Research Report on Standardisation Requirements for Intelligent Cockpit

Sino-German Sub-Working Group Intelligent and Connected Vehicles

November 2023

VDA NTCAS GPQI Dialogues for Innovation and Trade

Published by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Bonn and Eschborn, Germany

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On behalf of
German Federal Ministry for Economic Affairs and Climate Action (BMWK)
Berlin, Germany 2023
Beijing, China 2023

The German Federal Ministry for Economic Affairs and Climate Action (BMWK) has commissioned the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH to implement the Global Project Quality Infrastructure (GPQI).

Federal Ministry for Economic Affairs and Climate Action

Implemented by

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This publication is a result of the Sub-Working Group Intelligent and Connected Vehicles of the Sino-German Standardisation Cooperation Commission in cooperation with

中华人民共和国工业和信息化部

SAC 中国国家标准化管理委员会 Standardization Administration of the P.R.C.

Partners involved

SINO-GERMAN STANDARDISATION COOPERATION COMMISSION

The central body for standardisation cooperation between Germany and the People's Republic of China is the Sino-German Standardisation Cooperation Commission (SGSCC). Under the chairmanship of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Standardization Administration of the People's Republic of China (SAC) as part of the State Administration for Market Regulation (SAMR), experts from standardisation organisations, authorities and companies from both countries work on a variety of topics in the Commission. These include electromobility, Industrie 4.0/ intelligent manufacturing as well as intelligent and connected vehicles. Professional exchange within SGSCC is conducted by the German Institute for Standardization (DIN), the German Commission for Electrical, Electronic & Information Technologies of DIN and VDE (DKE) and the Standardization Administration of China (SAC).

SUB-WORKING GROUP INTELLIGENT AND CONNECTED VEHICLES

The Intelligent and Connected Vehicles Sub-Working Group of the SGSCC is the decisive platform for the Sino-German exchange on standardisation for ICV. Founded in 2021, it supports the coordination of common positions in international standardisation bodies and the promotion of ISO standards. Through technical exchange in the sub-working group (SWG), existing standardisation gaps are identified and bilateral cooperation in these areas is promoted. The cooperation of BMWK with SAMR and the Ministry of Industry and Information Technology (MIIT) of the People's Republic of China in the SGSCC is supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH within the Global Project Quality Infrastructure (GPQI). On behalf of BMWK, GPQI advises and supports technical policy dialogues and implements agreed technical measures in collaboration with the actors involved. At the technical level, the work is led by the German Association of the Automotive Industry (VDA) and China Automotive Technology and Research Center Co., Ltd. (CATARC). In annual meetings, priority topics are agreed for the SWG, which are implemented during the year under the guidance of experts from the two countries.

VDA

The German Association of the Automotive Industry (VDA) was founded in 1901 and is headquartered in Berlin with more than 650 member companies. They develop innovative mobility services and produce automobiles, trailers, bodies, buses, automotive parts and accessories in Germany and worldwide. The task of the VDA is to ensure the right framework conditions so that companies, from start-ups to global corporations, can realise their visions and successfully bring their offers to market. VDA is also the organiser of the top auto show IAA (IAA Mobility & IAA Commercial Vehicles) in Germany with over 120-year history.

CATARC

Established in 1985, China Automotive Technology and Research Center Co., Ltd. (CATARC) is a comprehensive technological enterprise group directly under the State-owned Assets Supervision and Administration Commission of the State Council and with significant influence in both the domestic and international automotive industry. The business scope of CATARC covers ten major areas, including testing and inspection, engineering technology research and development services, digitalisation, engineering design, consulting services, certification, and strategic emerging businesses.

Global Project Quality Infrastructure

To promote the development of well-functioning and internationally coherent quality infrastructures, the German Federal Ministry for Economic Affairs and Climate Action (BMWK) has established the Global Project Quality Infrastructure (GPQI). GPQI supports the political and technical dialogues and implements bilaterally agreed activities in collaboration with all relevant stakeholders. The project aims to reduce technical barriers to trade and enhance product safety through bilateral political and technical dialogues on QI with some of Germany's key trading partners.

Foreword

We would like to offer our sincere thanks to all the institutions, organisations and individuals that participated in compiling this research report.

Furthermore, we are grateful to the industry's many research achievements referred to during the process of report compilation.

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Subcommittee on Intelligent and Connected Vehicle of National Technical Committee of Auto Standardization, German Association of the Automobile Industry.

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Participating organisations

Volkswagen (China) Investment Company Limited, BYD Company Limited., Huawei Technologies Co., Ltd., Pateo Internet of Vehicles Technology (Shanghai) Co., Ltd., Faw Jiefang Automotive Co., Ltd., Lantu Automobile Technology Co., Ltd., Neusoft Group Co., Ltd., Polar Krypton Automobile (Ningbo Hangzhou Bay New Area) Co., Ltd., Beijing Horizon Robotics Technology R&D Co., Ltd., Qualcomm Wireless Communication Technologies (China) Co., Ltd., Beijing Automotive Research Institute Co., Ltd., Shenzhen Huituo Infinite Technology Co., Ltd., Beiqi Foton Motor Co., Ltd., Chongqing (Yu) Microelectronics Technology Research Institute Co., Ltd., General Institute of Innovation and Development of SAIC Motor Corporation Limited, Shanghai Lingang Jueying Intelligent Technology Co., Ltd., Chongqing Changan Automobile Company Limited, China Automotive Engineering Research Institute Co., Ltd., iAuto (Shanghai) Co., Ltd., Beijing Chehejia Automobile Technology Co., Ltd., NIO Automobile Technology (Anhui) Co., Ltd., Shanghai Motor Vehicle Inspection Certifaction & Tech Innovation Center Co., Ltd., Arm Technology (China) Co., Ltd., Chery Automobile Co., Ltd., Beijing Baidu Zhixing Technology Co., Ltd., Geely Automobile Research Institute (Ningbo) Co., Ltd., SAIC Volkswagen Automotive Co., Ltd., China First Automobile Co., Ltd., SAIC-GM-Wuling Automobile Co., Ltd., Guangzhou Xiaopeng Motors Technology Co., Ltd., Shanghai Intelligent and Connected Vehicle R&D Center Co., Ltd., Bosch Automotive Products (Suzhou) Co. Ltd., DONGFENG-NISSAN Passenger Vehicle Company of Dongfeng Motor Company Limited, Automotive Intelligence and Control of China (Beijing) Co., Ltd., Huizhou Foryou General Electronics Co., Ltd.

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1 Research background

1.1 Overview

Technical development of the automobile intelligent cockpit is currently booming and related functional products in the intelligent cockpit field are rapidly iterating – thus greatly enriching the functional application of the cockpit and improving the user experience. At the same time, intelligent cockpit products are directly related to user experience and have become one of the key factors in the core competitive strength of automobile products. However, some performances involving existing intelligent cockpit products do not match the needs of users, meaning optimisation and upgrading are urgently required.

Looking at the development history of the automobile industry and the evolution of automobile products, we can see the development of the intelligent cockpit has basically experienced three stages: the mechanical era prior to 2000, which mainly involved (1) the mechanical dashboard and simple audio playback equipment, single physical button functions, low integration and no intelligence; (2) the electronic era from 2000 to 2015, involving mostly physical keys and some touch screens, with low integration and intelligence; and (3) the intelligent era from 2015 to the present, in which the intelligent cockpit has moved towards a focus on driver demand and user emotion, driven by scenarios and meeting the different needs of drivers and passengers. Essentially, the intelligent cockpit creates a brand-new user experience for drivers and passengers in the cabin by means of a richer and larger full-LCD dashboard, comprehensive touch-type console equipment, an advanced in-vehicle infotainment system and a handy biometric system.

With the vigorous development of the new energy automobile industry, the hardware/software industry chain for the intelligent cockpit ushered in a period of demand explosion. Data shows that the penetration rate for intelligent cockpit configuration levels in China is about 48.8%.[1] By 2025, the penetration rate for the intelligent cockpit in China's new vehicle market is expected to exceed 75%, and the market size will exceed 160 billion yuan by 2030[2].

The field of intelligent cockpit design was late to start and quick to develop. With the rapid integration of new technologies, an increasing number of different product forms made irreversible appearances in intelligent cockpit systems, and human-machine interaction also showed a diversified development trend. However, many related technologies were still developing and progressing, leading to a deviation between product performance and user demand. At the same time, construction of a standards system for the field of intelligent cockpit systems was seriously lagging behind. Current relevant standards are relatively traditional and unsystematic. The technical requirements and testing methods mainly concern the hardware output level of products, and do not yet completely cover the emerging system functional products in various sub-areas, including interactive functions inside and outside the cockpit, the audio-visual touch-smell interactive terminal, communications, basic technologies such as controllers and sensors, and even top-level design areas such as cockpit intelligentisation classification and cockpit evaluation.

Therefore, constructing a set of intelligent cockpit standards systems – with human-machine interaction as the core and covering hardware, software, equipment, technology, functions, general interfaces and evaluation methods – provides vital support to the development of intelligent cockpit systems.

1.2 Development of intelligent cockpit technology

1.2.1 Overview of overall intelligent cockpit technology development

The intelligent cockpit is an important part of intelligent and connected vehicles. Today, with the continuous development of global automobile industry 'electrification, networking, intelligence and sharing', cockpit intelligence and differentiation are not only the new competitive selling point among OEMs at this stage, but also an important consideration for consumers with regard to vehicle purchase. With the ongoing popularisation of intelligent technology in the years ahead, users will place higher demands on the driving experience and vehicles will no longer be just a means of transportation. The mission of intelligent cockpit development – and an important development direction for the future – is to make communication between people and vehicles more convenient and intelligent and to create a personalised third living space that meets all driving and safety requirements.

Intelligent cockpit systems involve the development of various technologies, including basic technology class, hardware terminal class and functional class. Basic data class mainly includes chips, cockpit domain controllers, operating systems, cloud service platforms and communications, etc. Hardware terminal class includes sensors, controllers and interactive terminals, etc. Functional class includes recognition and monitoring class, voice interaction systems, gesture interaction systems, vehicle-mobile phone interconnections, display interaction, environmental class and multi-modal interaction, etc.

1.2.2 Technical development of foreign intelligent cockpit systems

1.2.2.1 European and American models

The electronic architecture for American companies manages different area control units and their components in a unified way through the central computing module (CCM). This makes all-round innovation on traditional automobile electronic architecture, realises the 'software-defined automobile' and accelerates the iteration speed of automobile products.

Through the application of ambient lights, welcome lights and intelligent devices, the European cockpit system makes the vehicle more entertaining. The convertible cockpit form integrates office, rest and entertainment, rendering the home-based design mainstream. The design of city and electrification is more prominent. Sharing + on-demand travel is more extensive. In future, the operation mode of intelligent cockpits will be mainly voice + gesture, supplemented by biometrics, eye tracking and holographic images, etc. Using an all-round perception system, it will deepen the response to human habits, emotions and conditions at different times to build different cockpits, making the design more humanised.

In terms of hardware, European models prefer mature and stable SoC, whereas American models pursue more powerful performance and greater hash rate. European and American models mainly apply the leading screen display technology to the cabin, but do not pursue screen size and quantity. Instead, they design the display and interaction forms of vehicle information, entertainment information and safety tips for drivers or cabin personnel according to the positioning of the vehicle.

In terms of software, the main operating systems for the intelligent cockpit at home and abroad are currently QNX, Linux and Android. Of these, QNX has the highest global market share, with strong security and high real-time performance. Linux is a stable system, open source and free, while Android has a strong ecology and rapid development. On the other hand, most European and American vehicle manufacturers adopt the business mode of a self-developed operating system. In terms of interaction, voice has become the core interaction mode for intelligent cockpit systems and has almost become the standard configuration for vehicles. At present, active visual interaction based on DMS and gesture recognition is gradually becoming the development direction for in-cockpit interaction in the next stage.

1.2.2.2 Japanese and Korean models

Japanese and Korean models pay more attention to traditional in-vehicle experience and meet people's travel experience in different scenarios through multi-scenario design. High-tech applications such as AR-HUD and facial recognition reflect a more humanised design. For example, new technology is applied to the seat, which can be automatically adjusted according to the size and weight of occupants, providing users with a more comfortable and convenient driving experience.

1.2.3 Development of domestic intelligent cockpit technology

1.2.3.1 Basic technology aspect

Chip – the brain of the vehicle, required to boost cooperation between different functions. During the stage of vigorous intelligent cockpit development, in particular, the complexity of calculation and processing increases exponentially and the traditional chip can no longer meet current demand. One is obliged to opt for a system-level SoC chip that integrates multiple modules, such as the central processing unit (CPU), AI processing unit, image processing unit (GPU) and neural network processing unit (NPU). As various OEMs are more and more inclined to adopt embedded hardware for the intelligent arms race, it is also one of the mainstream trends to adopt a single SoC chip with a higher hash rate or multiple SoC chips.

Cockpit domain controller – controls multiple systems by loading new virtual machines on the operating system. At present, with the continuous maturity of software and the application of new ARM architecture, software security is expected to be significantly improved and the cockpit domain controller will begin to penetrate rapidly. As an essential component of intelligent cockpit systems, the cockpit domain controller has gone through three stages (separated, divided and centralised domains) and its growth is highly certain. Although there are certain technical barriers, domestic suppliers have already emerged, including Desay SV, Norbo Technology, Pateo, Junsheng Electronics, Hangsheng Electronics and Yuanfeng Technology. Although most of the domestic participants entered the market relatively late, given that domestic vehicle manufacturers are speeding up the layout rhythm of intelligent cockpit systems and that domestic suppliers have obvious advantages in terms of cost and service terminals, the leading domestic cockpit domain controller manufacturers have strong competitive strength in independent and joint venture markets.

On-board operating system – this mainly involves two operating systems, i.e. the vehicle control operating system and cockpit operating system. The vehicle control operating system is mainly responsible for vehicle chassis control, power system and autonomous driving. The cockpit operating system provides a control platform for on-board infotainment services and human-machine interaction in the vehicle, which is the operating environment for the vehicle to realise intelligent cockpit and multi-source information fusion.

Cloud service platform – a platform that exists on the internet and can expand and provide basic services, middleware, data services and software services to other users. It runs through R&D, production, sales, management, service and other links of vehicle manufacturers, and can effectively help vehicle manufacturers to improve automobile products, user experience and service ecology. It is the core of and basic platform for digital transformation for vehicle manufacturers. The cloud platform can be divided into: IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and SaaS (Software as a Service).

