GAST Automotive Industry & Technology Research Report
No. 842_October 08, 2022

Subject: The Latest Development Trends of ICV Technologies in China

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Ideas for Pursuing High-Quality Development of ICVs

Intensify the top-level design and plan to seize the window of opportunities for intelligent and connected technologies	• Strengthen the top-level strategic layout, formulate plans to develop intelligent, connected and low-carbon ICVs, explore ways for upstream and downstream players along the industrial chain to support and cooperate with each other, and define strategic priorities and key milestones • Use intelligent and connected technologies as the engine to drive electrification, support sharing, boost coordinated deployment and comprehensive advance in NEVs, ICVs, and smart mobility to achieve high-quality development
Deepen industrial cooperation to build multi-field and multi-party "reticular ecosystems"	• Integrate automotive, energy, transportation, information communication, smart living, smart home and other fields at a faster pace, improve the consensus, give play to the advantages in IoT, information communication, Beidou-based positioning and other basic fields, enable the automotive industry and improve the core competitiveness • Explore to cultivate business models for various emerging industries, create reticular industrial ecosystems in which market entities integrate with and rely on each other, cooperate and share benefits, and realize efficient and synergetic development of the "vehicles, roads, clouds, networks, and maps"
Focus on "bottleneck" issues and boost the R&D of cutting-edge generic technologies	• For technological problems as bottlenecks that hinder development, overall efforts should be made centric to the automotive industry to make further breakthroughs in the R&D of intelligent chassis systems, automotive operating systems, next-generation perception systems, information security, smart cockpit chips, people-vehicle-road-cloud information aggregation platforms, etc. to forge global competitiveness • Adhere to independent innovation and further cooperate with innovation centers, colleges & universities, research institutes, and industrial players to build national platforms, joint labs/technology centers, etc. via technological cooperation, in a bid to boost the R&D of cutting-edge generic technologies and sustainably improve industrial innovation capabilities
Develop basic and safety technologies to become pathbreakers and pioneers	• Actively participate in major R&D projects, vigorously invest in the R&D of basic technologies, and explore new mechanisms for the R&D of basic technologies, transfer & expansion of technologies, first commercial application, and large-scale application • Study development specifications and technology standards that meet the national security and large-scale product recognition, take the lead in practicing automotive cybersecurity and data security, and improve the value and status of Chinese standards

Content

Updates on and Prospects of Vehicle-Road-Cloud-Network-Map Integration in the ICV Industry

■ Relevant industrial players are actively promoting the integrated development of “vehicles, roads, clouds, networks and maps” related to ICVs

	Updates on vehicles, roads, clouds, networks and maps
Vehicle	Enterprises: accelerate the R&D and industrialization of key technologies and components • Faster scale up the application of EEA, locally produced chips, system and functional software, intelligent connected functions, etc.
Road	Government: expedite V2X facility construction + strengthen the application in V2X scenarios • Shift from testing and verification to multi-scenario demonstration applications + promote data sharing and mutual recognition of results
Cloud	Localities: step up the construction of cloud control platforms and promote the application of connected facilities and safety practices • Beijing, Shanghai, Changsha and other places carry out comprehensive demonstration projects based on cloud control basic platforms for ICVs → build an integrated cloud control environment and a system that integrates perception, decision-making and control
Network	Industry: conduct R&D, testing, verification & demonstration application of V2X technologies • Stay committed to the C-V2X path → C-V2X interconnection: multimode communication + demonstration activities + cybersecurity
Map	HD maps are applied for commercial purposes • The government supports pilot projects + HD map companies in China initially develop a complete solution for the application in production vehicles • HD maps are applied to OEM-installed vehicles at a faster pace → the basic platform of high-precision dynamic maps will be the priority in the future

Prospects of system integration

Make breakthroughs in core technologies
- Promote breakthroughs in core basic technologies such as high-precision sensors, chips, OS, x-by-wire, simulation, and basic industrial software

Build a new industrial ecosystem
- Strengthen cross-industry cooperation, clarify industry consensus, and give full play to the driving role of public support platforms and leading enterprises

Unify platforms, architectures and standards
- Promote the unification of basic platforms, technology architectures and standards in various places → vehicle models are more adaptable in different cities

Build a national unified cloud control basic platform
- Break the barriers to build a national unified cloud control basic platform featuring “layered decoupling and cross-domain sharing”

□ **With the continuous integration of ICV-related systems, the boundary between industries will become increasingly blurred → in addition to legacy OEMs, technology companies, mobility service providers and infrastructure construction & operation units will all become integral to the ICV industry**

Challenges Facing the Vehicle-Road-Cloud-Network-Map System for ICVs

- The components of ICV-related systems vary in terms of life cycle and development status → pose challenges to the development of systems on the whole

Components	Vehicle	Road		Cloud	Network	Map	Overall analysis
		Road	RSU				
Life cycle (years)	3-7	20-30	5-10	0.25-3	2-5	0.25-1	The life cycle varies greatly by component ↓ Extreme difference between the whole system and components
Development status	Fast	Slow		Fast	Fast	Moderate	Inconsistent development levels of components

- The big gap in the life cycle of the system and components poses challenges to the design, construction, operation, maintenance, renewal, and upgrade of the ICV system and its components
- Different levels of development of components pose challenges to the design, construction, operation, maintenance, renewal, and upgrade of the ICV system

The automation level, reliability, resilience, and robustness of the ICV system (vehicle-road-cloud-map) depend on the improvement of components in an integrated manner → the system requires overall design, development, operation, maintenance, replacement, and upgrade

Cloud: Cloud Becomes a New Productive Force for the Automotive Industry → Value of Vehicle-Cloud Integration

Core changes in the automotive industry → increased importance of the cloud

On the eve of commercializing AD technologies	Continuously expand profit models of intelligent services	Players: better resilience + safe & compliant growth
result in massive data computing and huge storage	cloud platforms: enable OTA updates + connect rich ecosystems	enterprises: strengthen the management of IT and cloud security

Key to the industrial competition: vehicle-cloud integration + data as the driver

Provide ultimate user experience	Upgrade applications in the cloud to bring more scenarios for user experience	• User-oriented + rich ecosystem + on-demand iteration: automotive application frameworks → rich ecosystem service space • Intelligent scenario-driven + reshaped interaction experience: new scenario engine – automotive perception + cloud AI → translate intelligent technologies into scenarios • Accurate, vivid, and real-world intelligent driving & navigation pilot experience: new intelligent driving maps → vehicle-map-cloud integration
Optimize R&D efficiency	Develop systems with digital technologies and drive R&D via automation approaches	Cloud-native technology architecture / Automation toolchain / Proprietary cloud service Data + algorithms → co-build dual engines to improve R&D efficiency Faster data storge + algorithm development & training + cloud-native software development + cloud service dedicated to ICVs
Enhance business resilience	Use digital technologies to connect all links to secure business development	Safe and compliant / Scalable / Sustainable

Vehicle-cloud integration → define intelligence, experience, and business models from the cloud

