Annex 3

New Energy Vehicles Key Project 2021 Project Application Guidelines

(exposure draft)

The National Key Research and Development Program has launched the "New Energy Vehicle" key special project. The overarching objectives of this initiative are: to adhere to the pure electric drive development strategy, strengthen industrial foundation R&D capabilities, address critical bottleneck technologies in the new energy vehicle industry, break through core chokepoint technologies in the industrial chain, achieve self-reliance in key technological links, generate internationally forward-looking and leading scientific achievements, consolidate China's early-mover advantages and scale leadership in new energy vehicles, and gradually establish technological superiority.

In accordance with the deployment of this key special project, we hereby propose recommendations for the 2021 project application guidelines. Following the principles of phased implementation and focused priorities, the 2021 guidelines plan to initiate 19 guideline tasks across six technical directions: energy power, electric drive systems, intelligent driving, vehicle-network integration, supporting technologies, and whole vehicle platforms.

1. Energy and Power

1.1. All-Solid-State Lithium Metal Battery Techn-

ology (basic Research)

Research Focus: 1) Interface stabilization and self-healing mechanisms of electrodes (cathode and anode) in all-solid-state batteries with solid electrolytes; 2) Transport characteristics of electrons and ions in microstructured composite cathodes containing active materials, electrolytes, and electronic conductive media; 3) Influence of conductive framework structures on lithium deposition morphology in lithium metal anodes and solid-state battery interfaces; 4) Preparation techniques for ultra-thin high-ion-conductivity solid electrolyte layers with uniform surface ion transport, mechanical strength, and compatibility with cathode/anode interfaces.

New battery structures, dry electrode, new electrolyte layer preparation methods and packaging methods; battery internal temperature/mechanical/electrochemical field and failure characterization techniques and solid state battery comprehensive evaluation methods.

Performance criteria: The solid-state composite cathode must achieve a specific capacity exceeding 400 mAh/g; the composite lithium metal anode must surpass 1500 mAh/g. The solid electrolyte must have a thickness $<15\mu m$, room temperature conductivity >1 ms/cm, and lithium-ion migration number >0.8. For all-solid-state lithium metal batteries, the capacity must exceed 10 Ah, specific energy >600 Wh/kg, and cycle life under 1C charge/discharge conditions must be over 1000 cycles.

1.2 High Safety, All-Weather Power Battery System Technology (Core Common Technology)

Research Scope: Investigate the electrochemical mechanisms underlying performance degradation of power batteries during low-temperature charging/discharging. Examine how heating methods and strategies affect battery safety and lifespan. Develop innovative non-destructive rapid heating architectures, methodologies, and safety control technologies for power battery systems. Study safe charging/discharging protocols and management systems for all-weather operation, including weather resistance under extreme temperatures. Advance all-weather battery system technologies. Analyze the coupling effects between battery reliability and dynamic stresses from vehicle vibrations, ambient temperatures, and dynamic loads, along with fatigue damage patterns. Design safety protection methods under high compression strength conditions, and establish diagnostic, safety evaluation, and early warning systems for battery failures. Develop thermal runaway explosion equivalence estimation methods, characterize propagation paths and thermal runaway mechanisms, and implement delay/intermittent control strategies. Ultimately, create high-safety, all-weather power battery systems based on these core technologies.

Performance criteria: The power battery system must achieve temperature rise from-30°C to 0°C within ≤3 minutes with energy consumption ratio ≤ 5%; maintain temperature difference within ≤5°C (-30°C to 0°C) across the system; and demonstrate non-destructive heating cycle durability of ≥300 cycles (environmental

Temperature: -30℃; Battery system grouping efficiency ≥ 80%; Power battery system anomaly detection rate ≥ 95%, battery internal short-circuit fault diagnosis accuracy ≥ 90%. Develop ≥3 battery system safety risk prediction and early warning models, establish safety risk assessment system and technical specifications; Battery system shall not catch fire or explode within 90 minutes after thermal runaway signal emission; Battery system shall not catch fire or explode under 200kN compression; Fully climate-resistant and high-safety power battery system shall be installed in ≥1000 passenger vehicles or ≥100 commercial vehicles.

1.3 Development of Key Technologies for Solid Oxide Fuel Cells for Vehicles (basic Research)

Research Scope: To develop vehicle fuel cell power generation systems tailored for diverse fuel scenarios, this study focuses on key components, stack design, system architecture, and integration technologies for solid oxide fuel cells (SOFC). Key research areas include: optimizing electrode microstructures through high-performance rectangular cell designs and controllable fabrication techniques; improving interconnect structures and flow field configurations with cost-effective processing methods and dense coating technologies; establishing standardized long-life stack assembly processes for mass production; developing fuel processing technologies and critical components; creating SOFC combined cooling, heating, and power (CCHP) systems for various applications; researching rapid start-up response technologies integrated with SOFC; and proposing efficiency optimization strategies and integrated thermal management protocols.