1.2.3.2 Hardware terminal aspect

In recent years, the popularity of the intelligent cockpit in new automobile models has been accelerating. Various sensors, audio-visual interactive terminals, communication terminals and cockpit environment terminals included in the hardware have also been developed. The installation of a centre console screen, connected screen, intelligent communication, OTA upgrade, etc. is the most common choice for users and has gradually become an important criterion for judging whether the vehicle is equipped with an intelligent cockpit.

Sensor – one of the key links in the development of intelligent cockpit systems and even the intelligent automobile industry as a whole. The degree of automobile intelligence will be the key factor in determining automobile performance and function, and perception technology is one of the bases for intelligence. It can be said that the automobile is a platform for installing sensors, and sensors of various physical quantities, chemical quantities and biomass will be increasingly used in automobiles automobile intelligence develops. As the level of autonomous driving improves, the number of single-vehicle sensors increases exponentially. It is estimated that 10-20 sensors are needed for autonomous driving at Level 1-2, 20-30 sensors at Level 3 and 40-50 sensors at Level 4-5. In the future, multi-sensor fusion in automobiles will become the mainstream trend, improving perception accuracy and dimension, and at the same time enhancing environmental adaptability and further improving system decision-making reliability. Secondly, the combination of sensors and artificial intelligence technology will become ever closer, sensing people's emotions and behaviours and providing assistance with safe driving.

Screen, stereo – as the physical keys on mobile phones are replaced by ever larger LCD screens, commands can be completed smoothly through voice, gestures and other operations. The vehicle cockpit has also undergone the evolution from mechanical to intelligent. The early cockpit was mainly composed of mechanical dials and a simple entertainment system. As the cockpit entertainment system was constantly enriched, the intelligent cockpit was able to interact with the driver and passengers through various interactive terminals such as vision, hearing and touch instead of the original physical buttons. The display screen is the main terminal for visual interaction and the main medium for drivers and passengers to quickly obtain rich information. Large screen, HD display, multi-screen combination and curved display will be a long-term development trend.

From the newly launched models over the past two years, on-board large-screen and multi-screen displays have become a trend. High-end models equipped with more than four on-board displays are gradually introducing products such as co-driver entertainment screens, control screens, rear entertainment screens and streaming media rearview mirrors, and the demand for large-size screens is growing rapidly. As standards and regulations improve in the years ahead, the number of applications of on-board displays will continue to increase. Besides the screen, the main interactive cockpit terminal is also the stereo. At a time when users are paying more attention to the in-vehicle experience, all vehicle manufacturers are trying to redefine the in-vehicle stereo experience.

T-BOX – the key component of intelligent and connected vehicles, this serves mainly to realise the vehicle's internet connection and facilitate the information interaction between mobile phone, vehicle and the cloud. Not only can it execute vehicle control instructions sent by the owner to the cloud server, it also implements the functions of remote vehicle control, etc. It can also actively collect the necessary vehicle condition information and actively push information to the owner through the cloud server.

With the development of 5G technology and the cloud, the function of vehicle networking has become more and more abundant and has been gradually applied to the interconnection of smart homes. For example, users can turn on washing machines, A/C units and rice cookers from their vehicles. With the rollout and coverage of 5G base stations, the computing and storage capacity of cloud platforms and 5G transmission speeds provide a guarantee for the large data volume and low latency transmission requirements of intelligent cockpits. Mainstream cloud computing vendors have proposed hardware solutions for vehicle networking. Chip manufacturers, communication operators and other parties are actively promoting V2X-related (vehicle-to-everything) technologies, in order to achieve a smooth evolution of on-board 5G vehicle to-vehicle connectivity in the future.

With the development of intelligent cockpit systems, the cockpit environment is also an aspect that cannot be ignored. For this reason, many vehicle manufacturers have also put forward a number of epidemic prevention designs, including the anti-virus vehicle, clean cockpit, ultraviolet technology, health box, on-board Chinese medicine fragrance health care, and so on.

1.2.3.3 Functional aspect

With the rapid development of China's economy, the era of electronic information has gradually arrived and entered people's lives. Cockpit function has also changed: where once the focus was on making driving convenient, it is now a multi-functional place with electronic entertainment equipment. The interaction between human and mechanical keys has become the interactive experience between humans and intelligent AI systems. Compared with many mature markets, domestic users, who have long relied on mobile internet and smartphones, are paying more attention to the intelligent technology configuration of cockpit design, and the associated configuration is playing an increasingly important role in the vehicle purchase decisions of domestic consumers.

At present, the intelligent cockpit functions of vehicles in the domestic market are mainly concentrated in the fields of voice recognition, interior A/C, display, IoV application, enhanced perception, mobile phone connection, interior lighting, noise control and interior smell.

As the biometric technology which currently ranks highest for popularity and acceptance, voice recognition can realise many functions of voice control in different vehicle scenarios and improve driving safety. Cockpit areas that can currently be controlled using the cockpit voice control function include entertainment areas, A/C areas and vehicle body areas, as shown in Figure 1. At present, the share of vehicle models featuring voice control for entertainment is over 60%, for A/C with voice control over 30%, and for vehicle body (sunroof) with voice control less than 20%.

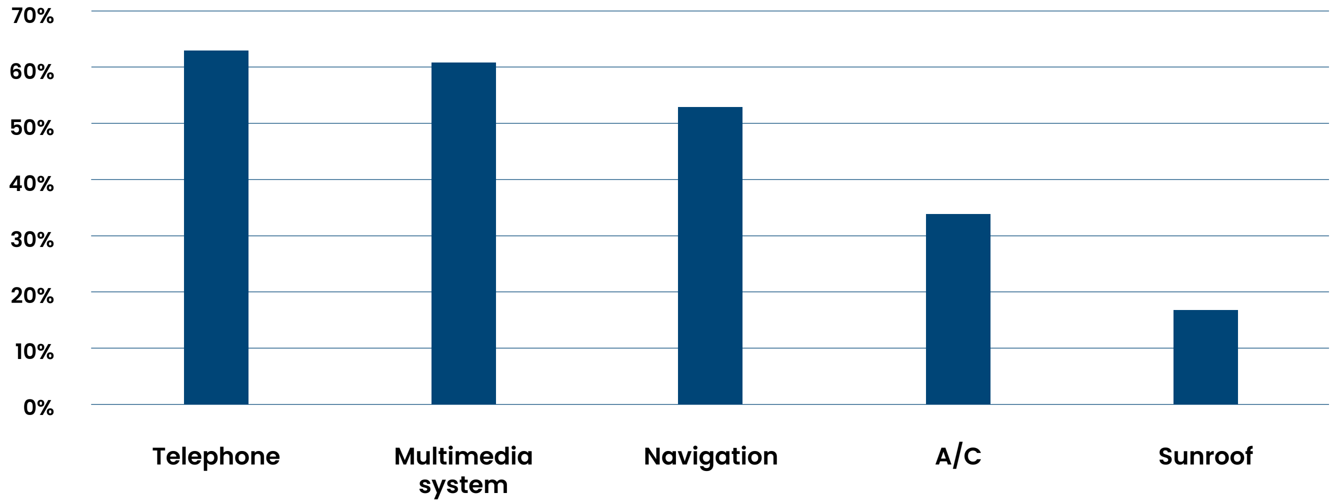


Figure 1 - Distribution of voice control function

As the basis and an important function of parking assistance, the current equipment rate of vehicles for parking images has already reached a high level: the equipment rate for reversing images has reached 97%, while that of 360-degree panoramic images is 63%.

It has become an important trend in cockpit product design to meet the personalised needs of occupants in different situations. The temperature control function for different seating positions, as the basic function and hardware guarantee of personalised automatic temperature control in the cockpit, has been quickly applied. At present, there are five temperature zones at most. The equipment rate for two-zone temperature control has exceeded 30%, and equipment rates for three-zone, four-zone and five-zone temperature control for rear seats have reached 8.23%, 0.25% and 0.09% respectively.

As an upgraded product of mechanical instruments, LCD instruments can be used as the carrier for enhanced information display. At the same time, as the size of LCD instruments increases, more functions can be applied. At present, 10-15 inch LCD instruments account for nearly 30% of the market, while LCD instruments of 5 inches or less and 5-10 inches account for 10.31% and 18.02% respectively. In addition, the development of instrument LCD screens also demonstrates the trend for multi-screen layouts, such as dual screens and triple screens, which can display different types of information in different zones.

As an important element of on-board entertainment systems, the number and size of centre console screens have a key influence on the infotainment experience in the intelligent cockpit. At present, the number of centre console screens has reached three at most, and the size of a single screen has reached nearly 20 inches at most. However, the form of centre console screen currently used is mainly single screen, with a size of less than 10 inches. As a function of realising the intelligent cockpit scenario and creating emotional atmosphere, the interior ambient light is gradually being applied. At present, the colour of ambient light has reached 256 shades at most, but nearly 80% of vehicles are not equipped with ambient light. This function still has room for enormous development in the future.

In-vehicle connection mapping for mobile phones and the convenience of using a mobile phone in the vehicle are important functions of the intelligent cockpit and also key indicators for meeting the needs of users. At present, there are four ways to achieve connection mapping for mobile phones: CarPlay, CarLife, Android Auto and original interconnection. Of these, the main approaches to connection mapping are original interconnection, CarLife and CarPlay.

Wireless mobile phone charging has achieved a high penetration rate in non-mobile application scenarios, but its application in vehicle application scenarios remains very limited, in particular for wireless mobile phone charging for rear seats, with an equipment rate of just 0.04%.

In the future, intelligent cockpit functions will see new developments, which will be embodied in driving situation awareness, real-time information transmission, driver control interaction, driving state fusion and driving state assistance, etc. The driving situation awareness function mainly provides help in two scenarios: early observation of the surrounding traffic conditions and accidents due to blind spots in vision. In addition to the sharp decline in visibility due to extreme weather and poor weather conditions, little is known as yet about external environmental detection and surrounding traffic conditions, and accidents may also occur as a result of poor road conditions. The real-time information transmission function can transmit real-time road conditions, which is of great help to holographic perception of the surrounding environment in bad weather and real-time state monitoring of automobiles. As for the interactive function of driver control, realising 'information transmission' is only the basic requirement for vehicle development on hardware facilities. The general trend for future cockpit upgrades is to achieve intelligent information transmission and ensure comfort while driving. As for the driving state fusion and driving state assistance functions and based on demand for intelligent driving, future intelligent cockpit upgrades for automobiles can learn to a certain extent from aerospace technology, such as the synthetic vision avionics hub (SVAB). This approach could provide drivers with better, more efficient, more convenient and safer driving plans, saving time on decision-making and hesitation, reducing the burden on drivers and perceiving the surrounding driving conditions in real time during driving. It would also develop the aspects of vehicle hardware facilities and experience.

1.2.4 Standardisation significance of intelligent cockpit systems

With the development of intelligent and connected vehicles, the intelligent cockpit will be popularised as the standard for automobiles and intelligent cockpit design may become the key factor in future automobile development and innovation. If we are to open up information resources in the intelligent cockpit industry, dismantle technical barriers, strengthen industry exchanges and promote the unified and coordinated development of resources, it is vital to study and formulate the intelligent cockpit standards system so as to guide the efficient development and standardised application of intelligent cockpit technology across the automobile industry.

Development of an intelligent cockpit standards system will help to promote industrial popularisation and technological innovation, and at the same time guide the healthy development and orderly operation of the industry as a whole. For consumers, the standardisation of intelligent cockpit systems not only provides a broader innovation space for the industry, it also further enhances the driving experience and personalised needs.

1.3 Trend development of intelligent cockpit human-machine interface interaction

The future development of intelligent human-machine interaction is one of the three elements of intelligent and connected vehicle development. This will be an important link in bringing about the connection between people and vehicles as well as people and ecology. The approach to human-machine interaction has changed from passive interaction, based on physical keys and voice interaction, to active interaction, based on biometric identification and camera identification, and will shift in future to personalised interaction based on data. The development of human-machine interaction will move from independent interaction to integrated multi-modal interaction, providing users with a better experience on the basis of ensuring driving safety. Specifically, the development trend of human-machine interaction (HMI) can be summarised from scenarios, humanisation and personalisation.

1.3.1.1 Interactive interface towards scenario design

This trend is to explore the complete value experience of the 'human-vehicle ecosystem', comprehensively analyse the experience needs of users in different usage scenarios, make breakthroughs and innovations in service and interactive experience, and really focus on users. However, current HMI function design has a large number of homogeneous functions which do not fully tap the actual travel scenario needs of users. In the future, HMI will bring about the development of scenario design in the following directions:

(1) Maximise the mining of user application scenarios

User application scenarios cover the whole life cycle of 'human-vehicle' interaction. We need to tap different potential scenarios for different users, such as the elderly and novice drivers, and tap demand value points in the process of vehicle purchase, use, socialisation and maintenance.

(2) Functional interoperability and technical application based on application scenarios

At present, many interior HMIs have various seemingly rich functional modules, such as entertainment, news, life services, etc. At the same time, many vehicle manufacturers can also successfully develop functional technologies such as fingerprint recognition, face recognition, autonomous driving technology, gesture interaction, etc. However, when these technologies and functions are put into actual user scenarios, they are sometimes worthless and not at all what users need. The functions provided by high-quality HMI will no longer be simply isolated and unrelated functional modules.

Future HMI design will be more based on the user scenario, establish the interaction between functions in the vehicle, provide reasonable function jump according to the user scenario and choose the appropriate technology and interaction mode to realise the complete scenario design based on scenario demand.

(3) Highly scenario-based information and task provision

With the development of technology, automobiles are featuring an increasing number of technology configurations and functions. As a result, the operation of too many functions and information feedback can easily lead to the phenomenon of 'excessive information', increasing the cognitive load on drivers. The information and task provision of HMI will be based to a great extent on user scenarios and driving data. For this reason, future HMI in automobiles will be designed to provide drivers as far as possible with limited and need-to-know information in line with different usage scenarios and driving conditions and in an intelligent and adaptable way. Moreover, based on driving data and road condition information available at the time, any road information (such as obstacles, pedestrians, etc.) that poses a threat to driving safety will be processed and actively provided to users in a more concise and convenient way, with reminders and selective guidance.

1.3.1.2 Interactive interface towards humanised design

A humanised HMI experience should minimise driver distraction, maximise the information utility of HMI input and output data, and at the same time use the most appropriate interactive mode to enable users to complete operational tasks efficiently, simply and happily. It mainly includes the following aspects:

(1) Minimise the visual interaction of users

The core of future HMI design is to minimise unnecessary visual content, weaken visual forms as far as possible and reduce the information load and interference to drivers during driving. Visual interaction in the vehicle environment must be considered from the perspective of users (drivers and passengers) rather than designers. The primary purpose of the visual experience is safety and efficiency, not innovation and novelty. It is necessary to ensure that drivers spend as little time interacting with visual information as possible and that users' eyes are focused on the road ahead.