Network: BeiDou Navigation Satellite System Fuels ICV Development

■ BeiDou Navigation Satellite System (BDS) serves as an important pillar to support ICVs with high-precision positioning and HD map technologies

Time synchronization	Spatio-temporal accuracy	Absolute position	Relative position of fields	Relative position of objects
• Timing, time synchronization, precision clocks	• Spatio-temporal accuracy: cm-dm, 1ms-200ms • Scheduling and monitoring: 1s-1m	• Global path planning, tracing, scheduling of shared operation vehicles, scheduling and monitoring of large-scale traffic, recognition and switching of scenarios, map matching and navigation	• Local path planning, parking, operations	• Obstacle avoidance, path planning, lane line-based tracing, traffic sign recognition, scenario recognition and switching of Operational Design Domain (ODD)

Time-space digital base for ICVs – BDS "cloud + terminal" solutions provide high-precision positioning & maps for ICVs

Cloud + terminal: realize high-precision positioning → more advanced technology + lower cost + larger application scale

- Terminal fusion: evolve from GNSS to integrated positioning and to fusion positioning → improve the accuracy and reliability of automotive positioning terminals
  Fusion: automotive perception + V2X + GNSS/IMU/RTK + HD map
- Cloud fusion: fully integrate the navigation satellite LBS (location-based service) cloud with HD maps in the cloud, cloud-based information, cloud control platforms, and edge clouds → improve high-precision LBS capabilities

□ **BeiDou Navigation Satellite System serves as a time-space digital base for ICVs to support timing and positioning in various scenarios**

Network: Application of BDS-Based High-Precision Positioning Technology

■ BDS-based high-precision positioning technology enables lane-level navigation, autonomous driving, and V2X

Lane-level navigation

Lane-level positioning: GNSS + inertial navigation module + lane-level visual recognition + lane-level ADAS maps

- **Lane positioning:** inertial navigation + on-board sensors + lane-level map layers + fusion positioning algorithms
- **Lane yaw:** "yaw" is refined to lane level → more agile path planning capability
- **Lane guidance:** inform lane selection and lane change in advance while driving → ensure timely reactions of human drivers

The window of opportunity for lane-level navigation has been there

- OEMs apply lane-level navigation systems to production vehicles or kick off mass production plans → by 2025: ~30% of smart cockpits would be outfitted with a lane-level navigation system and more than 1.5 million new vehicles would be armed with lane-level navigation systems

Autonomous driving

AD requires lane-level self-localization of vehicles

- Fusion of GNSS/IMU + in-vehicle sensors (cameras, radars, LiDARs) + 5G/V2X

High-precision positioning is expected to become a standard offering of AD products

- OEMs in action: new automakers apply it to vehicles + traditional OEMs make plans
- Multiple use cases: robotaxis, autonomous delivery vehicles, self-driving logistics vehicles, unmanned agricultural vehicles, autonomous mining trucks, self-driving sanitation vehicles, etc.

V2X

High-precision positioning enables comprehensive fusion perception of V2X

- Fusion of high-precision positioning + real-time segmented HD maps + full-time roadside perception + traffic management information

New vehicles fitted with C-V2X devices would surge

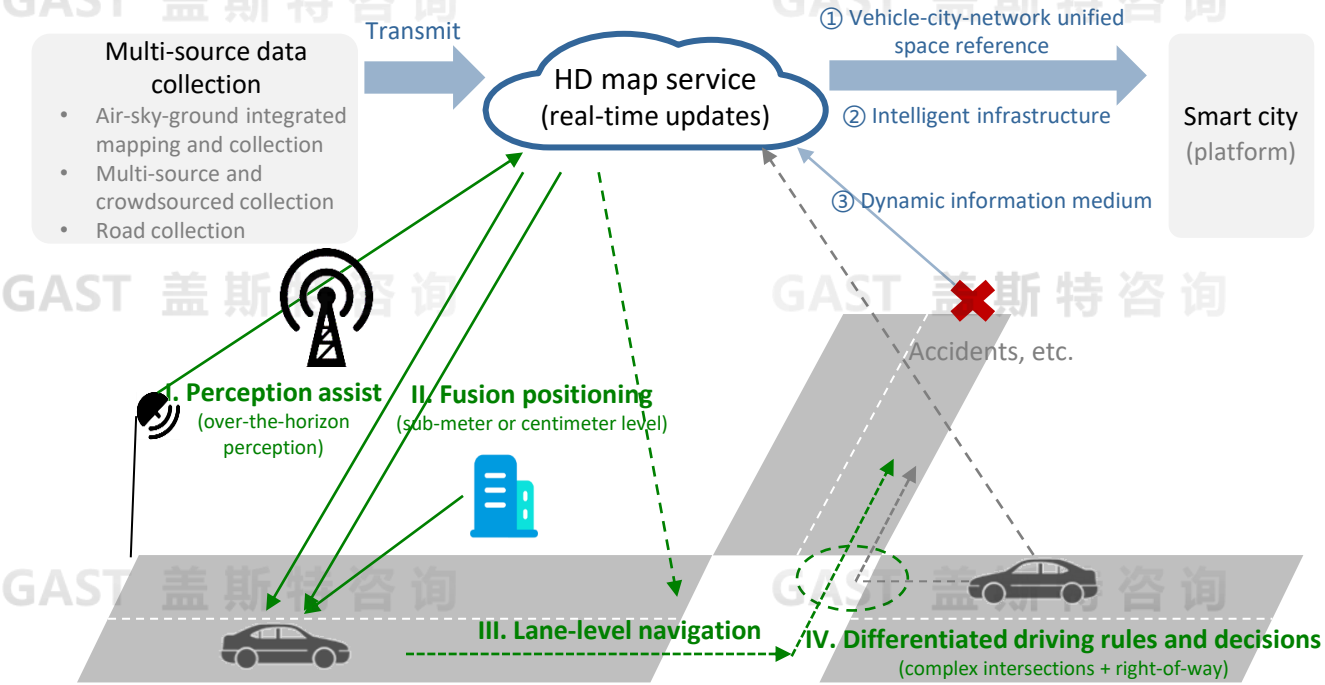
- The proportion of new vehicles to be equipped with C-V2X devices is estimated to surpass 50% and 100% by 2025 and by 2030, respectively

□ **Various applications related to the BDS-based high-precision positioning technology adopted by ICVs are getting more and more sophisticated → play a major role in boosting the development of ICVs**

Map: High-Definition Map Becomes More Important in an Era of ICVs

- HD map serves as an important medium for data to travel in an era of ICVs → it is of crucial importance to autonomous driving and other functions