Key Performance Indicators: Develop a comprehensive technical framework for SOFC systems tailored to various fuel scenarios, establishing engineering technologies for SOFC components, fuel cells, and integrated systems. Complete structural design and validation of high-reliability rectangular fuel cells with voltage degradation ≤4‰/1000 hours at current densities ≥300 mA/cm^2. Develop cost-effective manufacturing processes for metal connectors and coating materials. Achieve engineering breakthroughs in SOFC stack technology, delivering single-stack power ≥1.0 kW, power density ≥1.0 kW/L, and electrical efficiency ≥60%. Finalize solid oxide fuel cell systems utilizing hydrogen, natural gas, and alcohol-based fuels.

Fuel cell combined heat and power (CHP) system development, rated power ≥ 50kW, startup time in seconds, 50% output power reached within 3 minutes, power generation efficiency ≥ 55% (DC, LHV), total CHP efficiency ≥ 85%, lifespan ≥ 5000h, voltage degradation ≤ 5‰/1000h.

1.4 Design and Key Components of High-Density Large-Capacity Gas Hydrogen Vehicle Storage and Supply System

Systems (common key technologies)

Research Scope: To address the long-range endurance requirements of fuel cell heavy-duty vehicles, this study focuses on the design, manufacturing, and testing technologies for on-board hydrogen storage tanks and systems. It investigates the release and leakage patterns of high-capacity hydrogen storage under various operating conditions. The research involves developing 70MPa high-capacity Type IV hydrogen storage tanks, integrated valve assemblies, pressure regulation valve groups, hydrogen storage system controllers, and hydrogen leak detection sensors. These efforts aim to establish a high-pressure, large-capacity on-board hydrogen storage system.

To meet the hydrogen supply requirements of high-power fuel cell engines, the research focuses on the integration and control technology of hydrogen supply system under complex working conditions such as high flow rate and high dynamic range, and the development of core-components such as hydrogen flow control valve group, circulation ejector and mechanical circulation pump.

To address the rapid refueling needs of fuel cell heavy-duty vehicles, this study investigates the diffusion, pressurization, and temperature regulation mechanisms of high-pressure hydrogen gas with large flow rates at hydrogen refueling ports within onboard systems. The research establishes stable matching and safety threshold control technologies, defines material cycle loading requirements for various components, and standardizes mechanical interfaces between hydrogen storage systems and refueling nozzles. Furthermore, it develops high-reliability, high-safety operational procedures, plug-and-play connection specifications, and communication protocols for hydrogen fuel rapid refueling.

Performance metrics: The vehicle-mounted 70 MPa high-capacity Type IV hydrogen storage system must achieve ≥32kg hydrogen storage capacity, ≤10 mL/h hydrogen leakage rate, ≥7g/s hydrogen supply capacity, and a service life of ≥10 years. The system shall include standardized components, structural design, and integrated architecture.

Safety design principles. The 70MPa Hydrogen Type IV cylinder complies with T/CATSI 02007-2020 requirements, featuring a capacity ≥400L, single-bottle mass storage density ≥6.8wt% hydrogen, and carbon fiber usage per unit storage capacity <10.7kg/kg H2. The integrated cylinder valve design withstands ≥70 MPa pressure, with built-in solenoid valves lasting ≥ 50,000 cycles, power consumption ≤8W, and weight ≤ 1.2kg. The valve integrates electromagnetic switches, flow rate control devices, temperature and pressure relief mechanisms (TPRD), temperature sensors, and manual operation interfaces. The pressure regulator assembly demonstrates a cycle life of ≥50,000 cycles, maintaining output pressure fluctuations within 10% -15% for ≤10s, with flow rates ≥7g/s and mass ≤1.2kg. The onboard hydrogen system controller supports independent refueling mode, infrared communication, and ≥6 hydrogen safety detection channels, featuring refueling status control and safety inspection strategies during parking. The hydrogen refueling port and nozzle achieve ≥7.2kg/min filling rate, with a service life of ≥20,000 cycles and temperature ≤85°C during refueling.

The high-flow hydrogen flow control valve assembly delivers a maximum injection flow rate of ≥7g/s (valve assembly flow rate), with internal/external hydrogen leakage rates ≤0.3 mL/h at 30 bar. Durability specifications: the injection valve must withstand at least 400 million cycles of operation (with proportional solenoid valves requiring ≥5 million cycles). The high-flow hydrogen recirculation ejector achieves a pressure rise of ≥50kPa, an ejector ratio of ≥2.2, and a power output range of 60-400 kW for fuel cell stacks. The high-flow hydrogen recirculation pump system demonstrates a pressure rise of ≥50kPa (using hydrogen-mixed gas at a flow rate of ≥3000slpm with hydrogen concentration ≥90%), consumes ≤1.5kW, operates at ≥46% efficiency, produces ≤70 dB noise, and has a service life of ≥20,000h.