(2) Multi-channel interactive coordination

The driver's eyes and ears provide the main channels of system interaction. However, single-channel interaction is currently a common problem in vehicle interaction. Multi-channel interaction is used to reduce the excessive burden of information processing through vision and hearing in the driving process and serves to balance information across all sensory organs. Future HMI control design will be based on the characteristics of the scenario task and will comprehensively consider the application and cooperation of different interactive channels. For the process of task manipulation, the trend of future multi-channel interaction design will be that one interactive channel will serve as the principal channel, and other interactive channels will serve as auxiliaries, such as voice + gestures or voice + buttons. For example, gesture control + a simple voice command combination can give full play to the interactive advantages of both, and smoothly complete discrete control tasks and continuous control tasks.

(3) Improve the visual design of HMI

Interior HMI design should in future be based on the user's cognition. For information such as vehicle status, enhanced visual design and graphic/pseudo-materialised style should be used to provide advice that is simpler, easy-to-understand and efficient. Efforts should be made to avoid or reduce the use of complex, excessively professional and technical icons and terms so as to avoid users staring at the screen for a long time, minimise thinking and understanding time and ensure that the user's eyes are focused on the road ahead.

(4) Integrate emotional design

For drivers, future HMI will be more de-mechanical and de-technical, and the relationship between human and HMI is no longer the cold relationship between human and machine. HMI will be integrated into more emotional design, reflecting human care and emotional interaction in the process of travel, increasing users' sense of trust, and giving users more driving pleasure and emotional experience.

1.3.1.3 Interactive interface towards personalised design

Based on the consideration of different people/vehicle brands/service scenarios, interior HMI needs to reflect more personalised and differentiated designs from functional services to interactive operations in the future. It mainly includes the following aspects:

(1) Differentiated design for different user groups

At present, there are vehicle models and hardware configuration designs for different user groups, but there is still a lack of differentiated design for different user groups from functional service to interactive operation of interior HMI. HMI design needs to subdivide the users, so as to locate the main groups to be covered and explore more varied user group characteristics, consumption concepts, regional differences, lifestyles, behaviour habits, etc., so as to provide diversified, personalised and differentiated products for vehicle users.

(2) Personalised operation mode

For family cars and increased shared travel scenarios in the future, interior HMI design needs to pay more attention to the application of 'personalised interactive control'. When different family members use a shared vehicle, they can remember and form their own interactive control modes and interfaces to meet the experience needs and driving habits of different family members.

For shared travel, the facial recognition camera installed in the vehicle can recognise the driver's facial features, judge whether to start the vehicle or not, and automatically select the driver's personalised driving mode and HMI interface and operate according to the user's own habits. This function will enable many more possibilities in light of sharing trips or time-sharing leases in the future.

(3) Reflect brand DNA through design

At present, interior HMI design in the industry tends to be homogeneous, lacking the differentiated design that can reflect the brand image. In the process of HMI design, we should try our best to leverage the characteristics of different brands, refine brand DNA, create brand story lines and run them through the whole HMI design, so as to achieve differentiated design and improve the brand recognition of HMI.

The ultimate goal of HMI design for automobiles is to better integrate information, provide travel services with good user experiences, and enhance users' driving pleasure or operating experience while driving. But compared with the user experience of the internet, the most different design of HMI is its unique environment, which pays more attention to driving safety. Therefore, no matter how HMI design develops and innovates in the future, a balance must be made between good user experience and safety, and to a large extent, safety always comes first.

2 Technical category of intelligent cockpit

2.1 Definition and technical connotation of intelligent cockpit

The core connotation of intelligent cockpit is the hardware terminal and technology realised by supporting functions. It has intelligent functions (non-intelligent driving functions) with human perception as the core, and it is an intelligent terminal with both soft and hard functions of 'self-learning, self-evolution and self-growth'.

The intelligent cockpit is equipped with sensors, controllers, display terminals, communication terminals, environmental terminals and other equipment, and uses basic technologies such as cloud services, network transmission, operating systems and chips to realise intelligent interaction between people and vehicles. It has the functions of information entertainment, human-machine interaction, safety reminders, network connection services, IoE, comfortable and intelligent experience, and creates a 'safe, comfortable, convenient and personalised' intelligent space.

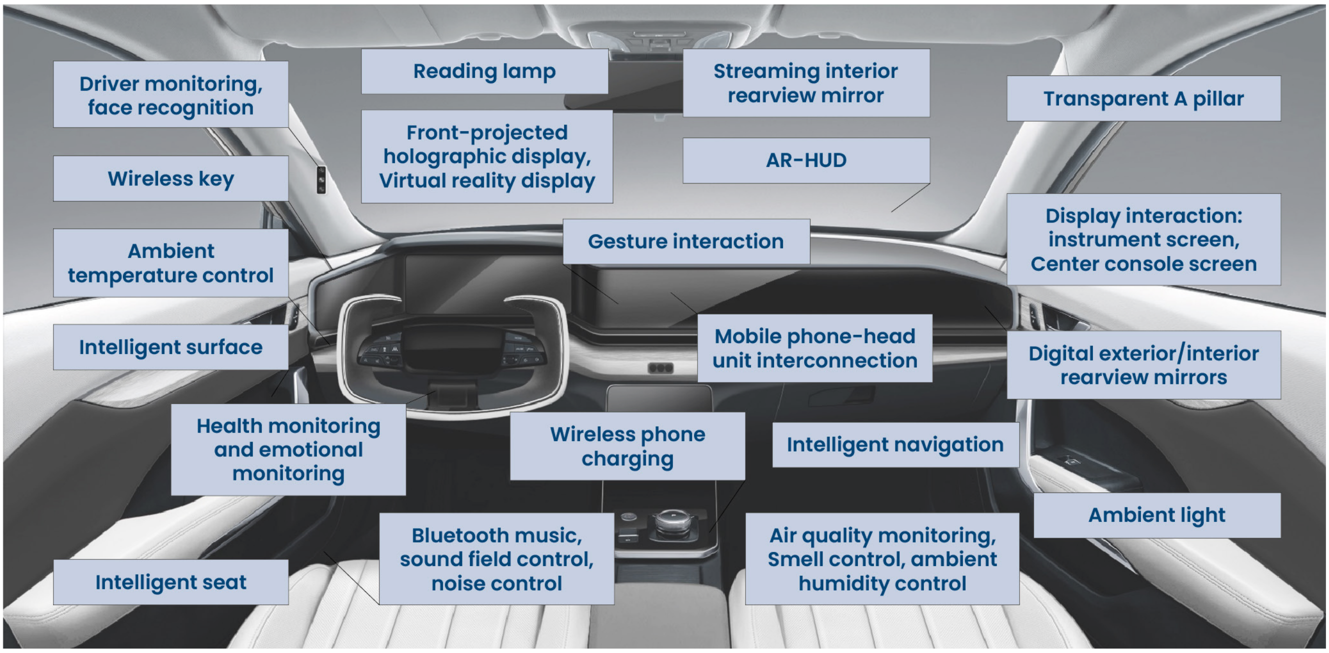


Figure 2 Technical diagram of an intelligent cockpit product

2.2 Term definition of intelligent cockpit

2.2.1 In-vehicle infotainment

In-vehicle infotainment (IVI) is an integrated information processing system formed by adopting an on-board central processing unit (CPU) based on the vehicle body bus system and internet services.

IVI includes, but is not limited to, vehicle information, vehicle settings, navigation, multimedia, games, online applications, leisure and entertainment.

2.2.2 Human-machine interaction

Human-machine interaction is an interactive way through vision, voice, hearing, touch, smell, etc., to enable the intelligent cockpit system to better understand the wishes of drivers and passengers.

Human-machine interaction includes single-modal interaction and multi-modal interaction:

1. single-modal interaction includes, but is not limited to, face recognition, gesture recognition, emotion recognition, eye tracking, voice recognition, odour conduction and touch control;

2. multi-modal interaction is a human-machine interaction mode that combines various single-modal interactions in scenario application.

2.2.3 Safety reminder

A safety reminder refers to the presentation of vehicle data, ADAS warnings and other information to drivers and passengers in the cockpit by means of sound, light, graphic information or vibration.

The presentation carrier for safety reminders includes, but is not limited to, dashboard, console, HUD, seat, steering wheel and seat belt.

2.2.4 Network connection services

Network connection services are application services presented in the cockpit system based on the cloud software platform and data analysis.

Network connection services include, but are not limited to, travel services, social life, personalised services, vehicle owner services and fleet services.

2.2.5 Internet of Everything (IoE)

IoE is the connection and protocol interaction between the cockpit and external terminals. It is used for driving infotainment, voice services, telephone, map positioning, digital key and other services from external terminals, including, but not limited to, the interconnection between cockpit and mobile phone, cockpit and wearable smart devices, and cockpit and smart home.

2.2.6 Intelligent light language

Intelligent light language refers to the interactive technology that takes external lighting (high/low beam lights, external signal lights, external ambient lights, etc.) and indoor lighting (ambient lights, indoor lights, etc.) as carriers, and can customise the display brightness, dynamic lighting effects, even projection patterns, video animation, etc., to implement safety reminders and atmosphere interaction between lights and drivers or other road users.

2.2.7 Intelligent surface

Intelligent surface is a product structure that adds electronic functions to automobile interiors (such as door armrests, steering wheels, etc.), so that interiors can realise a photoelectric display after touch, vibration feedback and other functions.

2.2.8 Intelligent seat

Intelligent seat is the function of adjusting the seat to a proper posture according to different scenarios. In addition to conventional adjustments to the level, height and backrest, the intelligent seat also supports the adjustment of rotation, leg rest, shoulders and flanks to achieve a comfortable sitting posture. At the same time, it supports the functions of heating, ventilation, massage, memory and welcome, etc. to meet the comfort of driver and passengers.

2.2.9 Smart shoot

Smart shoot refers to the taking of photographs, photo albums and other functions by means of face monitoring and AI processing through on-board cameras, buttons, gestures and other interactions, so as to provide personalised and entertaining services for cockpit occupants.

2.2.10 AR navigation

On-board AR navigation uses the camera (which can be integrated with ADAS recognition results) to capture the actual scenario of the road ahead in real time, and then integrates vehicle positioning, map navigation information and scenario AI recognition to generate a virtual navigation guidance model, which is superimposed on the real road, thus creating a navigation picture closer to the driver's actual vision. This greatly reduces difficulties for users in understanding the map.

2.2.11 Driver monitoring system (DMS)

DMS uses system perception ability to monitor and understand the driving state of human drivers, and makes timely multidimensional interventions on irregular driving behaviours in order to provide auxiliary functions conducive to driving safety.

2.2.12 Occupants monitoring system (OMS)

OMS is an extension of the driver monitoring system, which can further improve the safety performance of automobiles by monitoring the perception data of passengers in the cockpit.

2.2.13 Exterior monitoring system

The exterior monitoring system is based on the exterior camera, radar and vibration sensor. The system can effectively detect an external threat or out-of-loop state of the vehicle in park and leave mode, and trigger the functions of video storage, remote warning and vehicle notification, as well as other strategies.

2.2.14 Gesture interaction

Gesture interaction refers to the function that enables drivers and passengers to interact from a distance through gestures via cockpit sensors (cameras, infrared, etc.). It is another natural way of interaction that can increase interaction interest and express and convey emotions. Common gestures include, but are not limited to, single-finger sliding (up and down, left and right), double-finger sliding (left and right), double-finger tapping, etc.

2.2.15 Voice interaction

Voice interaction refers to the function that enables drivers and passengers to give instructions to the cockpit and communicate emotionally with the cockpit through natural voice via the pickup and playback equipment in the cockpit.

The main process of voice interaction includes listening, speaking and understanding.

2.2.16 Biometric identification

Biometric identification is a technology that combines the computer with high-tech means such as optics, acoustics, biosensors and biostatistics principles, and makes use of inherent physiological characteristics (such as fingerprints, facial features, irises, etc.) and behavioural characteristics (such as handwriting, voice, gait, etc.) of the human body to identify individuals.

At present, the cockpit is mainly equipped with voice recognition, facial recognition, fingerprint recognition, palmprint recognition, iris recognition, retina recognition and posture recognition.

2.2.17 Digital key

Digital key is a kind of virtual key which has no physical form. Through mobile phones or smart wearable devices, the driver only needs to approach the vehicle to apply the key function. Digital key mainly involves three technical routes: Bluetooth BLE with low power consumption, NFC and UWB.

2.2.18 Automobile remote fault diagnosis system

The automobile remote fault diagnosis system means that at vehicle start-up, the system receives any fault information and uploads the fault code to the data processing centre.

2.2.19 Emergency call (E-Call)

E-Call means that if a vehicle is involved in an accident, it will automatically/manually trigger an alarm to tell rescuers where the vehicle is located and the severity of the accident, so as to organise rescue as soon as possible.

2.2.20 Head-up display system (HUD)

HUD system projects images (virtual images) onto the windscreen through optical devices, so that drivers can obtain important driving information such as speed, navigation, fault alarm, etc. without looking down or turning their head.

2.2.21 Electronic interior/exterior rearview mirrors (CMS)

The electronic interior/exterior rearview mirrors (CMS) can obtain driving environment information for the rear and both sides of the vehicle via the cameras positioned in the vehicle body and display the real-time video inside the vehicle via the display screen. The viewing angle is adjustable and brightness is adaptive, so that driving safety is guaranteed and driving is worry-free on foggy and rainy days.

2.3 Classification of intelligent cockpit technology

Intelligent cockpit technology includes many functional applications and classification methods are diverse. Its principle is that intelligent cockpit technology covers all aspects and does not exceed its technical category. In order to make the classification of intelligent cockpit technology clear, definite, comprehensive and accurate, the following four classification methods are used:

1) Physical form

The function of the intelligent cockpit is realised based on a hardware terminal, and the classification principle of the hardware terminal is based on data acquisition, transmission and operation processing, and the scope of the hardware.
In this way, the intelligent cockpit is divided into sensor, controller, display terminal, communication terminal and environmental terminal.

2) Interaction ability

The function of the intelligent cockpit is to serve drivers and passengers, and place greater emphasis on human-machine interaction. The classification principle for human-machine interaction is based on people's perception and perception fusion.

In this way, the intelligent cockpit is divided into six categories: visual interaction, voice interaction, auditory interaction, tactile interaction, olfactory interaction and multimodal interaction.

3) Iterative upgrade

The intelligence of the intelligent cockpit lies in the artificial intelligence of 'self-learning, self-evolution, self-growth', which is realised by iterative upgrading. The principle of iterative upgrading is divided in line with the life cycle of cockpit products.
In this way, the intelligent cockpit can be divided into software upgrade (hardware embedded) and software and hardware upgrade.