Functions of HD map in an era of ICVs



HD maps

↓

Serve as an over-the-horizon sensor for AD

A key carrier of information flow for smart city

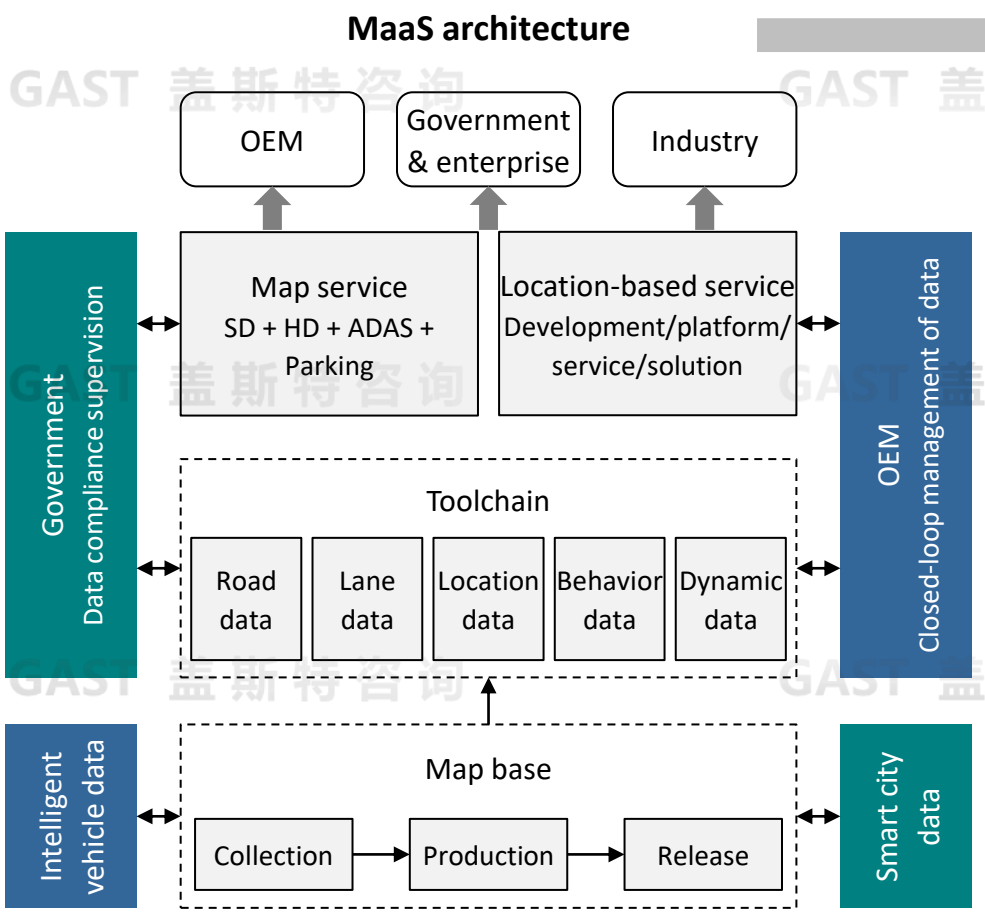
↓

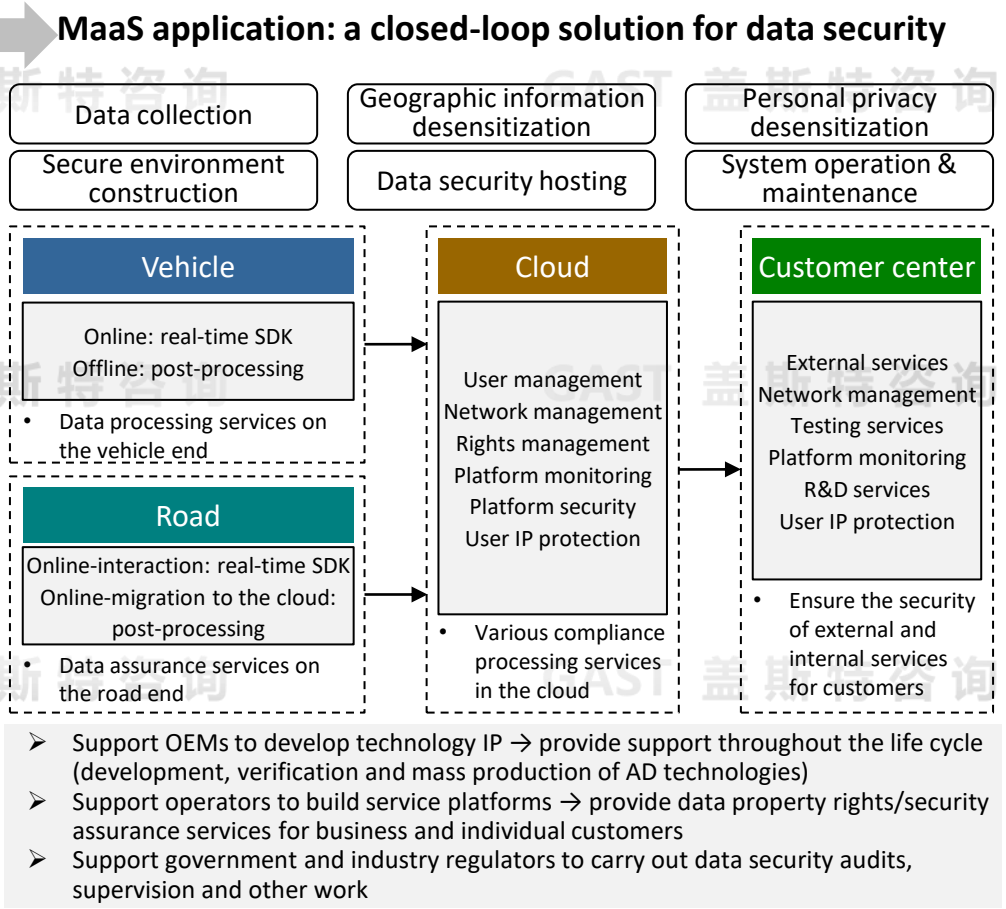
- Serve as a medium for V2X + real-time and dynamic information
- Provide a unified reference for the underlying operation of smart cities
- Provide accurate data for smart city managers to make decisions

Serving as a medium for both dynamic and static traffic information, HD map secures orderly operations of an intelligent transportation system

Map: Map-as-a-Service (MaaS) Architecture and Relevant Applications

■ Map-as-a-Service: link the physical world + depict the dynamic world + empower smart mobility





- Support OEMs to develop technology IP → provide support throughout the life cycle (development, verification and mass production of AD technologies)
- Support operators to build service platforms → provide data property rights/security assurance services for business and individual customers
- Support government and industry regulators to carry out data security audits, supervision and other work

Content

Challenges Facing China's Automotive Operating Systems: Affect the Information Security of ICVs

- China's automotive operating systems (OSs) face evident challenges: weak product basis, inadequate ecosystem support, slow toolchain development, insufficient talent pool, difficult market expansion → impact the information security (and even national security) of China's ICV systems

Immature technologies

- China's automotive OSs started late, and there is still a certain gap with foreign countries
  - Inadequate development of basic OSs makes China easy to be constrained by other countries
  - Lack of real-time microkernel OSs
  - Insufficient ability to integrate multiple OSs makes it difficult to meet the complex safety requirements of automotive OS