Establish standards for rapid refueling mechanical interfaces, communication protocols, and refueling operation specifications, and prepare a draft standard for review; the refueling protocol standard should meet international requirements.

2 Electric Drive System

2. 1. Electric Drive System Technology Based on New Materials and Devices (basic Research)

Research Scope: This study focuses on developing high-performance super copper wires and motor windings using copper alloys and copper/nanotube composites. It investigates carrier transport mechanisms in high-current SiC MOSFET chips under thermal shock conditions, along with reliability enhancement methods to suppress gate dielectric interface defects. The research also explores synergistic optimization of SiC modules and components for ultra-low stray parameters and efficient heat dissipation, achieving material-device integration. Key areas include innovative SiC electric drive system architectures, multi-field integration, and holistic control methodologies. The work examines electromagnetic compatibility characteristics and suppression techniques for SiC systems, addressing fundamental scientific challenges in high-density integration and efficient control. Additionally, the project conducts technical testing and benchmarking of cutting-edge electric drive technologies, while developing diagnostic and predictive methods for critical failures in power devices, motor insulation, and bearings under automotive service conditions. These efforts aim to establish a comprehensive technical framework and standardized specifications for electric drive system health management.

Evaluation Criteria: Under conditions maintaining constant parameters including elongation rate and insulation layer adhesion, the super copper wire exhibits 20% lower resistivity than conventional copper wire at 180°C while demonstrating 10% higher strength. It must achieve ≥250A current-carrying capacity in a single chip at 1200V, with a conduction voltage drop ≤2.5V at 250A/150°C and a maximum junction temperature of 250°C. The SiC motor controller must maintain ≥70kW/L peak power density at 300 kW peak power, and meet EMC compliance with CISPR Level 4 standards. Five benchmark test reports and technical analysis reports for electric drive systems shall be submitted, with 2 sets of samples annually. Additionally, one health management standard specification for electric drive systems must be submitted.

2.2 High-Performance Hub Motor and Assembly Technology (common Key Technology)

Research Scope: High-density Hub Motors. This research focuses on the integrated design and simulation of electromagnetic, mechanical, thermal, and acoustic fields in high-density hub motors, fault diagnosis and fault-tolerant control, torque ripple suppression, noise reduction, and reliability and durability verification methods. It also involves developing new materials, innovative structural designs, and advanced manufacturing technologies for hub motors, including cooling systems.

Dynamic sealing, etc.). Hub drive system integration: Overcoming technical challenges in deep integration and torque vector distribution between hub motors and braking, steering, and suspension systems, enabling continuous improvements in hub motor system performance, power density, and torque density, providing core component support for the development and industrialization of next-generation electrified chassis.

Evaluation Criteria: Direct-drive hub motors must demonstrate peak torque density ≥20 Nm/kg or ≥60 Nm/L, while geared hub motors require power density ≥5.0 kW/kg. The hub motor assembly system must achieve a maximum efficiency of ≥92% and a comprehensive CLTC (China Light Truck Corridor) operational efficiency of ≥80%. The 1-meter noise level must be ≤ 72 dB, with a protection rating of IP68 or higher. Impact and vibration standards must meet or exceed traditional hub specifications, and electromagnetic compatibility (EMC) must satisfy Class 4 or higher. A standardized reliability and durability testing protocol shall be established. The hub motor assembly must be fully operational when installed in vehicles.

2.3 Hybrid-Specific Engines and High-Efficiency Electromechanical Coupling Technology (common Interface Key technology)

Research Scope: This initiative focuses on hybrid engine technologies including structural optimization, high-pressure injection, high compression ratios, efficient combustion, electric valves, low-friction systems, and noise reduction, with the goal of developing specialized hybrid engines featuring high thermal efficiency and low emissions. The program also explores innovative configurations, integrated electromechanical systems, high-efficiency transmission mechanisms, advanced thermal management solutions, dynamic control systems, and low-noise technologies, aiming to create electromechanical coupling gearboxes that deliver superior efficiency, high integration, and cost-effectiveness.

The research focuses on integrated optimization of structural systems, dynamic collaborative control, high-voltage safety management, and testing verification for hybrid powertrain technologies, aiming to achieve high efficiency and reliability. Equipped with specialized power batteries, the vehicle achieves industry-leading performance metrics in power output and energy consumption through comprehensive optimization control.

Performance criteria: The thermal efficiency of the dedicated engine should be ≥44%, and the engine emissions must meet the specified standards.