4) Application space

The functions of different space areas of the intelligent cockpit vary, and the classification principle for applied space is divided according to the functional area and overall attribute.
In this way, the intelligent cockpit can be divided into driving domain cockpit, non-driving domain cockpit and 3rd space cockpit.

2.4 Technology and functional application of the intelligent cockpit

At present, the reconstruction of automotive electrical/electronic architecture (EEA) is promoting the shift from functional domain integration to an architecture based on spatial domain and central computing. At the same time, the Software Defined Vehicle (SDV) and Service-Oriented Architecture (SOA) have been rapidly developed and applied in the field of automotive software architecture.

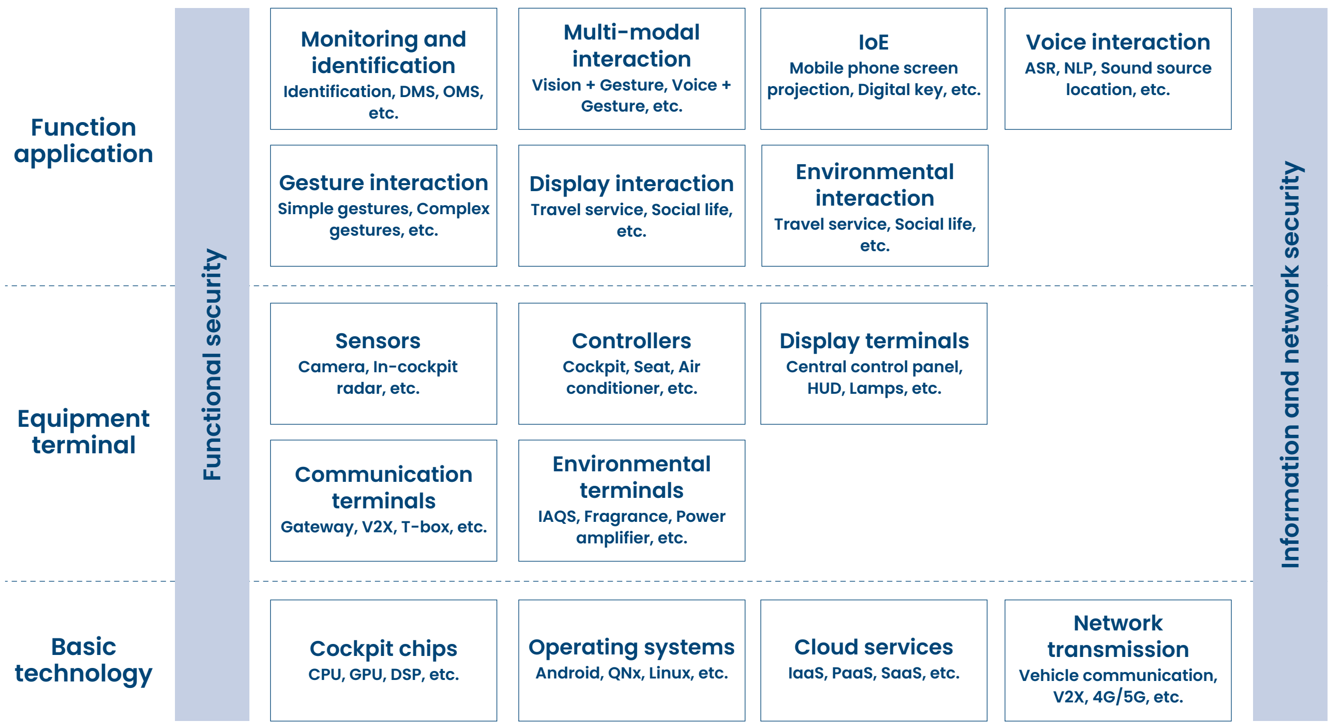


Figure 3 Reference architecture for the intelligent cockpit

Driven by the new technical background, the technical architecture for the intelligent cockpit has also undergone changes, which are mainly reflected in the following points:

1) Software-hardware separation

Against the background of SDV, based on SOA, software-hardware decoupling has become an inevitable trend. Cockpit software platform products are gradually evolving from fragmentation to a modular platform, and show the trend of layered design – OS, middleware, basic software platform, application software platform, application ecological services and other layered design layouts. Software technology companies have launched cockpit software platform products in succession.

The separation of software and hardware requires that the interface of each layer of the automotive software system architecture should be standardised, and that automotive software services should be flexibly and dynamically deployed. The standardisation, modularisation and reusability of the software platform can significantly shorten the software development cycle and simplify the development process. At the same time, application software and services can be customised according to different needs, providing users with differentiated functions and experiences.

2) Cross-domain fusion

Driven by the centralisation of EEA, high hash rate chips and the improvement of software development capability, the cockpit domain is constantly integrating new functions and the intelligent cockpit is evolving from single-domain to cross-domain integration, such as the integration of the cockpit domain and ADAS domain.

3) Vehicle-cloud integration

Compared with the traditional cockpit, the intelligent cockpit is no longer an information island, but a smart terminal integrating cloud services and IoE.

Due to the popularity of 5G and the increase in bandwidth, automobile manufacturers have found that the background processing system is placed in the cloud service space, and the functions of terminal display and information collection at the front desk of the automobile are given to the head unit, which can greatly simplify the difficulty of intelligent cockpit deployment, improve the level and efficiency of intelligent cockpit operation, and ultimately enhance the comfort and sense of technology of consumers when using automobiles.

A panoramic view of intelligent cockpit technology can be generated based on the following technical background for the intelligent cockpit:

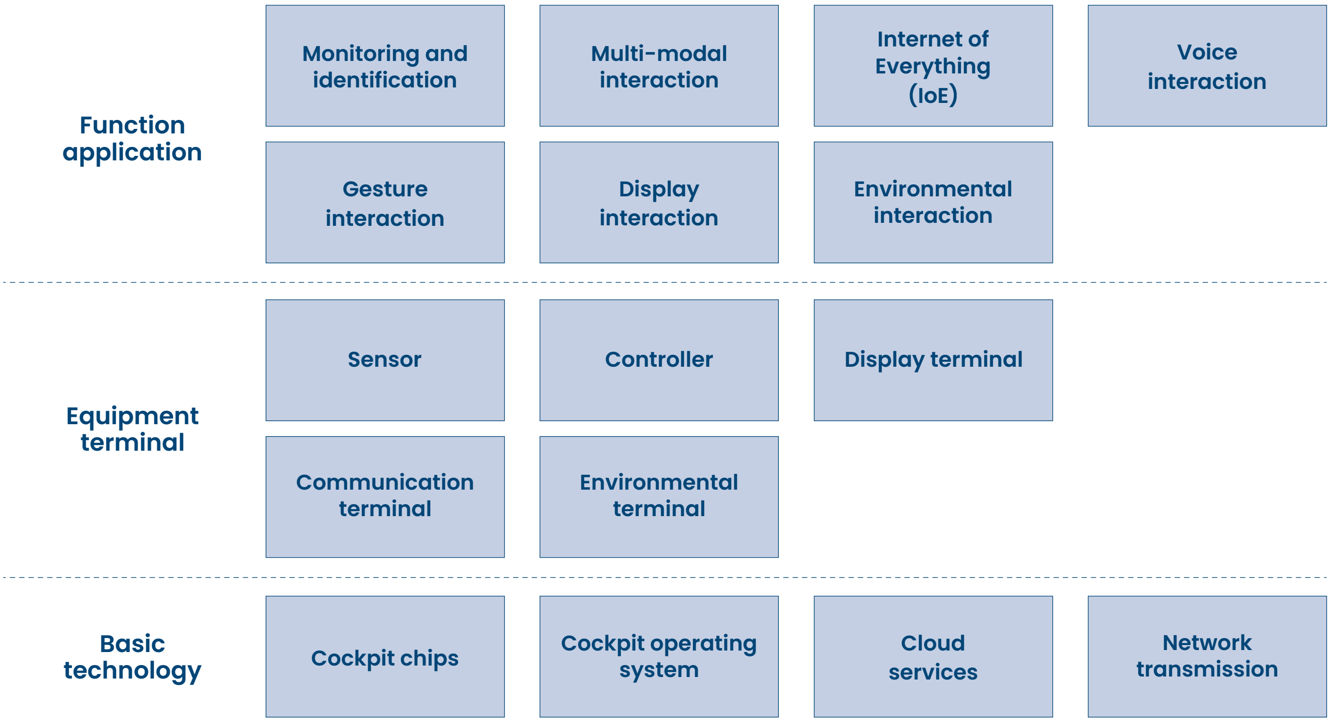
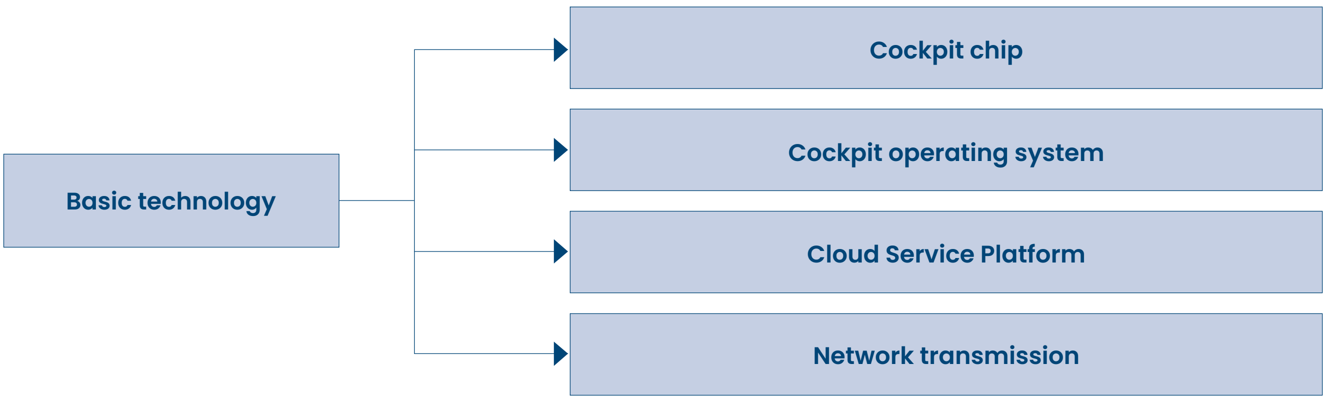


Figure 4 Panorama of intelligent cockpit technology

2.4.1 Basic technology



2.4.1.1 Cockpit chip

In order to achieve more advanced functions and a more centralised architecture, the core of the cockpit is the vehicle-level, high-performance, multi-core processing unit, such as SoC (System-on-Chip) composed of CPU (Central Processing Unit), GPU (Graphic Processing Unit), AI processing unit, DSP (Digital Signal Processing Unit) and ISP (Graphic Signal Processing Unit).

The information security and data security of the cockpit chip should also be considered. Running both secure and non-secure workloads (mixed criticality) on SoC is another core value of the current intelligent cockpit.

2.4.1.2 Operating system of the cockpit

The recommended national standard 'Intelligent and Connected Vehicle - Terms and Definitions' (draft for approval) clearly defines the on-board operating system as 'a collection of software that runs on the on-board chip, manages and controls the on-board software and hardware resources of intelligent and connected vehicles, and provides services for intelligent and connected vehicles except the realisation of driving automation functions, including on-board infotainment, networking, navigation, multimedia entertainment, voice, driving assistance, AI and other services.'

On-board operating system architecture can be classified from two dimensions: application of the on-board operating system and software architecture for the on-board operating system:

1. From the perspective of on-board operating system application, it can be divided into centre console operating system architecture, instrument operating system architecture and T-box operating system architecture.

2. From the perspective of software architecture for the vehicle operating system, it can be divided into single-system architecture and multi-system architecture. Both architectures can realise one-core multi-screen (multi-screen integration, multi-screen interaction), one-screen multi-system (virtual running environment, multi-application ecological integration) and one-core multi-function unit (infotainment, T-box, etc.) applications.

With the function of the vehicle gradually changing from a single safe-driving function to intelligence, entertainment and personalisation, the on-board operating system is gradually evolving from single system to multi-system architecture and single-core to multi-core technology to support different on-board applications, diversified basic services (including but not limited to interconnection services, driving assistance services and AI services), and provides a unified interface for hardware and applications that offer strong support for the packaging and modularisation of subsequent products.

2.4.1.3 Cloud services

Cloud service technology is the core support for automobile networking; networking functions for the intelligent cockpit mainly include interactive intelligence and service intelligence. Interaction intelligence is turning the intelligent cockpit into an 'assistant', which can help users solve some problems and relieve anxiety. When there is emotional resonance between the user and the 'assistant', the assistant will become a 'companion', with knowledge encyclopedia and empathetic memory, able to perceive the user's state and manage the user's health. At the same time, there should also be a living design of the interior space.

Service intelligence is mainly used for accommodation, food, social entertainment, etc. These are driven by scenarios, so it is necessary to identify the scenarios and provide services based on these.

Equipment cloud, data cloud and service cloud are the most basic forms and requirements of current vehicle networking. In order to realise V2X, build an all-round network connection between vehicles, vehicles and roads, vehicles and people, vehicles and things, improve the overall intelligent driving level of vehicles, provide users with safe, comfortable, intelligent and efficient driving experience and traffic services, and improve traffic operation efficiency and the intelligent level of social traffic services, it will be essential to have high-performance and highly scalable cloud platforms as foundation to support.

The IoV cloud platform is generally divided into IaaS, PaaS and SaaS. The IaaS layer is generally provided by various cloud server vendors and is responsible for infrastructure construction, including cloud hosting, cloud storage, cloud network and basic security services. The PaaS layer provides support for rapid iterative deployment and continuous integration. The PaaS platform with flexible design needs to support the automatic restart of the system, rapid and automatic expansion of the system, isolated access of multi-tenants, dynamic scheduling of resources, quick online preview of applications, automatic testing and building of codes, etc. At the same time, the PaaS platform also needs to provide basic services such as object storage, message queuing, load balancing, log statistical analysis, unified account management, search engine, system security management, etc. for the SaaS layer. According to different services, the SaaS layer can be divided into equipment connection and control platform, user management platform, big data platform, map and traffic information platform, voice platform, AI platform, SaaS service management platform, IoT aggregation platform, OTA upgrade management platform, CPSP data exchange and service integration platform, payment and financial management platform, vehicle intelligent service platform, vehicle enterprise digital empowerment platform, operation service platform, operation and maintenance management platform, etc.