Inadequate ecosystem support

- At present, China's OS development is in its infancy, so is the establishment of an ecosystem system
  - Necessitate the involvement of more enterprises + advance and support by the top-design power

Unsound standards

- Lack of systematic standards and specifications → independent development of all systems make it hard to form scale
  - Safety standards and specifications (especially functional safety/information security): mainly rely on foreign countries due to the lack of its own standards system

Slow toolchain development

- The toolchain is monopolized by foreign OEMs → high cost
  - China's automotive toolchain is still in its infancy, basically serving as software support → fail to form a standardized, high-quality development pattern with top-level planning

The development of automotive OSs is a systematic project → involve problems in multiple facets of technologies, standards, tools and ecosystems → entail the support of multiple industries, multiple fields and all ecosystems

Technology: TEE OS Guarantees the Security of Automotive Software

- The testing of OSs mainly focuses on their performance and interfaces. With increasing attention paid to data security and information security in the industry, Trusted Execution Environment (TEE) OS will be a key test indicator

TEE is an application runtime environment that coexists with the rich execution environment (REE) on the device and provides security services to the REE

Build a secure area in CPU via hardware and software methods to ensure the confidentiality and integrity of the programs and data loaded inside it

REE (plentiful tasks):
- Realize such functions as autonomous driving, infotainment and vehicle control, and feature an open ecosystem and flexible and rich applications
- Run general-purpose OSs, like Linux and Android

Hardware isolation

TEE (simple tasks + high security):
- Ensure the underlying security via identity verification, face recognition, payment verification, etc., to flexibly adapt to the security requirements of various businesses
- Run dedicated OSs, such as HarmonyOS, V-Trust, etc.

- TEE OS enjoys higher privileges and security with independent execution space and access to all resources of the chips → **require the coordination of chip companies**
- One technology innovation of HarmonyOS is that it can run in TEE, which doesn't mean that HarmonyOS can only run in TEE, but it is also available in REE

TEE OS can evolve into two generations based on different application scenarios

First-generation TEE OS
- Oriented to bank card payment scenarios, aiming to replace independent security chips via software
- Deployed inside components to realize openness + high security within chips
- Provide a single interface + only support a single kernel and a single thread, failing to meet various business needs

Second-generation TEE OS
- Oriented to IoV and other complicated emerging business scenarios, deployed on intelligent connected modules via Ethernet + SOA to ensure the publishing and subscription of security services
- Provide more business interfaces and support multiple kernels and threads to fully utilize the computing power resources

Standard: the Industry Accelerates to Formulate Standards for Automotive OSs – Build an Evaluation Technology System

- China Automotive Technology and Research Center (CATARC) has preliminarily built an automotive OS evaluation technology system → plan to further improve national standards for automotive OSs

Automotive OS test system → define different test metrics for different OSs given the technical similarities and differences

Test item	Vehicle-control OS High requirements on performance and security	On-board OS High requirements on multi-system interfaces	TEE OS High requirements on information and data security
Function	• Standards conformance, function verification	• Standards conformance, function verification	• Inter-application communication, security storage, encryption and decryption, safety time, trust management
Performance	• Reliability, time characteristics, resource utilization, internet performance, task scheduling performance, input/output (I/O) performance	• Reliability, time characteristics and internet performance	• Starting performance, communication performance, concurrency
Security	• Functional safety, information security	• Functional safety, information security	• Hardware layer security, system software layer security, external setting security
Interface	/	• Service interface, I/O interface, application interface	/
Others	• Tool and configuration tests and security level authentication	• Technical specifications and test methods for Point Of Interface (POI)	• Fuzz test, penetration test

- Will support the formulation of national standards: *Technical Requirements and Experimental Methods for Vehicle-Control OS for ICVs* + *Technical Requirements and Experimental Methods for On-Board OS for ICVs*

Test basis

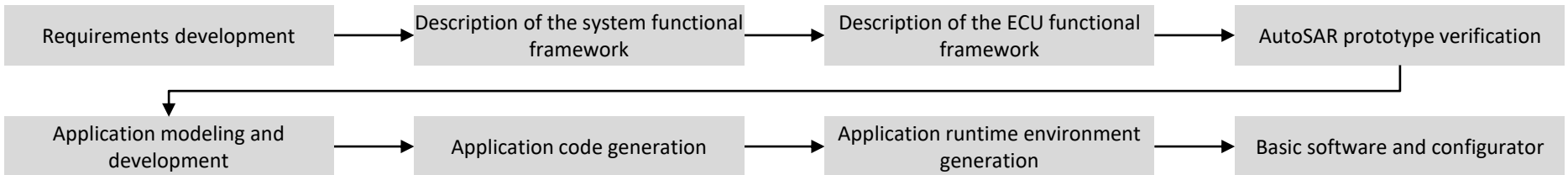
- **Hardware:** program running hosts, debuggable cable clips, storage reading devices, etc.
- **Software:** compiling and running environment, debugging analysis software, reverse analysis software, etc.

Challenges to the automotive OS evaluation technology system: the performance of different OSs varies on different hardware platforms; it is difficult to define uniform parameters to evaluate the performance of OSs

Tool: Chinese Enterprises Start to Develop Automotive Toolchain

- The toolchain to develop basic automotive software is monopolized by foreign players, and China is still in its infancy in terms of developing toolchain, basically serving as software support

In foreign countries: software developed based on AUTOSAR toolchain of Vector, Mathworks, etc. has been widely applied in production ECUs



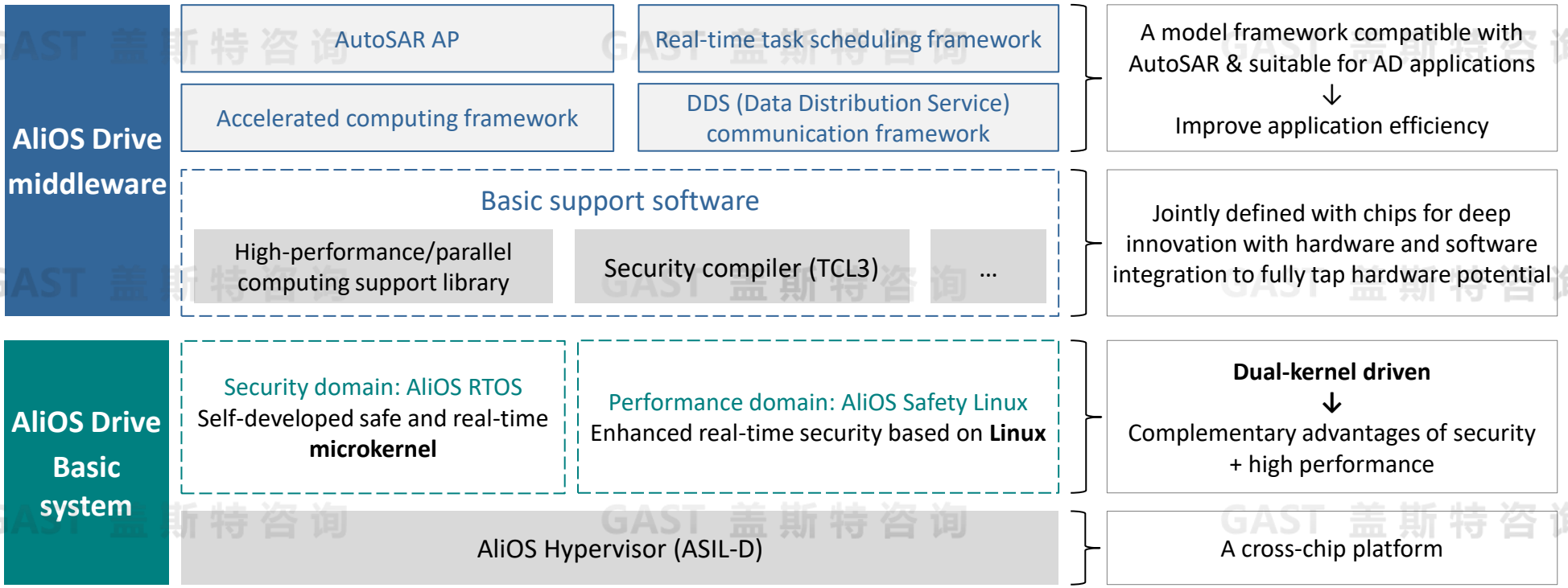
Foreign products cover each stage of the AutoSAR development process