China VI b+RDE; the mechanical transmission efficiency of the electromechanical coupling system is ≥ 95%, under China's CLTC conditions, the proportion of the engine's high-efficiency zone is ≥65% (high-efficiency zone definition: 5 percentage points below the highest thermal efficiency), and the comprehensive efficiency of the electromechanical coupling system is ≥85%; the product reliability and lifespan meet the vehicle requirements, achieving operational capability. The vehicle equipped with this system has a 0-100km/h acceleration time of ≤7s, and the fuel consumption of Class A vehicles in power maintenance mode is ≤3.8L/100km. The dedicated high-efficiency hybrid engine has a total noise pressure level of ≤90dB(A) at 1 meter under rated power; the electromechanical coupling system has a total noise pressure level of ≤78dB(A) at 1 meter at its base speed point (torque turning point).

3 Intelligent Driving

3. 1. Multi-Domain Electronic and Electrical Information Architecture (EEI) Technology (Basic Research)

Research Scope: Develop a service-oriented integrated architecture for vehicle-road-cloud-network convergence. Explore high cohesion, low coupling design principles, and optimize computational resource allocation across vehicle terminals, edge nodes, and cloud platforms. Establish standardized interfaces for intra-domain, inter-domain, and vehicle-cloud integration, enabling software module reuse and comprehensive vehicle management. Key research focuses include: 1) Core software design for C-V2X and vehicle network convergence; 2) Advanced communication technologies like vehicle Ethernet and Time-Sensitive Networking (TSN); 3) High-performance software architectures with ultra-high bandwidth, minimal latency, and robust reliability; 4) Integrated remote data analysis, diagnostic, calibration, and upgrade platforms; 5) Electronic architecture redundancy solutions using multidimensional security frameworks; 6) Real-time simulation systems for multi-layered testing; 7) Application integration and demonstration of converged electronic architectures.

Evaluation Criteria: The architecture supports a high-level autonomous driving system that integrates vehicle-road-cloud collaboration, enabling independent software/hardware operation and cross-domain collaborative computing. It features a centralized elastic computing platform with distributed regional management controllers for vehicle-wide software-defined functionality development, supporting ≥400 standardized software/hardware interfaces and multiple operating systems. The integrated electronic-electrical architecture platform enables C-V2X communication, ensures ≤20-minute vehicle-wide software updates, delivers 10Gbit/s network speeds, and guarantees <50μs latency for time-sensitive traffic with <20ns synchronization accuracy. It incorporates high-reliability redundancy mechanisms and establishes redundancy design principles for functional safety. The system meets electromagnetic safety requirements in complex environments, having passed GB/T18387 and GB34660 standard certifications. It implements layered defense strategies for information security and establishes a comprehensive simulation, evaluation, and testing verification framework for vehicle electronics. The technology has been adopted by over two automotive manufacturers, with three technical standards or drafts completed.

3.2 Key Technologies for Learning Autonomous Driving Systems (common Key Technologies)

Research Scope: Develop multi-scale scenario understanding technology for human-vehicle-road integrated systems, creating long-term behavioral prediction systems for road users. Advance online evolutionary learning technology for autonomous driving's perception-decision-control functions, developing efficient iterative algorithms powered by model-data synergy, and creating universal modeling, optimization, and analysis software. Investigate high-performance real-time computing solutions for autonomous vehicles, including low-power heterogeneous computing architectures, distributed task management, and strategic model compression/compilation/deployment. Build multidimensional driving performance analysis systems and training platforms, featuring edge-scenario natural driving databases, safety-focused performance evaluation models, and semi-physical in-loop training for virtual traffic scenarios. Develop autonomous driving

The system integrates and tests functional verification technologies, including development methods and test processes that meet automotive-grade standards, as well as auxiliary modules such as functional optimization, fault diagnosis, remote monitoring, and human-machine interaction, as well as trials in closed test fields and open demonstration roads.

Evaluation Criteria: The prediction time domain for typical traffic participant behavior must be no less than 5 seconds, with trajectory prediction errors within ≤0.5m (lateral) and ≤2m (longitudinal) for extended-range predictions. The system must support self-evolving training for Level 3+ autonomous driving functions, covering ≥5 typical road scenarios and ≥ 4 traffic participant categories, with online learning system updates occurring every ≤30 minutes. The autonomous driving controller must achieve ≥2 Tops/W computing power, with average latency for core modules under 150ms. Edge scenarios must include ≥ 10,000 natural driving sample clips across ≥80 scenario types, ensuring the autonomous driving performance evaluation model achieves ≥90% accuracy. The training platform must support ≥100 virtual traffic nodes and enable parallel training access for at least 5 autonomous vehicles.

