexible ways of cooperation for customers, including but not limited to:

- Executive-oriented strategy, management and technology consulting services
- All-round and customized special project research: covering macro strategy, industrial development, interpretation of policies and regulations, the internet, business models, corporate strategy and management, auto market, product research, product design methodology, research on auto shows, interpretation of forums, energy conservation and emission reduction, new energy vehicles, intelligent vehicles and comprehensive automotive technologies
- Serve as reliable resource that can win customers' long-term dependence and provide open cooperation that can meet customers' specific requirements at any time
- Provide a high-end sharing platform (CAIT) for industrial communication, exchange and in-depth research
- The company provides nearly 1,000 research reports in Chinese, English and Japanese at present

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