In China: the toolchain products of Jingwei HiRain, iSoft Infrastructure Software and others have started to be applied to OEMs like SAIC Motor

Company	Product	Application
SmartSAR	SmartSAR Studio + SmartSAR Configurator	The earliest to see commercialization in China
iSoft Infrastructure Software	ORIENTAIS series tools; AUTOSAR AP design, development and deployment tools	The largest market size + the most professional in China
Jingwei HiRain	INTEWORK-EAS series tools	Large-scale commercial use in China
ReachAUTO	NeuSAR toolchain	Large-scale commercial use in China

Case-AliOS: Develop Autonomous Driving OSs Tailored to China

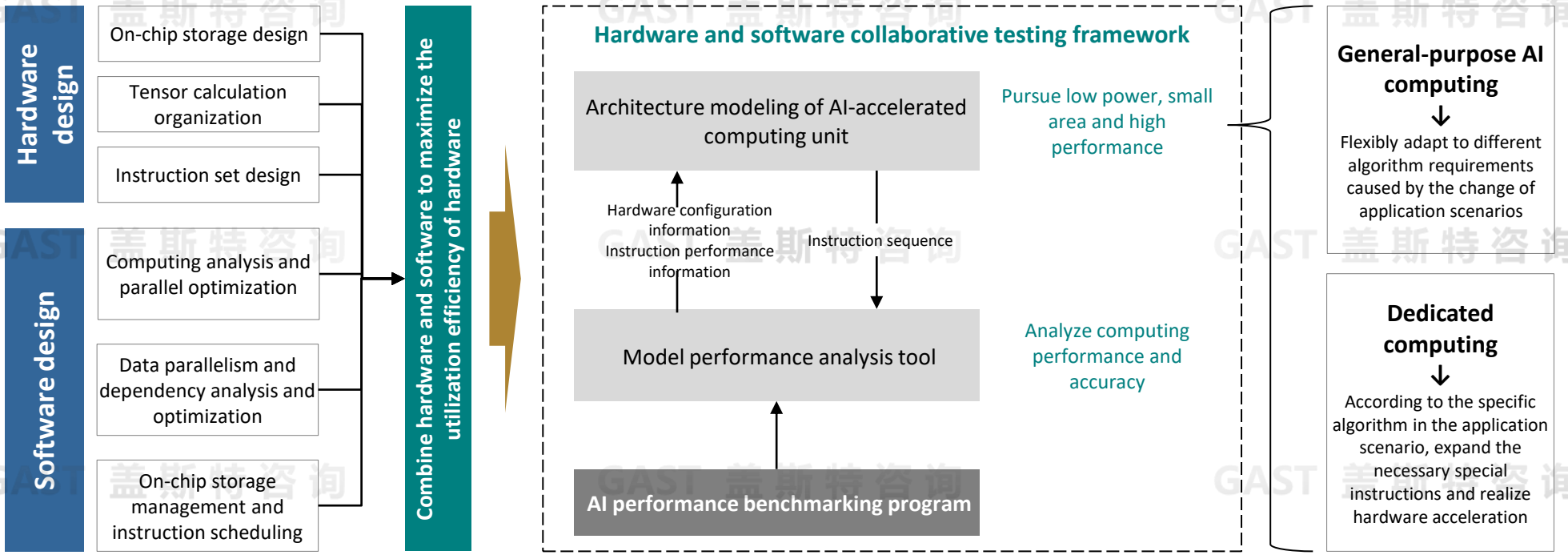
- AliOS aims to build a high-performance, high-security, platform-based technology base, helping to unleash the potential of AD algorithms through innovation



- **AliOS not only accommodates various chip platforms, but also is compatible with many mainstream AD development frameworks → break the "chimney model" in which software and hardware are bound together and build an open and collaborative ecosystem**

Chip: Automotive AI Chips Will See Coordinated Development of HW & SW

- The goal of coordinated optimization of software and hardware: build a new-generation AI computing architecture with “performance (priority) + flexibility” to meet the demand for various application scenarios of intelligent vehicles



- **With the emergence of a unified neural network computing architecture, more than 95% of the SoC area and power consumption will be used for general-purpose AI computing, while no more than 5% of the SoC area for dedicated computing instructions**

Chip: Adaptive Computing Platform Flexibly Adapts to Future Complicated Application Scenarios of Vehicles

- Rapidly changing demand for vehicles + increasingly complex systems + continuous upgrade of standards and architectures → traditional computing platforms cannot adapt to plenty of application scenarios where adaptive computing platforms show stark advantages – more flexible after optimization

Facing increasingly complicated scenarios, traditional computing platforms must rapidly update functions, but the semiconductor manufacturing cycle fails to support the rapid update

- **Multi-sensor fusion:** realize high-precision synchronization of heterogeneous data
- **Multi-screen display:** solve problems such as display color difference, format, and non-uniform resolution
- **Electronic rearview mirror:** deal with the dizzy feeling caused by latency
- **Camera debugging and tuning:** solve the problem of different cameras being limited by hardcore
- **LiDAR technology path:** solve the problems such as ADC (Analog-to-Digital Converter) sampling requiring high-speed access, and TDC (Time-to-Digital Converter) requiring multi-channel and delay chain adaptation

Adaptive computing is not confined to computing itself, but can meet atypical computing needs e.g., adaptation interfaces and display unification

Non-computational adaptive acceleration:
- High throughput: solve the bandwidth bottleneck of multiple I/O interfaces and massive data
- Low latency: make faster feedback on results to improve system efficiency
- Reliability: address the risk of data disconnection and function failure