3.3 Intelligent Vehicle Expected Functional Safety Technology (common Key Technology)

Research Scope: 1) Develop cognitive technologies for expected functional safety in intelligent vehicles, including forward hazard analysis integrated with the "V" process of system development, risk identification, and machine learning algorithm uncertainty/ explainability studies to establish quantitative evaluation models; 2) Research real-time protection technologies for expected functional safety, developing real-time monitoring and defense systems; 3) Key technologies for machine learning growth systems to mitigate expected functional safety risks, including data systems for autonomous driving platforms and high-performance cloud computing solutions for big data applications; 4) Critical human-machine interaction technologies for safety assurance, encompassing safety protection mechanisms and functional simulation techniques for both interior/exterior vehicle interfaces; 5) Development of expected functional safety scenario libraries and evaluation methodologies, including priority subset selection algorithms, coverage gradient analysis, and simulation infrastructure construction.

Test the model, study the expected functional safety quantification and test evaluation technology, and establish the expected functional safety test verification specification and standard.

Development Objectives: 1) Develop a real-time protection system for expected functional safety to ensure real-time assurance, with technical validation conducted in at least 20 edge scenarios; 2) Establish a high-performance cloud computing platform for digital twin technology supporting big data applications; 3) Create a comprehensive suite of tools for analyzing, simulating, and managing expected functional safety in autonomous driving systems; 4) Develop a test case library for intelligent connected vehicles with conditional autonomous driving capabilities or higher, containing ≥300 test cases; 5) Build a real-world functional safety testing platform; 6) Collect ≥1 million kilometers of real-road data and construct ≥1,000 functional safety scenarios; 7) Finalize a standard or draft for quantitative development and evaluation systems of expected functional safety.

4． Vehicle and Network Integration

4.1. Cyber-Physical Systems (CPS) Technology for Intelligent Vehicles (Basic Research)

Research Scope: 1) Develop integrated modeling technologies for communication and system dynamics in cyber-physical systems (CPS) for vehicle-road-cloud networks, including formal expression of heterogeneous modular models and system design library construction. 2) Establish framework architectures for efficient CPS-CPS collaboration, achieving breakthroughs in CPS architecture design and configuration optimization to define system requirements, functional logic, and physical architecture. 3) Advance concurrent component design for CPS, develop traceable continuous transmission databases, and create cloud-based collaborative design tools. 4) Conduct experimental system evaluation and validation through semi-physical testbeds and case studies. 5) Implement CPS applications and build demonstration platforms for intelligent vehicle-infrastructure coordination.

Evaluation Criteria: The system design model library shall contain no fewer than 20 sets of system communication and dynamics model collections, accommodating at least 500 system models with accuracy ≥90%; the system architecture framework shall feature ≥7 design analysis dimensions; system requirements shall define ≥2,000 items, with system functions, logical, and physical architecture elements totaling no less than 4,500; the cloud collaboration system prototype shall enable concurrent database access modifications and unique data version traceability for at least 50 user terminals; the in-loop semi-physical test facility shall include no fewer than 3,000 test cases; the intelligent vehicle cyber-physical system demonstration platform shall support at least 40 square kilometers of demonstration zones, 200 kilometers of smart city road mileage, 150 intelligent roadside facilities, and coordinated operation of 300 smart vehicles; complete at least 5 technical standards or drafts, and finalize one system engineering application manual.

4.2 High-Precision Autonomous Driving Dynamic Map and Beidou Satellite Fusion Positioning Technology

(Common key technologies)

Research content: Study high-precision dynamic map models and architectures supporting autonomous driving, research map data models for China road characteristics that support incremental updates and expansion, establish mechanisms for expressing and storing dynamic and static map data with variable resolution; research online map update technology for crowdsourced data of production vehicles, study real-time encryption and redirection technology for map data; research collaborative perception technology for connected vehicles based on map-aware containers, establish multi-source fusion mechanisms for vehicle-road-cloud connectivity information; study automotive-grade BeiDou positioning chips and multi-source positioning terminal technologies, build an integrated vehicle positioning, navigation, and timing system based on BeiDou and its enhanced systems, research intelligent holographic combined active positioning technology integrating vision, inertial guidance, and maps; study vehicle software and hardware integration technology for autonomous driving maps and positioning systems.

Evaluation criteria: The map model supports dynamic and static multi-layer data access, including self

The application interface protocol for dynamic driving perception and decision-making features: a map coverage area of ≥10,000 km²; high-precision maps with a relative error ≤15 cm/100m, achieving ≥99% accuracy through professional data collection vehicles and ≥90% accuracy via crowdsourced data; ultra-long-range blind-spot-free perception detection accuracy ≥ 90%, with dynamic information transmission latency ≤ 1 second; high-precision positioning system errors ≤ 10 cm under normal conditions and ≤20 cm under satellite interference conditions; support for ≥2 demonstration zones of high-precision maps with vehicle-road coordination perception capabilities, and completion of ≥5 relevant technical standards or drafts.