PaaS platform

1. Function introduction

Before the emergence of Platform as a Service (PaaS), company IT needed to separately purchase, deploy, maintain and upgrade operating systems and some strongly dependent middleware products or tools. The complexity of these products was challenged with the continuous expansion of business, which was a painful burden for company IT maintenance. At this time, PaaS came into being. The PaaS platform managed this middleware in a centralised way, provided a standardised API suite to the outside world, and promised a production-level SLA guarantee. The PaaS platform allows developers to realise commercial value only by paying attention to the code of the business itself, rather than the underlying hardware, middleware licensing/deployment/maintenance, application running environment and other development tools. Developers need only to submit the business code, and the PaaS platform can completely manage the whole life cycle of applications: building, testing, deployment, management, updates, etc.

2. Technical requirements

(1) Containerised deployment of all applications

(2) Support the separation of cold and hot services

(3) Free selection of micro-service registration discovery components

(4) Continuous integration and delivery of the whole platform

(5) Intelligent monitoring and alarm platform

(6) Perfect platform security protection strategy

(7) Link tracking with service

(8) Ability of dynamic scheduling of resources

(9) Set the service fuse strategy according to the performance indicators, such as business response results and delays, and ensure the availability of the whole system

(10) Traffic can be distributed nearby according to the fault domain, which not only ensures service availability, but also reduces the call delay between services

(11) Observable grey-scale publishing system can help the business go online quickly, can check faults in the new version in advance and reduce the scope of influence

IOV connection and control platform

1. Function introduction

Responsible for access management and communication management of various parts of the vehicle.

2. Technical requirements

(1) Support multi-device access capability

(2) Support multi-protocol adaptation, including access and extension of GB32960, JT808 and private protocols.

(3) Support the adaptability of multiple message channels (TCP, HTTPS, MQTT, etc.)

(4) Unified query abstraction on data storage, so that developers no longer need to care about the storage mode and extraction logic of the underlying data, but only about the program itself.

(5) Manage all database metadata in a unified way, realise unified data management, establish an enterprise-level data dictionary, unify data caliber, eliminate redundancy, reduce communication cost, and achieve the goal of cost reduction and efficiency increase.

(6) It has the ability for visual query, visual monitoring, visual ETL and metadata integration.

Big data platform

1. Function introduction

A big data platform mainly provides stable data support, data exploration and data storage services both inside and outside the company. At the same time, it is the main tool to provide data insight, analysis and empowerment for all company departments. It is necessary to lower the basic threshold for business personnel to obtain and operate data and liberate data R&D personnel who have been working repeatedly, so as to achieve the goals of cost reduction and efficiency increase, data insight for all staff and data empowerment.

2. Technical requirements

(1) It has the ability to customise event tracking, set user paths, and A/B conversion analysis.

(2) It is necessary to adopt the technical framework for the integration of storage and calculation and separation of storage and calculation, so as to logically distinguish between hot and cold data.

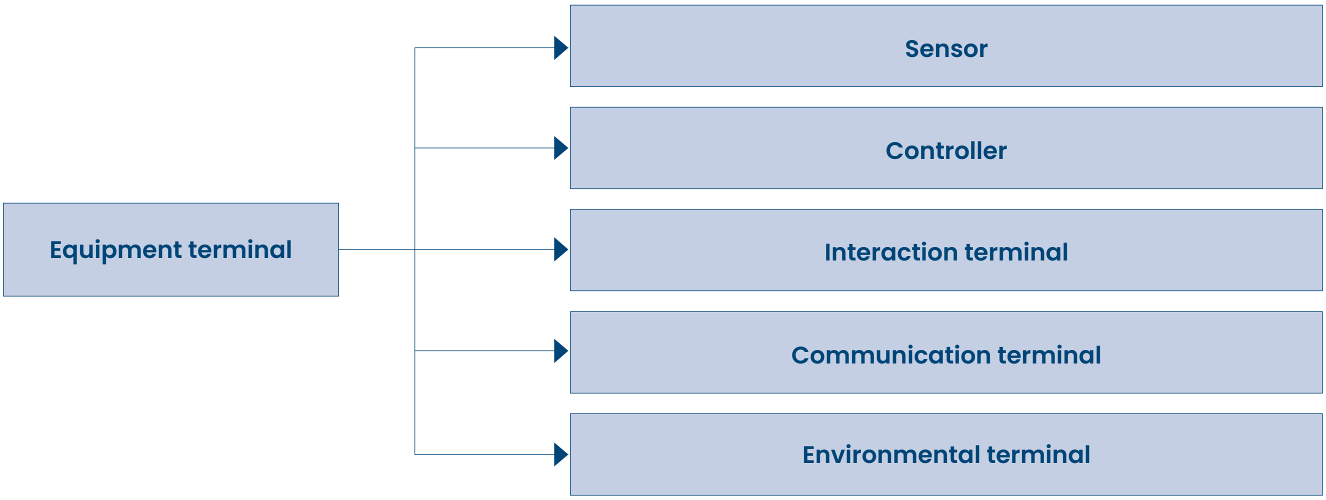
(3) It is necessary to achieve the Lakehouse storage form.

2.4.1.4 Network transmission

There are two kinds of network transmission technologies used in the intelligent cockpit: one is wired and wireless, the other is local and wide area.

Network transmission technologies mainly include in-vehicle bus communication (Ethernet/CAN/LIN), in-vehicle local area communication (Bluetooth/Wi-Fi/UWB/NFC/USB), short-range communication (LTE-V/DSRC), wide area communication (5G), communication framework and protocols.

2.4.2 Equipment terminal



2.4.2.1 Sensors

Sensors are equivalent to the 'five senses' for vehicles. They are used to sense and judge the surrounding environment and provide an important data source for vehicle intelligence. At present, AI technology has been widely used in cockpit sensors, which can sense people's emotions and behaviours and provide help for safe driving. It can process real-time data from cameras, microphones, biosensors and even radar, and then help vehicles make decisions.

Besides sensing people, the sensor can also sense external devices (such as wireless chargers).

With the improvement of chip hash rate and AI precision requirements, the intelligent cockpit demands ever higher performance indicators from sensors, and sensors are developing towards high performance, high precision and large data volume.

Vehicle camera

1. Function introduction

Generally, the vehicle camera consists of lens, image sensor, image signal processor (ISP) and serialiser. Generally, basic information about the object is collected by the lens, then processed by image sensor, then handed over to ISP for processing before being serialised and transmitted.

The vehicle camera is an important sensor for the intelligent cockpit and autonomous driving. Different from a mobile phone camera, the module process of the vehicle camera is complex, mainly because the vehicle camera needs to keep a stable working state for a long time under various complex working conditions such as high and low temperature, heat and humidity, strong light and vibration. Overall, the technical barriers of vehicle cameras are significantly higher than those of mobile phones. The application fields of a vehicle camera in the intelligent cockpit include DMS, OMS, CMS, reversing assistance, etc.

2. Technical architecture

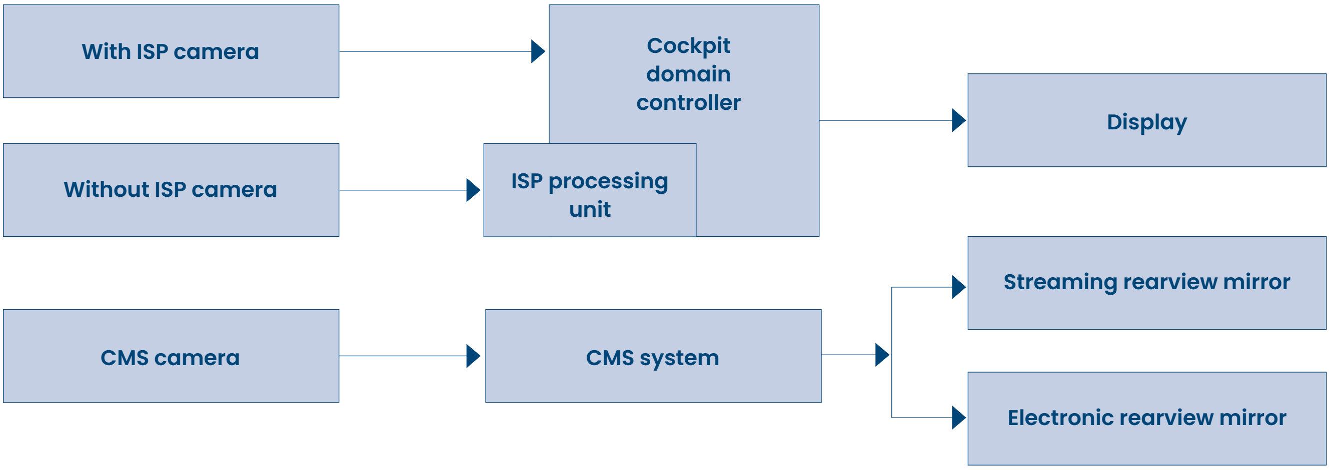


Figure 5 Reference architecture for a cockpit camera system

Below are descriptions of the reference architecture:

(1) Cameras can be distinguished between those with/without ISP. Cameras without ISP are required to be processed by the ISP processing unit before being sent to the cockpit domain controller.

(2) ISP processing unit can be in-built or external to the cockpit controller.

(3) In view of the requirement of real-time display, the CMS system needs a separate system for processing.

(4) The camera transmission mode can be divided into LVDS-based transmission on coaxial cable or twisted pair or direct transmission through ethernet.

3. Pain spot analysis

The development of vehicle cameras is relatively mature, but with the improvement of chip computing power and development requirements of the intelligent cockpit and autonomous driving, vehicle cameras are also facing increased challenges and developments. Compared with traditional industrial cameras and mobile phone cameras, the working environment of vehicle cameras is more stringent, requiring cameras to work in high and low temperature, strong and low light, heat and humidity, extreme weather and other environments. In addition, pixel upgrading and high dynamic requirements are also key concerns.

4. Standardisation prospect

Relevant standards for vehicle cameras already exist: QC/T 1128-2019 Automotive Camera.

In-cockpit radar

1. Function introduction

In-cockpit radar usually uses millimetre-wave radar to monitor the vital signs of drivers and passengers. In application, it can also cooperate with the vehicle camera to monitor facial features and vital signs to ensure the driver's attention.

Millimetre-wave radar detects vital signs using DoA spectrum estimation to generate the distance-angle heat map of the motion signal in order to comprehensively analyse whether there is a living organism in the cabin and quickly lock the position of that living organism. It can eliminate interfering clutter by window filtering and get vital signs information such as respiration and heartbeat of the target in each occupied partition by spectrum analysis, so as to accurately judge whether the living body exists or not. Then, using multi-channel virtual aperture technology, the angular resolution of space exploration is greatly improved, so as to capture occupant information and quickly lock the living body position.

In practice, once the door is locked, millimetre-wave radar can quickly detect whether there is a vital sign signal in the cockpit. Once a vital sign signal is found, it can quickly send an alarm via mobile phone (vehicle management platform or the vehicle itself) and other ways to avoid accidental injuries.

2. Technical architecture

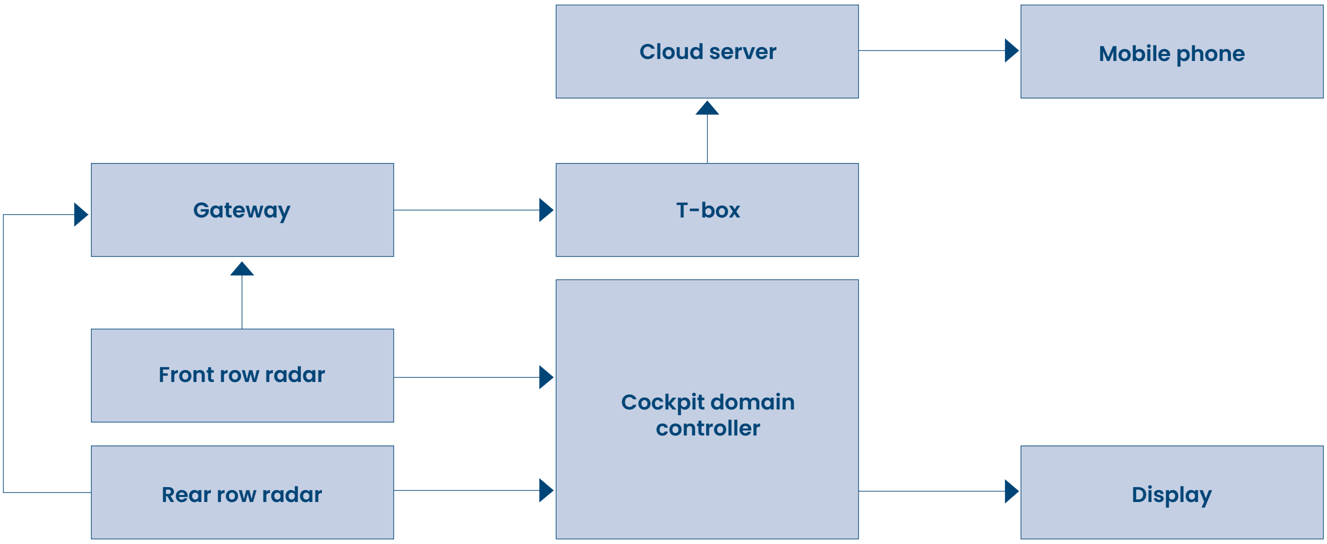


Figure 6 Reference architecture for an in-cockpit radar system

Below are descriptions for the reference architecture:

(1) In-cockpit radars can be divided into front row radar and rear row radar.

(2) The radar vital signs data can be sent to the cockpit domain controller and displayed to drivers and passengers via the display.

(3) When the vehicle enters the low power consumption state, the radar vital signs data can also be transmitted to the cloud server through the gateway T-box and displayed to the user via mobile phone.

(4) The in-cockpit radar usually outputs the target data and the bandwidth requirement is not high. The output interfaces can be CAN, LIN, ethernet, etc.

3. Pain spot analysis

At present, the in-cockpit radar is not popular and there are some problems, including the fact that it cannot be used when driving. Moreover, monitoring accuracy is also an industry challenge, since it is prone to false positives and false negatives. It can be integrated with a camera, health bracelet, intelligent steering wheel, etc. to provide complementary and more accurate vital sign data.

4. Standardisation prospect

In-cockpit radar can realise in-cockpit health monitoring – the healthy cockpit is an important branch of intelligent cockpit systems. Monitoring the status of drivers and passengers by multi-sensor means is the key direction of cockpit safety.