Computational adaptive acceleration:
- Adaptively allocate peripheral interfaces according to the type and number of sensors
- Adaptively allocate computational units for functional operation based on different functional requirements
- Adaptively allocate computing power based on different algorithm models

*Adaptive computing platform: include the highly optimized hardware chips tailored to specific application scenarios → this optimization takes place after hardware is manufactured and can be repeated indefinitely

Content

Independent and Open Roadside Operating Systems Boost Vehicle-Road-Cloud Integration in China

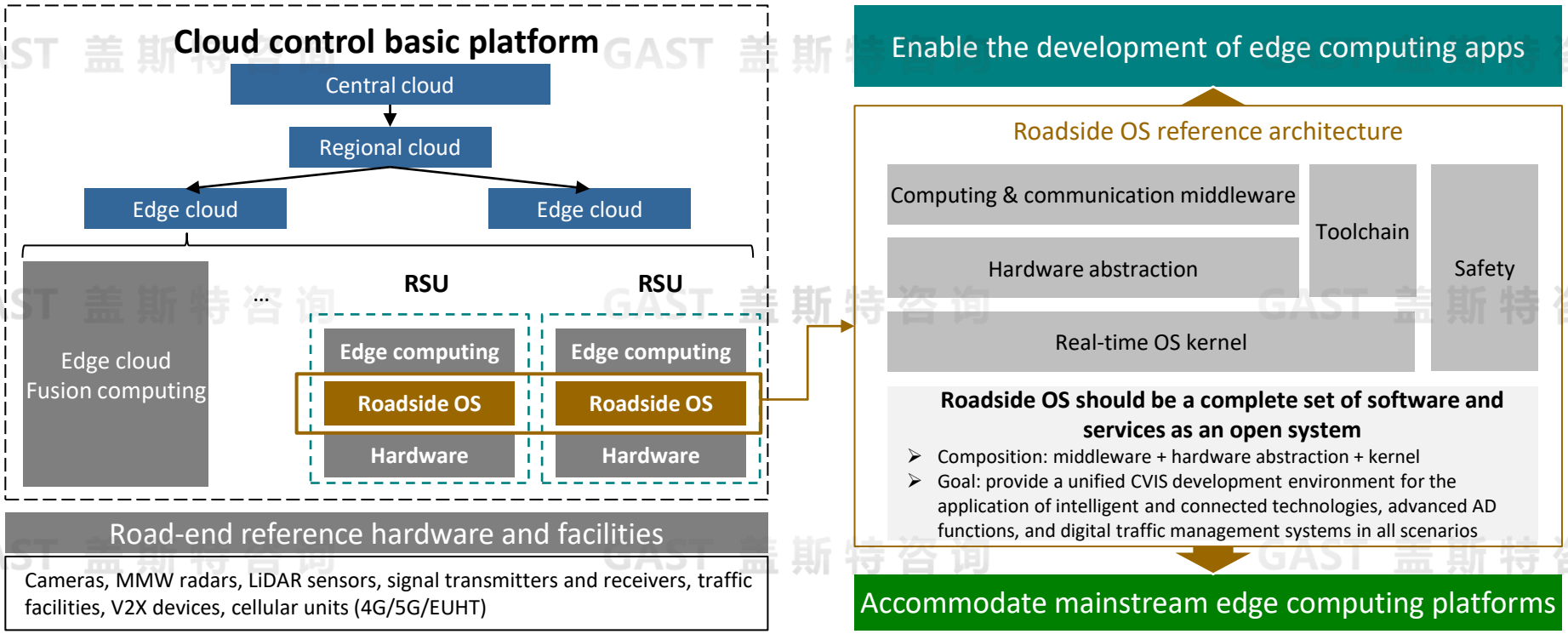
- Roadside operating systems with the integration of vehicles, roads, and clouds: non-decoupled software and hardware, inconsistent standards, and difficult management → require unified macro plans and architectures to connect all industrial ecosystems → building open and independent roadside operating systems is an important link

Pain points of the vehicle-road-cloud integration industry in China (road & cloud)			Building open & independent roadside OS unified underlying standards + decoupled roadside SW & HW
Industrial development	Non-flexible hardware development	➢ Smart transportation hardware facilities: no scalability/upgradability + one-time construction	➢ Support in-advance deployment of smart transportation hardware + future scale-up and upgrade → secure the stability and foresight of infrastructure structure
	Insufficient applications	➢ Smart transportation applications: no long-term accumulation + information silo + repetitive work + long development cycles	➢ Open and connect isolated intelligent and connected automotive and cloud-based applications + lower the threshold of application development → make application ecosystems more prosperous
	Data fragmentation	➢ Hardware products and solutions: a mixed bag + no data connection + inconsistent standards	➢ Rely on the unified underlying software and standards + connect with various transportation facilities and equipment → remove data barriers
	Hard-to-harmonize management	➢ Cross-industry + multi-field + obvious regional characteristics → unconcentrated construction, market, and management	➢ Transportation operators and government departments can share new infrastructure construction platforms → avoid repetitive efforts
National security	Information security Data security	➢ Traffic information security is closely related to national security → the pressing demand for independence and controllability	➢ Accommodate various self-developed chips and transportation equipment + develop independent and controllable key technologies and industrial ecosystems

- **In an era of intelligent vehicles, the vehicle-road-cloud integration (especially AD) is expected to become an important track for China's auto industry and transportation industry to overtake → independent and open roadside OS can help China to grasp the initiative and forge a larger influence**

Positioning and Reference Architecture of Roadside Operating Systems

- Roadside OS builds a unified technological and digital base for the upstream and downstream ecosystems of the roadside system: a full set of underlying software/platform