4.3 Autonomous Driving Simulation and Digital Twin Testing Evaluation Tool Chain (common Interface)

Key technology)

Research content: "Human-vehicle-road-environment" coupled high-fidelity modeling and simulation technology, studying high-precision sensors, dynamics, environmental modeling technology, and strong coupling mechanisms, developing real-time simulation software supporting L3 and above autonomous driving; cloud-based simulation technology integrating autonomous driving scenarios and traffic flow characteristics, researching macro-micro integrated traffic flow modeling and accelerated testing technology including China's autonomous driving accident scenario characteristics, developing scenario batch generation and high-concurrency large-scale cloud computing testing platforms; vehicle-cloud-field collaborative online accelerated testing and evaluation technology for autonomous driving, studying cloud-based collaboration and continuous field twin evaluation technology for driver behavior and autonomous vehicle behavior based on traffic flow; multi-vehicle collaborative whole-vehicle traffic in-loop digital twin technology, developing highly sensitive integrated whole-vehicle-level system platforms for driving, braking, and steering, researching real-time simulation and virtual-real integrated interaction testing technology for "human-vehicle-road-environment"; autonomous driving testing and evaluation platforms and toolchains, studying intelligent driving rating, automatic defect identification, and safety performance certification technology, building standardized tool software and hardware platforms.

Evaluation criteria: Dynamic performance of high-precision autonomous driving simulation software under extreme operating conditions

Simulation accuracy ≥90%; Over 1,000 real-world autonomous driving accident scenarios on public roads; Cloud control platform supports PB-level data scale with 99.9% task execution success rate, achieving 10,000 use case generation/min and 10,000 use case testing/hour; Digital twin testing system supports speeds up to 150km/h, maximum braking force 10m/s^2, and maximum steering angle 40°; Digital twin enables virtual-real sensor signal superposition; Toolchain supports full L3+ autonomous driving testing, completed at least 2 technical standards or drafts, and serviced 20+ autonomous vehicle models.

5． Supporting Technology

5. 1 Key Toolchain Development for Automotive Electronic Control Units (common Key Technologies)

Research Scope: 1) Develop modular-level software modeling tools for automotive electronic control units (ECUs) to enable model-based software design; 2) Create ECU software testing and validation tools with standardized workflows, unified interfaces, and automated testing; 3) Build integrated hardware-software testing and calibration systems for real-time performance optimization; 4) Design vehicle communication bus simulation and testing platforms for functional verification and performance enhancement; 5) Develop cloud-based ECU design simulation platforms and model libraries with parallel computing capabilities for autonomous toolchains.

Evaluation Criteria: The critical toolchain for automotive electronic control unit (ECU) software development and verification must comply with the V-model development process, featuring at least four essential tools covering software modeling, hardware/ software testing, and communication bus simulation/ testing. ECU module-level software modeling tools should support at least three core functionalities including system graphical modeling, continuous/ discrete simulation, and state machine modeling. ECU software testing and verification tools must enable graphical test case creation and support automated testing.

The system shall implement at least three core functionalities: defining test case libraries and unified management of test plans. The automotive electronic control unit (ECU) integration testing and calibration tool must support at least two calibration protocols, provide a customizable graphical calibration interface, and enable calibration data recording and writing. The vehicle communication bus simulation and testing tool shall include bus monitoring analysis, bus excitation, and diagnostic services. The cloud-based development platform for autonomous vehicles must support cloud user login with a minimum of 1,000 monthly logins over 12 months, while the toolchain's cloud model library shall contain at least 50 valid models.

5.2 Research on Testing Technologies and Evaluation Systems for Critical Automotive-Grade Chips (Common key technology)

Research Scope: This study investigates the reliability of automotive-grade control, communication, computing, security, and storage chips under vehicle usage requirements, along with electromagnetic compatibility (EMC) testing technologies. It involves designing and developing functional safety test case libraries and corresponding testing techniques for automotive-grade chips using FPGA semi-physical platforms and physical chip platforms. For intelligent driving applications, the research focuses on computational power and energy consumption testing technologies for automotive-grade computing chips. Regarding connected vehicle requirements, it examines information security testing technologies for automotive-grade security chips based on national cryptographic algorithms. The project also establishes a comprehensive testing platform for automotive-grade control, communication, computing, security, and storage chips, while developing evaluation methodologies and systems tailored to vehicle usage requirements.

Evaluation criteria: Establish an environmental stress testing system capable of supporting multi-sample (≥20) simultaneous trials, operating within a temperature range of-40°C to 250°C, relative humidity>65%, and pressure ≥ 15psig (pounds per square inch). Additionally, develop a life testing system with power bias capability (voltage range 0-20V, resolution 10mV). Create an EMC testing environment that supports both conducted interference (20Hz-108MHz) and radiated interference.