The in-cockpit radar can be standardised for installation position, angle, precision and other indicators, forming a standard with industry guidance significance.
Below are the key cockpit sensor parameters:

Camera

Location	Type	Main indicator parameters
DMS camera	Ordinary camera	Frame rate
OMS camera	Infrared camera	Effective pixels
Gesture camera	Wide-angle camera	Field of view
Face camera		MTF value
Live camera		SNR
CMS electronic rearview camera		Dynamic range
		Maximum illuminance
		Minimum illuminance
		Optical axis centre accuracy
		Automatic gain
		White balance
		Start-up time
		System delay
		Colour rendition
		Dazzle
		Ghostimage

In-cockpit radar

Location	Type	Main indicator parameters
Front row radar	Millimetre-wave radar	Frequency
Rear row radar		Frequency modulation mode
		Detection distance
		Horizontal FOV
		Vertical FOV
		Horizontal resolution
		Vertical resolution
		Size
		Weight
		Degree of protection

2.4.2.2 Controller

The controller is the 'host' of the intelligent cockpit, which is responsible for the logical control of the whole intelligent cockpit. It integrates the arithmetic unit, input interface and output interface, and different controllers are responsible for the logical control of different functional domains.

The controllers include, but are not limited to, cockpit controller, door controller, seat controller and A/C controller.

Cockpit domain controller

1. Function introduction

The cockpit domain controller mainly includes the entertainment information system, in-cockpit monitoring system, dashboard, AR HUD and other functions.

In design, it usually includes two chips: SoC and MCU.

MCU is mainly responsible for power management, realising functional security, connecting with the whole vehicle network and exchanging data with SoC. With the development trend of SOA, the whole vehicle network can directly connect with SoC without MCU.

SoC usually uses Hypervisor to run QNX and Android. QNX is used to deal with quick start-up or real-time functions, such as meters, DMS, OMS, AR HUD, etc. Android is used to realise most human-machine interaction functions, connect with cloud servers and support navigation, voice, online applications, etc. With the development trend of SOA, the functions of the cockpit domain controller can also be dynamically deployed, such as those with a higher security level, or moved to the ADAS domain controller.

2. Technical architecture

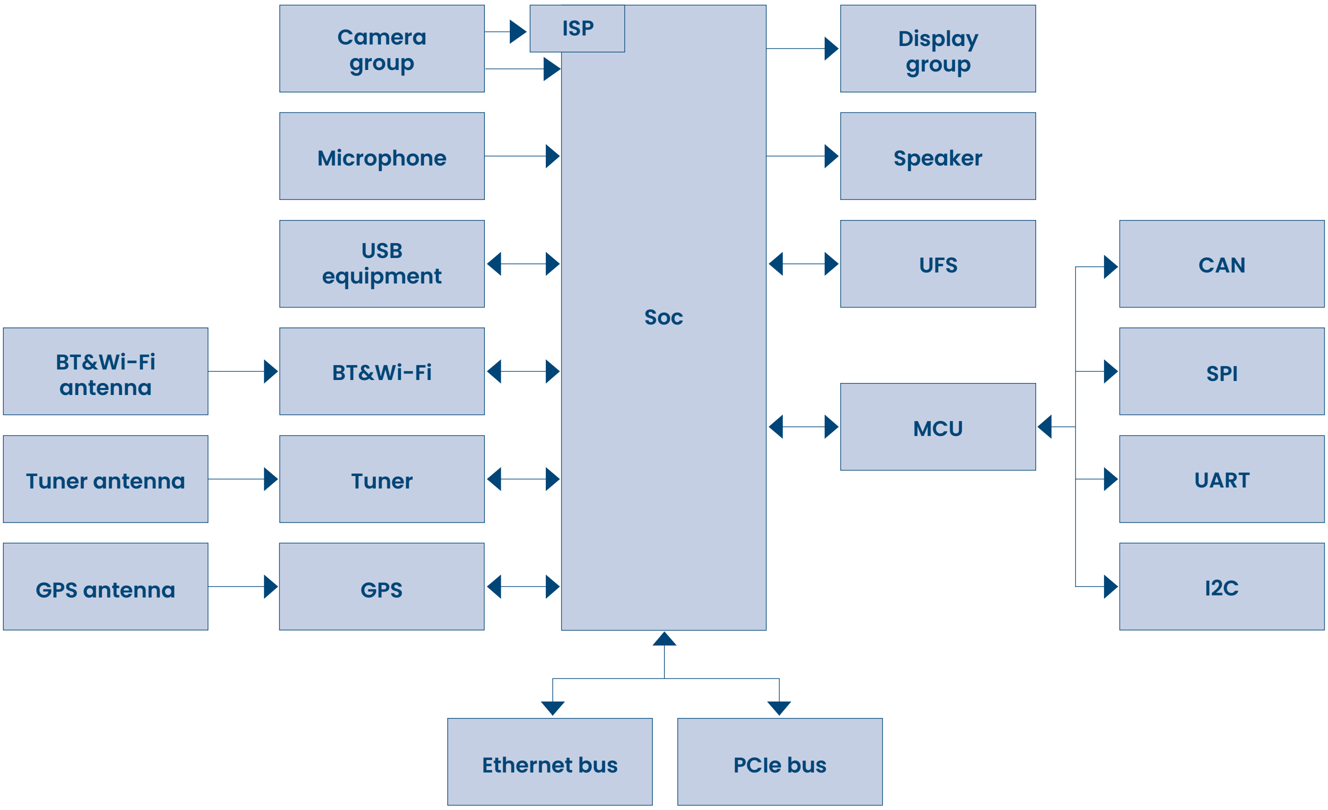


Figure 7 Reference architecture for the cockpit domain controller system

Below are the descriptions for the reference architecture:

(1) The cockpit domain controller mainly includes SoC, MCU, peripheral IC and interface design.

(2) The external interfaces of MCU mainly include CAN, SPI, UART and I2C.

(3) SoC can communicate with MCU via SPI.

(4) SoC is connected with the Ethernet bus and PCIe bus. The Ethernet bus is mainly responsible for SOA communication, and related protocols, such as SomeIP and DDS, while the PCIe bus is mainly responsible for data stream transmission, such as video data streams.

3. Pain spot analysis

(1) The electrical interface of the hardware is not standardised

Generally, the cockpit domain controller has external interfaces such as video input and output, audio input and output, CAN/LIN, Ethernet, USB, control interface, antenna interface, power supply, etc.

At present, the cockpit domain controller does not standardise the electrical interface in the industry, which leads to excessive dependency of hardware on peripheral devices and poor modifiability. In the early stage of development, component selection requires a lot of time, including concerns about problems such as lack of chips and disruption to supply. This often leads to hardware redesign due to the lack of materials.

In terms of standardisation, we can integrate and standardise the interface definition, connector model and so on.

(2) The functional interfaces are not standardised

The cockpit domain controller needs to be standardised on the interfaces of some functional modules, such as 4G/5G, Wi-Fi, Bluetooth, positioning, core board, etc.

4. Standardisation prospect

Unifying the hardware and functional interfaces has the following advantages:

(1) Cost saving: the interfaces of different OEMs and Tier1 are unified, and the hardware is no longer changed due to the changes of interface definitions and connectors, which reduces the cost of hardware changes.

(2) Time saving: less time required for discussion, design change and test verification as a result of interface change.

(3) Resource reuse: equipment from different manufacturers and platforms can be used universally, which is convenient for replacement and resource reuse.

(4) Hardware upgrade: for vehicle owners, the hardware can be upgraded many times during the life cycle of the vehicle, which can enhance the fun of vehicle use and meet increasing demand from vehicle owners.

Body control module

1. Function introduction

Body control module (BCM), also known as the body computer, refers to the electronic control unit (ECU) used to control the body electrical system in automobile engineering, and is one of the key components in automobiles.

Common functions of the BCM include controlling power windows, power rearview mirrors, A/C, headlights, turn signals, anti-theft locking system, central lock, defrosting devices, etc. The BCM can be connected with other on-board ECUs through the bus.

2. Technical architecture

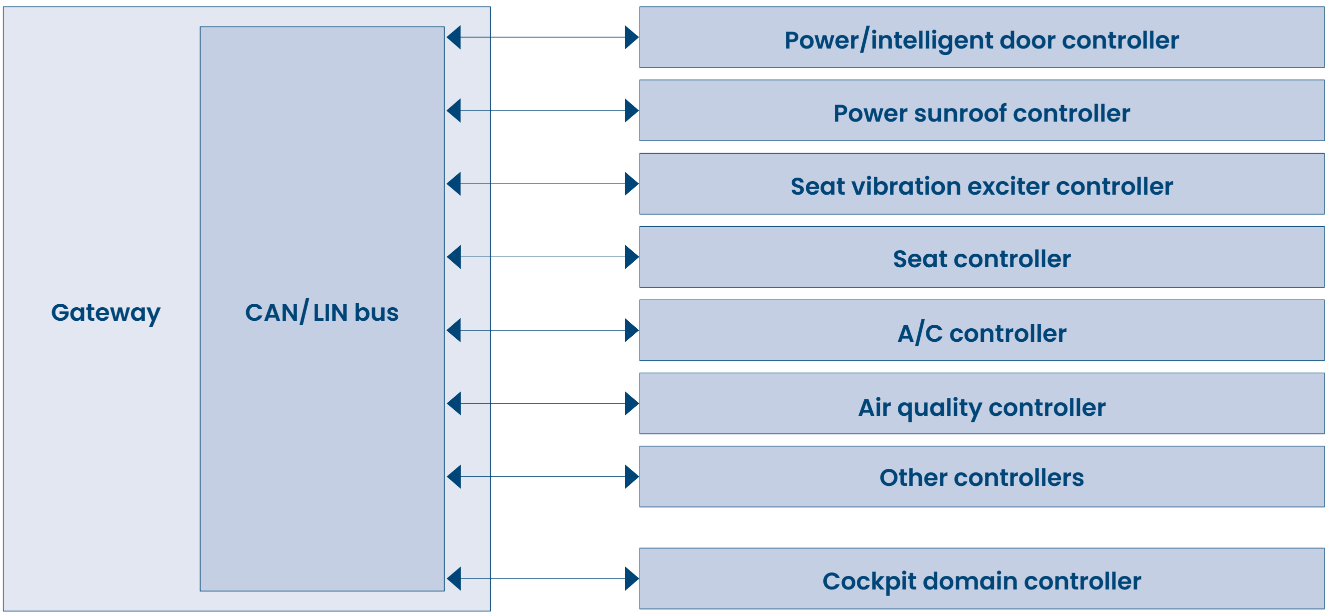


Figure 8 Reference architecture for distributed body control system

Below are the descriptions for the reference architecture:

(1) Each controller is connected to the gateway through CAN/LIN bus.

(2) The cockpit domain controller communicates with each controller through CAN/LIN bus.

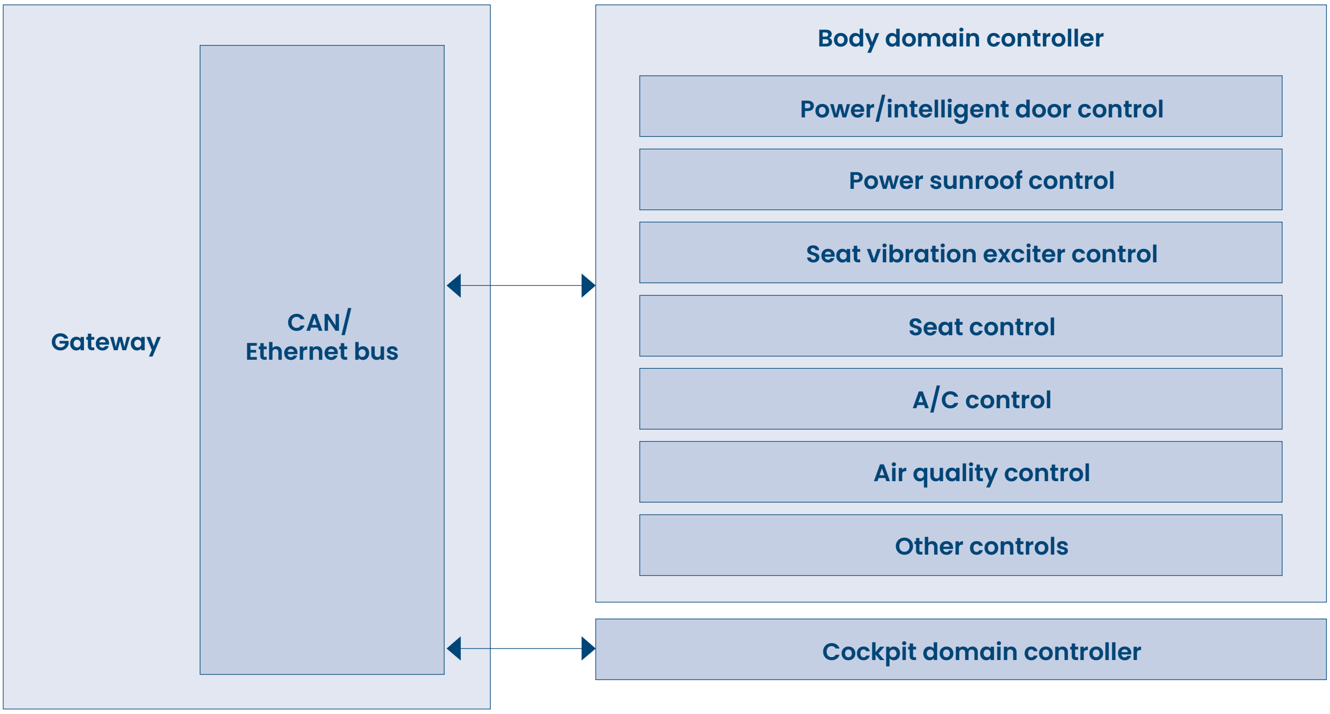


Figure 9 Reference architecture for the centralised body control system

Below are the descriptions of the reference architecture:

(1) Different from distributed type, the body domain controller integrates the body control function.

(2) The body domain controller and cockpit domain controller are connected to the gateway through the CAN/Ethernet bus for communication.

(3) Gateways are always integrated into the body domain controller.

3. Pain spot analysis

Traditional automobile electronic and electrical architecture adopts distributed architecture, and each ECU is connected by CAN and LIN buses. With the development of automobile technology, the total number of automobile ECUs is increasing, which leads to a complex wiring harness and rising cost, and it is difficult to meet the development of automobile intelligence and networking.

The body domain controller can solve the distributed problem. Each OEM integrates many ECU with similar functions into the body domain controller. At the same time, the body domain controller often integrates the gateway function and communicates with the outside world through the bus.

4. **Standardisation prospect**

From distributed to centralised, the electronic and electrical architecture for automobiles is developing towards central computing. The body control system needs standardised definitions from functional architecture, safety architecture, communication interface and communication protocol.