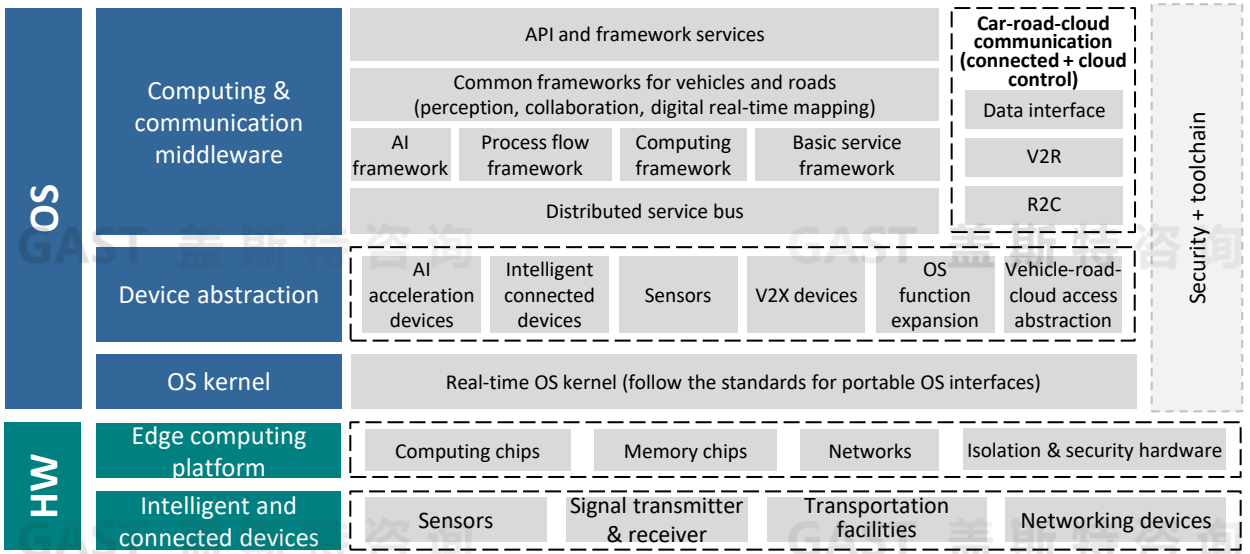


- **As an edge computing node of the edge cloud of the cloud control basic platform, roadside OS provides unified underlying software. Open and independent, roadside OS should accommodate various RSUs and computing chips and can help to improve the ICV technology ecosystem in China**

Practice in Independent & Open Roadside OS: "Smart Road OS" in Beijing

- Baidu partners with the Institute for AI Industry Research of Tsinghua University (AIR), China-SAE, and other four players to release an independent, controllable, open-source, and open-up intelligent connected roadside operating system coded "Smart Road OS"

Architecture of the "Smart Road OS"



Positioning

- For RSUs: establish a unified and safe technological and digital base
- For vehicle-road-cloud integration: provide an open environment for the development of edge computing

Significance

- For industries: open full-stack technology + address the "chip crunch"
- For city management: realize software-enabled connected traffic management
- For ecosystems: assist intelligent connected technology ecosystem providers to achieve efficient innovation with unified standards and accelerate the commercial application of technologies

Goal

Build independent, controllable, open-source, and open-up intelligent and connected technology ecosystems

- Accelerate the development of full-stack, independent, and controllable ICV technology systems centric to "automotive OS, AI cloud and RS OS"
- Promote the integration and innovation of AD and smart transportation → smart city ecosystem

Six features of "Smart Road OS" → have the international competitiveness

Synergy
- Integrated architectures
- Distributed service buses
- Unified SOA infrastructure

High performance
- Latency: milliseconds
- Concurrency: 1,000+
- Throughput: 20+ GB/s

Intelligent transformation
- Domestic AI frameworks
- Compatible and heterogeneous middleware
- Flexible scale-up of computing power

Openness
- Layered and decoupled architectures
- Open-source middleware
- Portable OS kernel

Compatibility
- Compatible x86/Arm architectures
- **Compatible with major AI chips**
- Compatible with mainstream traffic equipment and facilities

Safety
- CVIS safety communication interfaces
- National secret encryption interfaces
- Access control interfaces

"Smart Road OS" Enables an Independent and Controllable Ecosystem

- Independently developed fully based on domestic/open-source technologies, "Smart Road OS" is compatible with major RSU chips and transportation facilities, which can enable various application scenarios such as intelligent connectivity, CVIS, and digital traffic control

Local solution providers		Jingyinglutong, Digihai, Sinops, JD Logistics …
Smart Road OS	Middleware	Baidu PaddlePaddle's AI framework **(domestic),** AD computing framework Cyber-RT **(open-source)**
	OS kernel	Kylin OS kernel **(domestic),** Baidu's tailor-made Linux kernel **(open-source + domestic)**
Domestic chips		Baidu's Kunlunxin, Cambricon, Horizon Robotics, Blacksesame, Hygon CPU
		AI computing power: 5~256 TOPS independent and controllable + software and hardware synergy

Domestic transportation facilities	Camera	Signal transmitter and receiver	Communication device	Radar/LiDAR	Edge computing
	HIK Vision Dahua Uniview	SUPCON Hualu Yiyun	GoHigh China Unicom China Mobile	Hesai Technology Xiangde Technology Thor Hi·X	Inspur Desay SV TZTEK
	Cover 90%+ types of intelligent transportation facilities; continue to adapt to more brands, types, and models of facilities				

Division of duties in the ecosystem

Baidu: lead and participate in the construction of demonstration areas
- Design the smart road OS architecture and provide core technologies (secure independence and controllability for the government)

Local governments: incubation + supervision
- Realize the application and testing firstly in the Beijing High-Level Autonomous Driving Demonstration Zone

Open-source community: operation & updates and maintenance
- Open the full-stack technologies and pool industrial wisdom to make continuous improvement

Smart road OS committee: promotion
- Standards & policies + overall strategic plans + ecosystem resources & cooperation

Full-industry ecosystem developers: application
- Intelligent & connected software and hardware providers, city managers, smart transportation industry, etc.

"Smart Road OS" has attracted more than 50 players to become members of the ecosystem, including industrial organizations and firms. It officially marks the creation of a next-generation intelligent and connected roadside ecosystem in China

"Smart Road OS" Goes Open-Source and Open-Up

- Ensuring unified standards and interconnected ecosystems, "Smart Road OS" leaves sufficient space for players to forge differentiated innovations, allows for the upgrade, replacement, and scale-up of certain components, and provides completely open-source core technologies

Application	➢ "Smart Road OS" community provides service capabilities, interface specifications, development tools, and test environments → attract more small and medium-sized developers
Service interface	➢ Ensure unified and standard interfaces for the recall and development of upper-layer applications
Middleware	➢ Encourage cross-domain scale-up (e.g., V2X protocols)
Hardware abstraction	➢ Provide unified standards and native device drivers ➢ Southbound device vendors can perform closed-source solutions, but should leave the interfaces to remain open-source and compatible
OS kernel	➢ Enable different types of OS kernels • First release: domestic Linux as the official support • Enable the ecosystem to scale up OS kernels in line with POSIX specifications • Support microkernels and domestic non-x86 kernels & chips in the future

Standardization

Open-source	➢ Provide source codes, development tools, and documentation via the Gitee open-source community ➢ Provide an out-of-the-box OS image environment that can be automatically obtained from the cloud through open-source documentation and scripts
Governance	➢ The "Smart Road OS Council" will play a leading role, including evolution, industrial promotion, and cooperation; set an expert committee and a technical committee to ensure the authority ➢ Developer community: provide technologies ➢ Smart Road Lab: provide compliant test environments and test data → secure the access to resources for small and medium-sized developers

- **"Smart Road OS" insists on open-source and open-up core technologies → drive the "Chinese ICV technology solution" ecosystems to become more adequate + gradually harmonize ecosystems and standards**

Challenges Facing the Development of "Smart Road OS"

- As a common industrial offering, "Smart Road OS" still faces great challenges in ecosystem-wide promotion and technological progress

Hard to realize nationwide promotion

- ✓ The intelligent transportation industry has obvious regional characteristics → local governments are establishing demonstration areas to occupy the leading position. **For the sake of protecting the benefits of local businesses and meeting the needs of local industries**, local governments may not have high enthusiasm for the "Smart Road OS"