(20Hz-40GHz), HBM_ESD (10kV), power interruption drop test (time ≤ 1ms); Build an ATE test system supporting 1024 digital channel resources, 5G communication rate, excitation voltage range-0.5~+1.5V, and resolution of 10μV; Develop a vehicle-grade computing chip test system supporting GPU/AI and other architectures for vehicle-grade computing chips under different system configurations (configurable cores, minimum clock speed test accuracy 100MHz) to perform computational power testing (covering 5~20 TFlops, 5~300Tops) and energy consumption testing (maximum precision 0.1W); Design and develop a functional safety test system supporting semi-physical and physical vehicle-grade chips, covering bus, storage, DDR, clock, IO, interrupt, and underlying software modules of vehicle-grade computing chips, completing at least 1,000 functional safety test cases for 1-2 chip models; Develop a national cryptographic algorithm (SM1~SM4) detection system for vehicle-grade information security chips, supporting ≥5,000 signature verification tests per second for tested chips, and create a random data acquisition and randomness level testing platform with customizable confidence levels (α values 0.02~0.05) and at least 4 true random sources with arbitrary switching, developing at least 100 information security test cases (including security attack cases). Formulate more than 5 standard proposals for automotive chip testing.

5.3 Safety Assessment Technology and Equipment for on-Board Energy Storage Systems (common Key Technologies)

Research Scope: Investigate the mechanisms, evolution patterns, and evaluation technologies for battery system safety damage under multi-scenario, full-condition, and multi-factor coupling scenarios. Develop thermal runaway and heat diffusion assessment techniques for battery systems. Establish failure consequence evaluation methodologies for battery system hazards. Analyze coupling mechanisms and patterns between battery system lifespan and safety. Formulate multidimensional safety evaluation frameworks and standards for power batteries. Study the formation and evolution mechanisms of high-frequency failure behaviors in power battery systems, along with their recurrence assessment technologies. Develop safety risk evaluation techniques for in-service power battery systems through vehicle-end perception, offline detection, and cloud-based data collaboration.

Technology; development of intelligent nondestructive testing equipment and software.

This research focuses on three key areas: 1) Investigating failure mechanisms, failure modes, and quantitative safety assessment techniques for multi-scenario, multi-factor coupled hydrogen systems in vehicles; 2) Developing hazard assessment technologies for vehicle-mounted hydrogen systems and establishing a multidimensional safety evaluation framework; 3) Exploring hydrogen leakage visualization detection technologies, trace hydrogen leakage detection methods, and real-time monitoring approaches for hydrogen system safety risks.

Performance Metrics: Establish a multi-dimensional safety evaluation framework and supporting equipment for power batteries; Develop at least two intelligent non-destructive testing systems for in-service battery safety with 90%+ accuracy; Build a quantitative safety assessment system and real-time monitoring platform for vehicle-mounted hydrogen systems, validated in commercial and passenger vehicles with a 1-second response time; Achieve 50ppm+ detection accuracy for trace hydrogen leaks; Ensure over 90% accuracy in severe leakage prediction; Formulate at least five safety evaluation standard proposals for both power battery systems and vehicle-mounted hydrogen systems.

5.4 Key Technologies and Equipment for Efficient and Coordinated Charging and Swapping (common Key Technologies)

Research Scope: 1) Develop a multi-tiered physical information network architecture integrating vehicle-charger (station)-cloud systems; 2) Create big data-driven technologies for secure and efficient charging management; 3) Build real-time data exchange platforms enabling vehicle-charger (station) interoperability. 4) Establish spatiotemporal multi-dimensional prediction methods for EV charging loads using operational big data, along with optimized layout planning for charging and battery-swapping facilities. 5) Formulate operational management and decision-making frameworks for vehicle-charger-cloud collaborative services, incorporating user behavior analysis and real-time facility status monitoring for fleet charging coordination. 6) Advance integrated storage, identification, and charging technologies for multi-model battery packs at fast-swapping stations, standardize battery pack specifications, and develop cross-vehicle compatibility solutions for multi-model battery pack recognition.

The vehicle's power battery swap system is shared across multiple models; research wireless bidirectional charging and discharging technology compatible with various power levels, and develop high-power, high-efficiency, and intelligent bidirectional wireless charging and discharging equipment.

Key Performance Indicators: 1) Establish a vehicle-charging station data exchange platform enabling cross-platform interoperability, with cross-platform data response times ≤1s and high-concurrency capacity ≥2 million units. 2) Develop urban public charging station planning models and technical specifications, achieving nationwide coverage in ≥20 provinces. 3) Achieve ≥30% improvements in charging station utilization rates and vehicle charging wait times. 4) Implement fast battery swap systems compatible with ≥3 battery pack types and ≥3 vehicle models, ensuring ≤90s for battery replacement. 5) Wireless charging systems with ≥30kW bidirectional power output, 20cm transmission range, DC250-900V output voltage, and ≥92% system efficiency across 10%-100% load ranges, reaching peak efficiency of ≥94%.6) Ensure multi-vehicle interoperability through validation of at least 3 vehicle models.