The following are the key controller parameters of the cockpit:

Type	Main external interfaces	Main indicator parameters
Cockpit domain controller	CAN/CAN FD	Hash rate
Power/intelligent door controller	LIN	Storage
Seat vibration exciter controller	FlexRay	Startup time
Seat controller	Ethernet	Response time
A/C controller	PCIe	Voltage range
Air quality controller	UART	Current range
	GPIO	Temperature range
	USB/SD	Static current
	LVDS	Heat dissipation capability
	JTAG	

2.4.2.3 Display terminal

The display terminal is the interactive visual window of the intelligent cockpit, which is responsible for the interactive input and output control of human-machine display for the entire intelligent cockpit. With the improvement of users' requirements for interactive experience quality, display terminals tend to be extreme, exquisite and efficient in terms of the senses. The display terminal includes, but is not limited to, display screens and lamps.

Display screen

1. **Function introduction**

In terms of display, it involves technologies such as multi-screen and multi-screen linkage of one head unit.

(1) One head unit with multiple screens

One head unit supports multiple displays, with low cost and short delay, which can better support complex electronic cockpit functions such as multi-screen linkage.

(2) Multi-screen linkage

Multi-screens are interrelated, manipulated and shared with each other.

2. Technical architecture

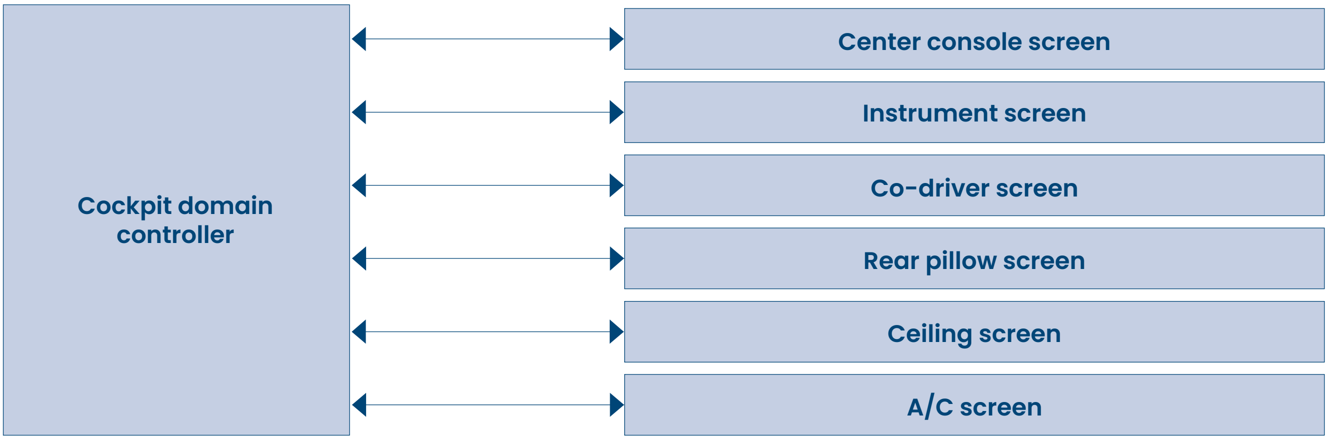


Figure 10 Reference architecture for the on-board display system

Below are the descriptions for the reference architecture:

(1) The on-board display screen is usually connected to the cockpit domain controller to present the human-machine interface to drivers and passengers.

(2) The on-board display usually supports GMSL and FPD-Link transmission interfaces.

3. Pain spot analysis

Traditional automobile display screens are mostly small in size, low in resolution, weak in interactivity and embedded. With the opening of the era of automotive electrification, all-LCD instruments and large centre console screen have gradually entered into mass production vehicles, which indicates that the automotive industry has truly entered the era of all-LCD. Within a short period of time, major automobile brands have focused on the application innovation of display screens, which lead to the mass production of product forms such as large screens, double or triple screen combinations.

Although the big screen improves human-machine interaction, there are some problems such as operating difficulty and influence on driving. Therefore, with the popularisation of large screens, the corresponding human-machine interaction design also needs to be more humanised and more in line with safe driving.

4. Standardisation prospect

The intelligent cockpit will develop towards large screen and multi-screen in the future.

(1) Large screen

The display area size of the centre console screen, co-driver screen and rear seat screen is over 15", and the resolution has reached SD, 2K or even 4K.

(2) Multi-screen

The number of display screens has increased, including an instrument display screen, centre console display screen, co-driver display screen, rear seat display screen, electronic rearview mirror display screen, intelligent surface display etc.

At present, flexible screens are also being introduced into the intelligent cockpit. Generally, OLED technology is used for the display, having the advantages of low power consumption, high brightness, high contrast and wide viewing angle. Because of their flexibility, flexible screens can be applied to curved, foldable and retractable displays.

The standards for on-board display screens are: GBT 22630-2008 Audio video-apparatus on-board electromagnetic compatibility requirement and methods of measurement; IEC/EN 62471 Photobiological safety of lamps and lamp systems; SJT 11272-2002 General specification for vehicle color monitor, etc. The main test items can be divided into two categories: light and colour performance test, safety and reliability test.

HUD

1. Function introduction

At present, the main products of HUD are divided into three types: C-HUD (combined type), W-HUD (windscreen type) and AR HUD (augmented reality type).

(1) C-HUD

Due to the shortcomings of the poor display effect and small display area, this has gradually been withdrawn from the market.

(2) W-HUD

With direct projection onto the front windscreen, this is the market mainstream.

(3) AR HUD

Based on AR technology, prompt driving-related information is projected onto the front windscreen and merged with the real picture, which makes picture presentation more realistic and humanised. This is gradually being introduced onto the market.

Of the three products, AR HUD has a higher technical content and is also the future trend. AR HUD includes AR Creator, optical machine, electronic display and other elements involving optical projection technology and AR technology.

2. Technical architecture

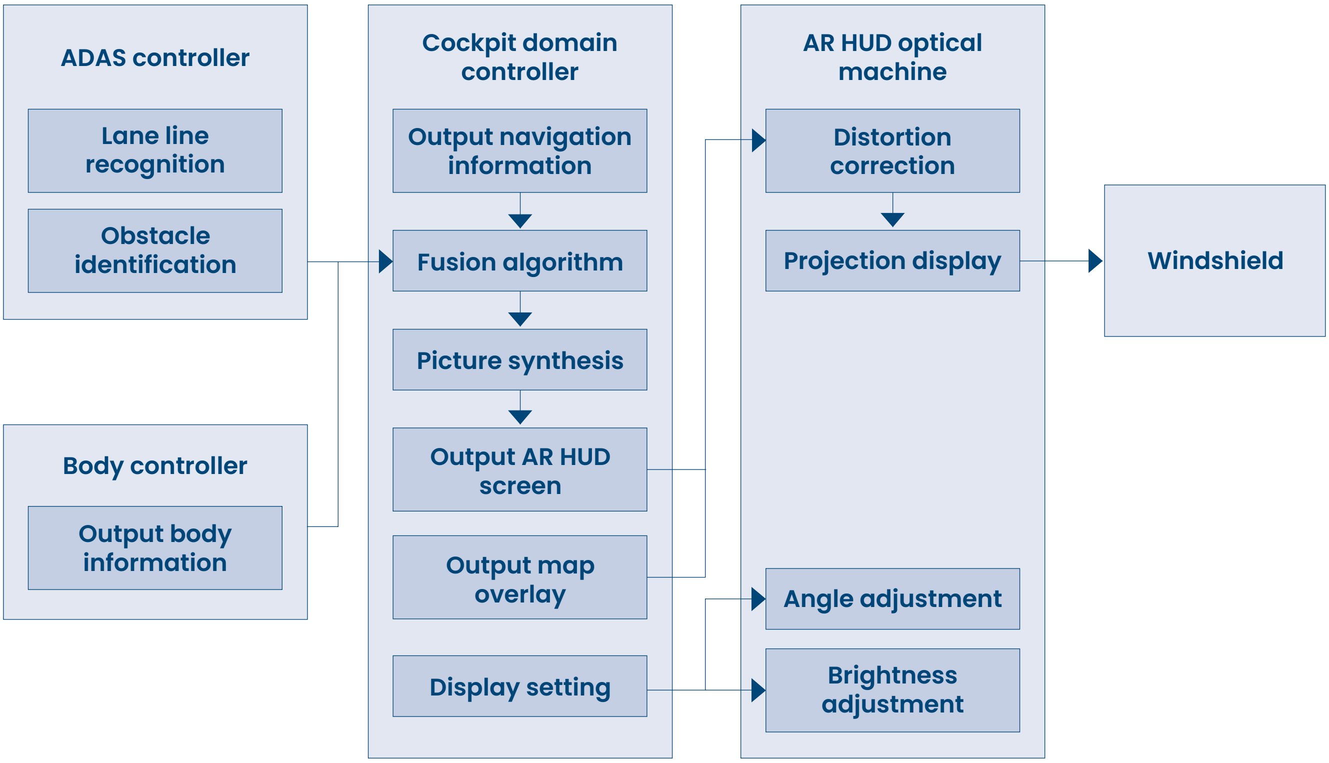


Figure 11 Reference architecture for AR HUD system

Below are the descriptions of the reference architecture:

(1) AR HUD mainly includes AR Creator, optical machine and windscreen, and is also connected to the ADAS controller, body controller and cockpit controller.

(2) For the cockpit domain controller, the AR HUD is a display device, and the AR HUD image has to be completed in the cockpit domain controller.

(3) The MCU inside AR HUD needs to complete the distortion correction algorithm and projection display.

(4) The MCU controls the motor for angle adjustment and controls the optical machine for brightness adjustment.

3. Pain spot analysis

The HUD system covers the R&D of optics, hardware and software, structure, technology, standards, etc., and has a high technical threshold. There are many technical problems to be solved for mass production of the AR HUD vehicle, including the serious sunlight back-flow problem, caused by the increased size of the imaging area, and industry pain points such as large volume, high power consumption and high cost.

4. Standardisation prospect

HUD will in the future develop in the direction of augmented reality and information such as the driving direction ahead, traffic light tips, POI tips, etc. can be integrated with the real picture to improve driving safety and convenience.

At present, the national standards drafting team for 'Performance requirements and test methods for passenger vehicle head-up display system' (hereinafter referred to as HUD Standard) is working intensively on the formulation and verification of its technical content.

The following are the key index parameters of the display terminals for the cockpit:

Display screen

Location	Form	Display mode	Main indicator parameters
Dashboard	Landscape screen	Monochrome screen	Size of display screen
Centre console	Vertical screen	AMLCD	Pixel size
Co-driver	Linked screen	AMOLED	PPI
Dashboard + centre console	Long screen	DLP	Gamma
Centre console + co-driver	Peculiar screen	LCOS	Number of colours or digits
Dashboard + centre console + co-driver	Curved screen	OLED	Radius of curvature
A/C control			Bright brightness
Interior rearview mirror			Dark brightness
CMS screen			Contrast
HUD			Visual angle brightness
Intelligent surface			Visual angle contrast
Rear seat entertainment			Colour
Armrest screen			Reflectivity
Ceiling screen			

Lamp

Type	Location	Main indicator parameters
Ambient lights	Dashboard, centre console, foot pedals, vehicle logo at door panel position, grille, body decoration, door handle, rim, welcome sill plate, A/C outlet, instrument panel of co-driver, centre console backlight area, roof, storage box, cup holder, speaker, buckle, trunk, etc.	Chroma Light intensity Uniformity Flashing characteristic
Welcome light	Door bottom Headlight through lamp Exterior rearview mirror	Chroma Light intensity
Reading lamp	Roof	Chroma Light intensity Uniformity
Intelligent headlamp (pixel headlamp)	Front end of vehicle	Chroma Light intensity Response time
Digital signal lamp	Rear end of vehicle, front end of vehicle	Chroma Light intensity

2.4.1.5 Communication terminal

The communication terminal is the data communication carrier of the intelligent cockpit and is responsible for data transmission control for the whole intelligent cockpit. At present, the complexity of the intelligent cockpit is constantly increasing, and the transmission efficiency and bandwidth requirements for data link are higher.

Communication terminals include, but are not limited to, gateway, V2X and T-box communication terminals.

Gateway

1. Function introduction

Gateway is the core of the communication local area network in the automobile. It permits information sharing on various buses and enables the functions of network management and fault diagnosis in the automobile to be realised. The gateway controller mainly has the following three functions:

(1) Message routing: the gateway has the function of forwarding messages and diagnosing the status of bus messages.

(2) Signal routing: realises the mapping of signals among different messages.

(3) Network management: network status monitoring and statistics, error handling, sleep wake-up, etc.

2. Technical architecture

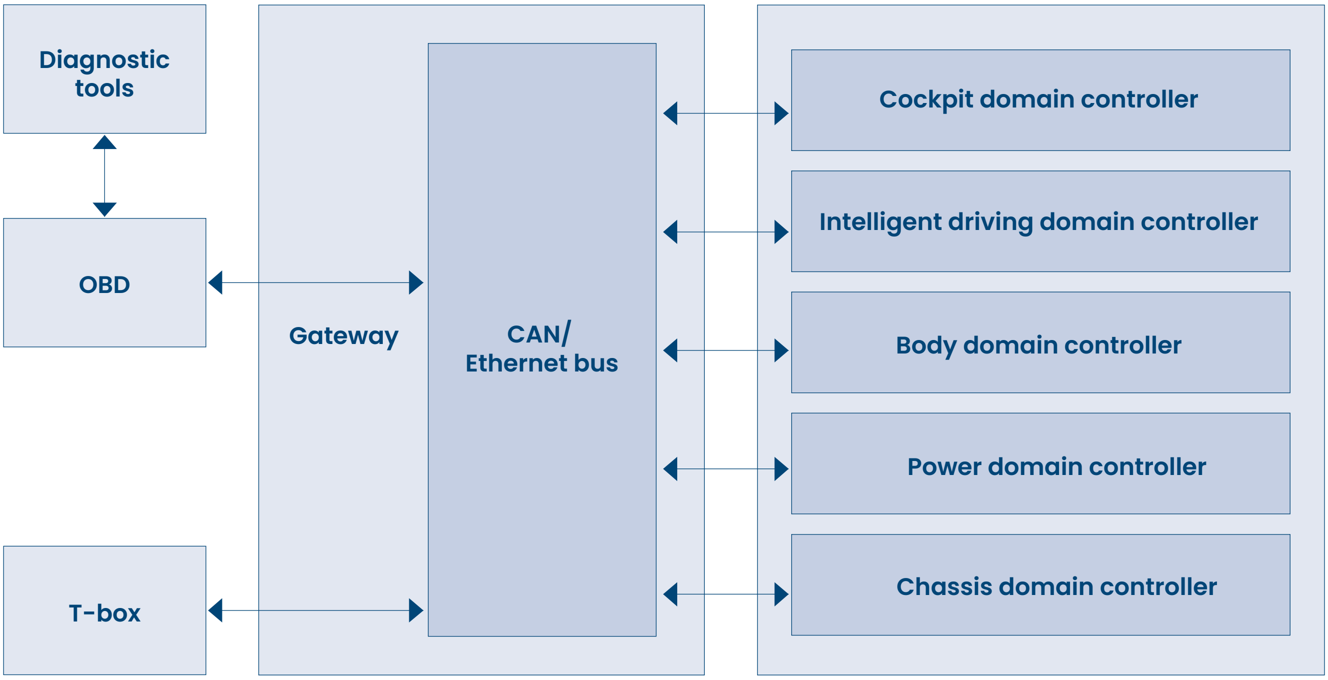


Figure 12 Reference architecture for the centralised gateway system

Below are the descriptions of the reference architecture:

(1) The gateway connects all domain controllers, external diagnostics and T-box.