Technology iteration may easily go out of step with industrial needs

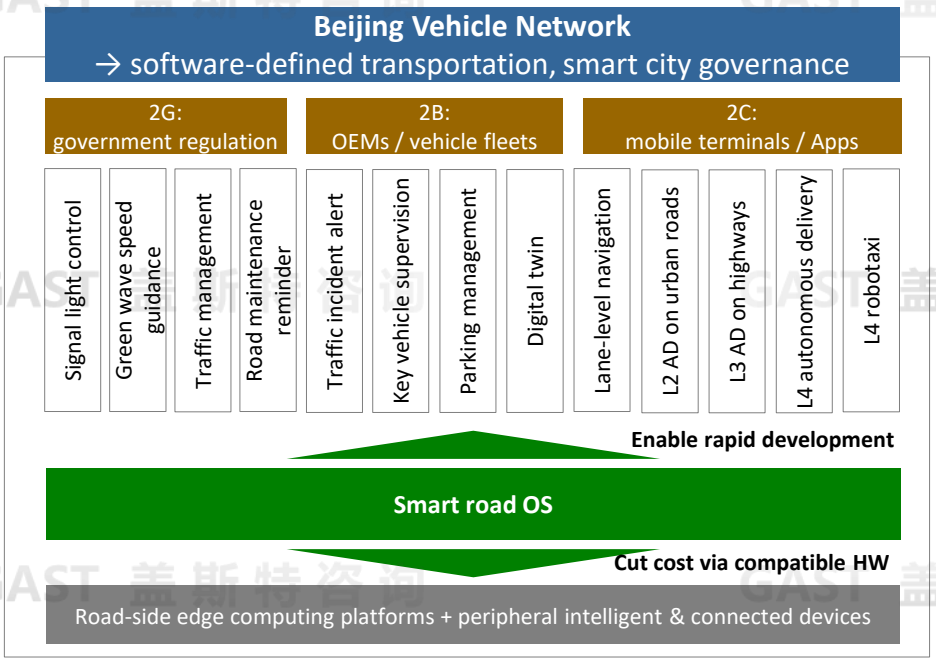
- ✓ The open-source model requires ecosystem participants to have high enthusiasm, otherwise, the speed of updating and upgrading technologies may not be satisfactory due to **the absence of market incentives**
- ✓ Without the compelling force for local governments and related enterprises, "Smart Road OS" is only applied in the Yizhuang District of Beijing, **resulting in only a small-scale data feedback**

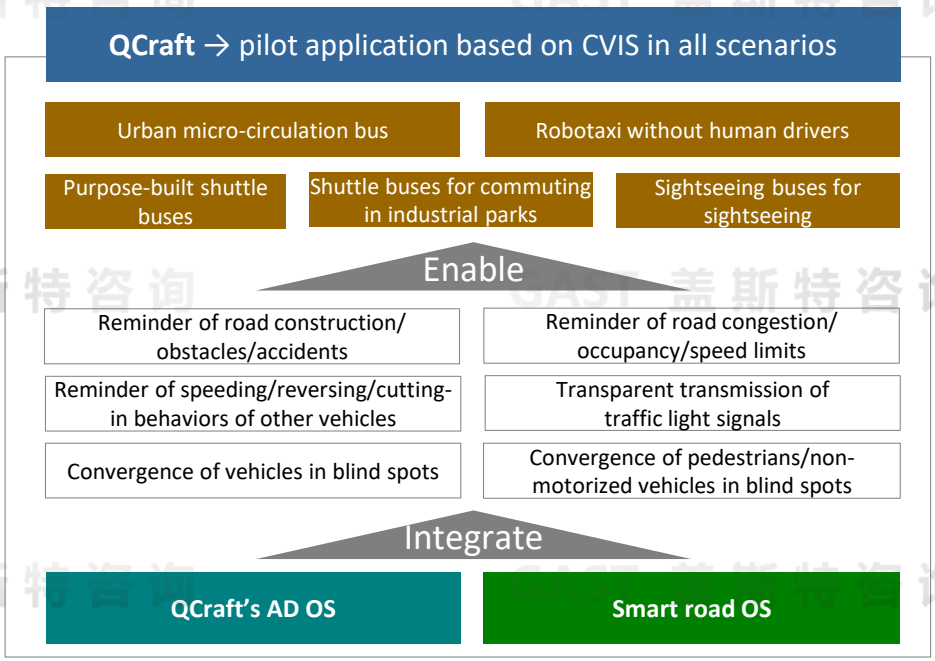
"Disguised monopoly" may appear

- ✓ **The core technologies of "Smart Road OS" are mainly provided by Baidu** (e.g., kernel, middleware, and some AI algorithms) → some technical services and products may be bound with Baidu (similar to Google's open-source Android), which is unacceptable to some internet giants (Huawei, Tencent, Alibaba, etc. have not joined the ecosystem)

Case: Practice Based on the Smart Road OS

- Integrating the perception, connectivity, computing, and other capabilities of roadside units, Smart Road OS translates basic capabilities into services that can be shared by players → open-source and open-up across the industry





- **Ensuring unified standards and interconnected ecosystems, "Smart Road OS" leaves sufficient space for players to forge differentiated innovations and allows for the upgrade, replacement, and scale-up of certain components**

Summary

The Latest Development Trends of ICV Technologies in China

- **ICVs deliver an increasingly evident trend that "vehicles, roads, clouds, networks, and maps" will develop in an integrated manner**
  - ✓ With further development of vehicles and clouds in an integrated manner → clouds are becoming a new productive force for the automotive industry: clouds will define intelligence, experience, and business models
  - ✓ Beidou Navigation Satellite System serves as the space-time digital base for ICVs, with various applications gradually getting sophisticated → significantly influence the development of ICVs
  - ✓ HD maps will function as an important carrier for data flow and transfer in an era of intelligence and connectivity → paramount for AD and other advanced functions
- **China's automotive OS still faces daunting challenges → involve the safety of China's ICV system**
  - ✓ The development of an automotive OS is a systematic project → require the comprehensive support of technologies, standards, tools and ecosystems
  - ✓ Chips underpin the development of ICVs: evolve towards software/hardware synergy + more flexible manufacturing and improvement
- **Players cooperate to promote the development of independent and open roadside OS products**
  - ✓ Smart Road OS, as the first intelligent connected RSU OS in China → features: independent, controllable, open-source, and open-up
  - ✓ Challenges facing the promotion of smart road "OS": hard to make regional breakthroughs; less enthusiastic ecosystem participants; potential monopoly of Baidu

Information Source (Non-Exhaustive)

- Title of the conference: The 9th International Congress of Intelligent and Connected Vehicles Technology (CICV 2022)
- Venue: Beijing City, China
- Organizers: China Society of Automotive Engineers, National Innovation Center of Intelligent and Connected Vehicles, Beijing Economic-Technological Development Area, and Suzhou Automotive Research Institute of Tsinghua University

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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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