6 Vehicle Platform

6. 1 Pure Electric Bus/Passenger Vehicle High Efficiency and High Environmental Adaptability Power Platform Technology

(Common key technologies)

Research Scope: Develop low-energy self-insulation technology for vehicles in extreme cold environments, high-efficiency cooling solutions for power platforms under high-temperature and high-humidity conditions, and advanced insulation and safety protection technologies. Explore electric drive systems for diverse applications, including predictive temperature control methods for power battery systems and intelligent thermal management circuit control technologies. Investigate energy coupling mechanisms between electric drive systems, power batteries, and cabin thermal management systems, while developing efficient intelligent thermal control technologies and integrated multi-source thermal management systems. Additionally, research multi-valve, multi-channel, and multi-cooling circuit integration with low-temperature compressor technologies.

Innovations in air conditioning technologies such as reliability and variable refrigerant charge (VRC) systems are driving the development of low-temperature, high-efficiency heat pump air conditioning systems. Research focuses on functional domain-based power platform control technologies and big data-driven optimization calibration for whole-vehicle energy management. Key initiatives include developing multi-functional high-voltage integrated controllers and connected vehicle comprehensive control systems using self-developed core chips, alongside creating high-adaptability powertrain platforms and specialized chassis designs.

Evaluation Criteria: 12-meter all-electric bus: Energy consumption ≤ 52 kWh/100km (CHTCA standard); All-weather driving range ≥ 300km (CHTCA standard) across-35°C to +40°C; At-35°C, driving range ≥ 85% of ambient temperature performance, cold start time ≤ 8 min, AC heating power ≥ 14kW, COP ≥ 1.3. At 40°C, AC cooling power ≥ 22kW, COP ≥ 1.7. Development of at least two models with: 30-minute top speed ≥ 100 km/h, 0-50km/h acceleration ≤ 15s, maximum incline ≥ 25%, and 100-unit validation.

Class B Passenger Vehicles: 1) Energy consumption ≤ 14 kWh/100km (CLTC); 2) All-weather capability (operating in-35°C to +40°C); 3) Range ≥ 500km (CLTC); 4) At-35°C, range ≥ 85% of ambient temperature performance; 5) Cold start time ≤ 5 min; 6) AC heating ≥ 4 kW; 7) COP ≥ 1.3; 8) At 40°C, AC cooling ≥ 7.5 kW; COP ≥ 1.7; 9) At least 2 developed models; 10)

Top speed ≥ 180 km/h; 11) 0-100 km/h acceleration ≤ 4s; 12) Maximum climbability ≥ 30% under full load; 13) Achieve 1,000-unit validation.

6.2 Key Technologies and Applications of Intelligent Electric Heavy-Duty Vehicle Platform (demonstration Application)

Research content: Develop an integrated platform architecture for intelligent electric drive heavy-duty vehicles, study the coupling mechanisms and design methods between the vehicle's physical structure, electric drive system, and intelligent driving system; develop heavy-duty vehicles for harsh environments with intelligent

The driving system research focuses on developing multi-source sensor fusion perception technology for large blind zones in dusty and bumpy environments. It explores vehicle fault diagnosis and intelligent guidance decision-making under strong vibrations and heavy loads, while investigating coordinated longitudinal-transverse control techniques for continuous steep slopes and variable load conditions. For heavy-duty vehicles operating in complex scenarios, the project develops high-power intelligent electric drive systems. This includes constructing integrated permanent magnet motor drive architectures for heavy-duty vehicles and researching adaptive torque distribution with predictive control under multi-state slippery slopes. Additionally, an intelligent electric drive heavy-duty vehicle simulation platform is being developed for multi-scenario operations, incorporating hardware-in-the-loop (HIL) simulation and formation operation modeling technologies. Demonstrative unmanned collaborative operations of intelligent electric drive heavy-duty vehicles are being implemented in typical scenarios such as open-pit mining.

Development Objectives: 1. Develop a complete vehicle platform prototype for intelligent electric drive heavy-duty vehicles. 2. Under moderate to severe dust conditions, achieve obstacle detection with small-sized (0.5m×0.5m×0.5m) obstacles at a distance of ≥

100m with detection error ≤0.3m, and parking control error ≤0.5m under 200-ton load conditions, enabling slope parking and lifting on 10% gradients. 3. Develop an independently controllable electric drive system that improves comprehensive energy efficiency by 10% and adhesion utilization rate by 15% compared to international counterparts, while maintaining effe-ctive electric braking at 1km/h speed. 4. Establish a simulation and verification platform for intelligent electric drive heavy-duty vehicles. 5. Conduct unma-nned collaborative operation demonstrations for at least 30200-ton class vehicles in typical scenarios like open-pit mining areas, ensuring stable operation for over 1 year with average energy consumption reduc-tion of 15% compared to international products. 6. Formulate 1 relevant technical standard or draft.