(2) Each communication node exchanges data through the CAN/ Ethernet bus.

3. Pain spot analysis

The electronic and electrical architecture in automobiles has been evolving from distributed to centralised and then to central computing, which brings many challenges to the gateway:

(1) The network security of the gateway in the new complex network environment, how to ensure data security and communication security;

(2) The gateway needs a higher hash rate to adapt to the high bandwidth data transmission in the vehicle.

(3) The traditional vehicle gateway pays more attention to real-time data forwarding. Under the new EE architecture and SDV trend, the gateway needs to be SOA-based.

4. Standardisation prospect

Trend of the automobile gateway:

(1) The Ethernet will replace CAN as the backbone network in the vehicle, and the central gateway will be upgraded from CAN to Ethernet;

(2) The central gateway is integrated with the body domain controller and becomes the central server.

(3) The automobile has changed from ECU distributed architecture to multi-domain controller architecture, and the central gateway has become a 'service gateway'. When multiple domain controllers are merged into a central computing platform for a long time, the 'service gateway' will further evolve into a 'regional gateway'.

Combined with the industry trend, the gateway system needs to be standardised in terms of functional architecture, security architecture and communication interface, etc.

V2X

1. Function introduction

V2X (vehicle-to-everything/vehicle-to-X) wireless communication technology is a key technology for intelligent transportation systems of the future. It takes the vehicle as the centre and communicates with surrounding vehicles, equipment and base stations to obtain a series of traffic information such as real-time road conditions, road information and pedestrian information, with a view to improving driving safety, reducing congestion, improving traffic efficiency and providing on-board entertainment information.

We generally think that V2X technology includes the following categories:

(1) vehicle-to-vehicle (V2V): common applications such as anti-collision safety systems;

(2) vehicle-to-infrastructure (V2I): traffic signal indications and time reminders;

(3) vehicle-to-pedestrian (V2P): warnings about safety distances involving pedestrians/bicycles;

(4) vehicle-to-network (V2N): real-time maps, cloud services, etc.

2. Technical architecture

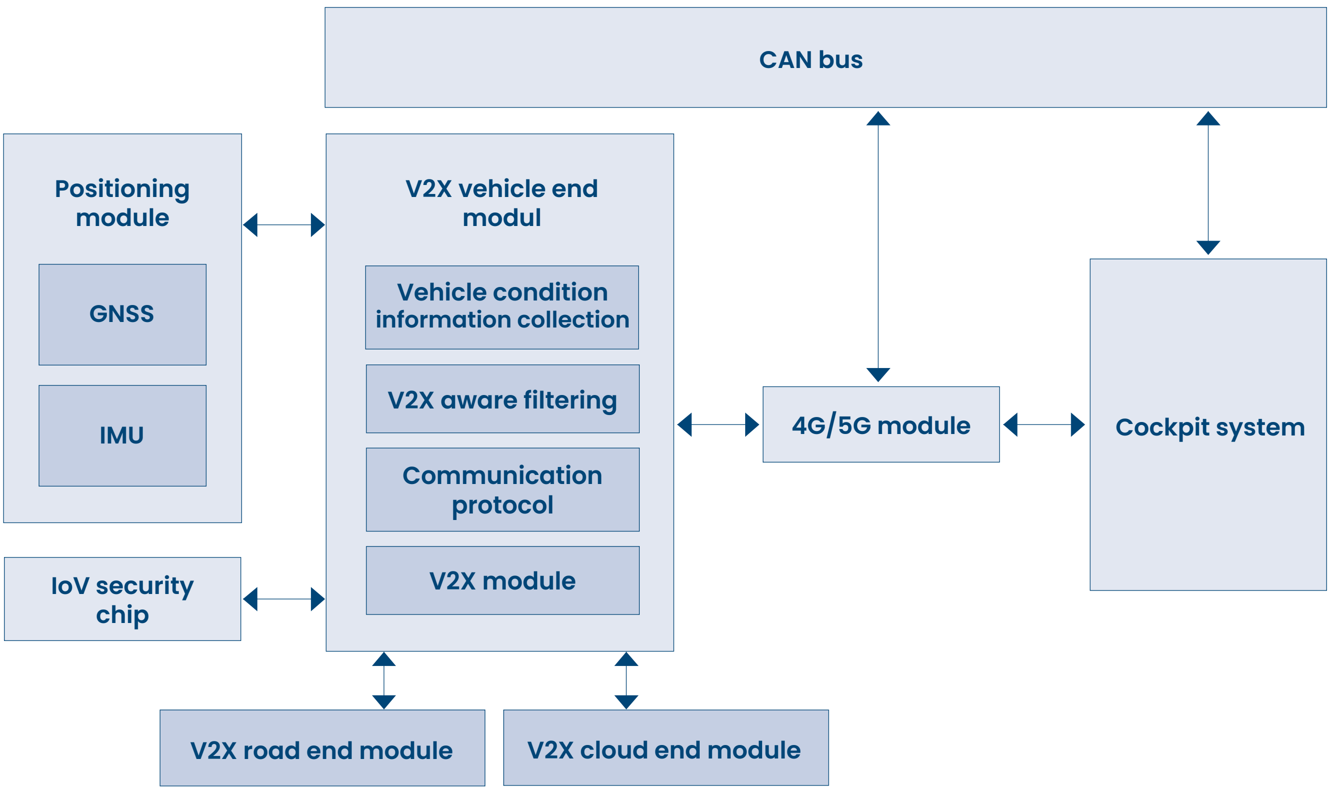


Figure 13 Reference architecture for the V2X vehicle end system

Below are the descriptions of the reference architecture:

(1) The V2X vehicle end system mainly includes the V2X vehicle end module, 4G/5G module, positioning module and IoV security chip, which are usually integrated into one controller.

(2) The V2X vehicle end module is responsible for data exchange with the V2X road end module and V2X cloud end module.

(3) The 4G/5G module is responsible for data exchange with cloud services.

(4) The V2X vehicle end module and 4G/5G module exchange data with the internal controller of the vehicle through the CAN bus.

(5) The cockpit system obtains V2X data through the CAN bus to meet the in-cockpit interactive scenario.

3. Pain spot analysis

In terms of V2X development, one of the main challenges is the need for extensive network coverage to support all fields. Large-scale connectivity and the need for digitalisation of road infrastructure are also important.

T-box

1. Function introduction

T-box (Telematics Box), a product integrating the functions of vehicle body network and wireless communication, can provide tele-communications services. T-box is a box with a communication function based on the Linux operating system. It contains a SIM card, usu-ally the SIM card of China Unicom and China Mobile, and also has a built-in GPS module. The hardware supporting this box includes 4G/5G antenna, GPS antenna, etc.

The T-box communication terminal solves communication between the cockpit and WAN and is an important carrier of cockpit external communication. T-box realises vehicle-cloud interaction and derives various application scenarios, including but not limited to remote monitoring, online application, online upgrade and real-time positioning.

2. Technical architecture

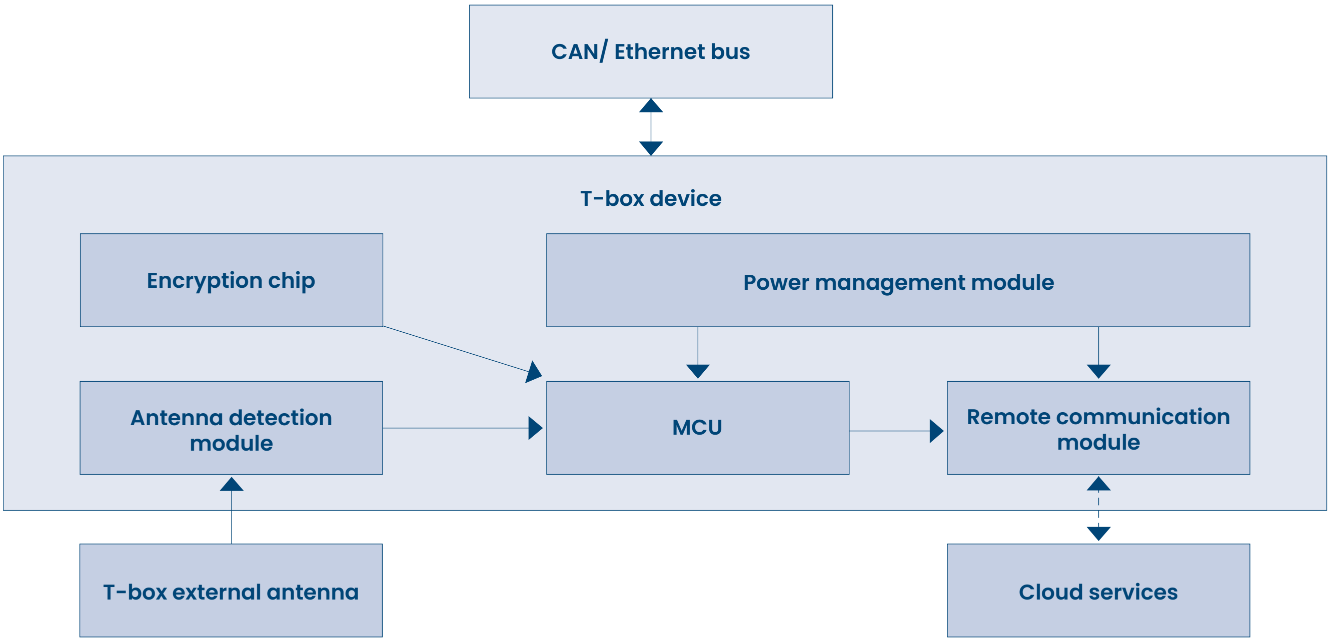


Figure 14 Reference architecture of the T-box system

Below are the descriptions of the reference architecture:

(1) The T-box system includes a power management module, MCU, remote communication module, antenna detection module and external antenna.

(2) The remote communication module supports 4G/5G, provides external network connection function, and realises data exchange with cloud services, which is the key capability of the T-box.

(3) Power management of the T-box needs to support low-power remote wake-up.

(4) The T-box is connected to the CAN/ Ethernet bus, which can obtain relevant vehicle end signals in real time and upload them to the cloud, and can also realise remote diagnosis and remote control.

(5) An encryption chip ensures the security of T-box communication.

3. Pain spot analysis

With the IoV development, the T-box faces the following challenges:

(1) 5G network stability;

(2) with the increase of CAN data, the performance requirement for full collection and full storage of CAN data is higher.

4. Standardisation prospect

At present, T-box needs to meet the require-ments of technical specifications of remote service and management system for electric vehicles (GB/T 32960).

2.4.2.5 Environmental terminal

The environmental terminal is responsible for interaction between the intelligent cockpit and the internal/external environment, and the feelings of drivers and passengers about the internal/external environment.
The terminal environment includes, but is not limited to, the vehicle compartment quality assurance system, fragrance system, power amplifier and speaker.

On-board air quality assurance system

1. Function introduction

The IAQS (Indoor Air Quality System) can be used as auxiliary equipment to the cabin climate control system. IAQS consists of a filter and a sensor. The filter is an element impregnated with activated carbonyuan, which can remove particles and pollen contained in the air entering the carriage. Activated carbon can absorb various gases and odours. At present, the main components of the tail gas emitted by diesel or gasoline engines are harmful substances such as nitrogen dioxide, carbon monoxide and hydrocarbons. IAQS sensors can detect these harmful substances in the surrounding air and quickly remove them.

2. Technical architecture

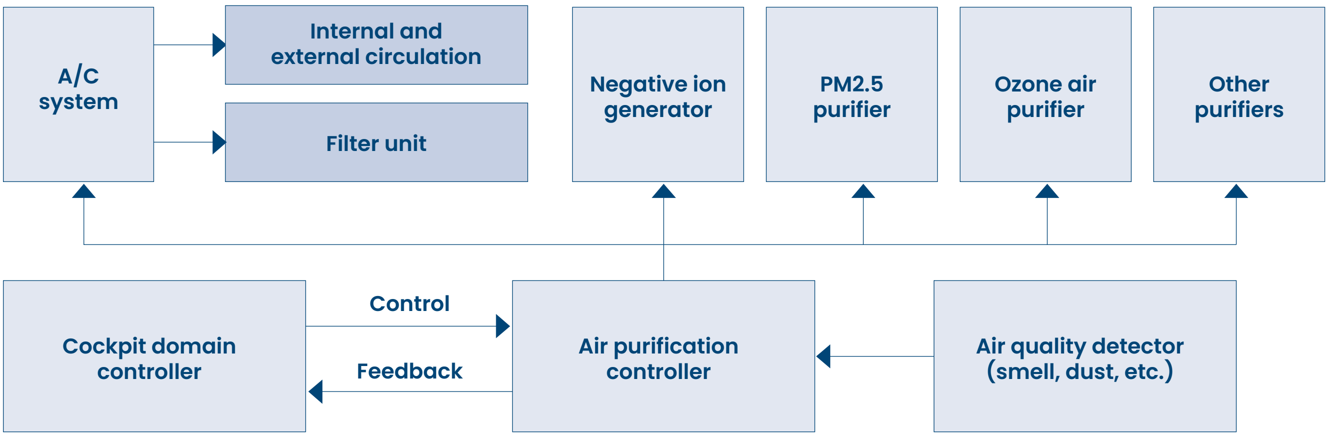


Figure 15 Reference architecture for the Indoor Air Quality Assurance System

Below are the descriptions of the reference architecture:

(1) IAQS core devices include an air purification controller, air quality detector, A/C system and purifier.

(2) The air purification controller is responsible for receiving instructions from the cockpit domain controller and performing on-off control, etc.

(3) When the air quality detector finds that air quality is abnormal, it will inform the air purifier to start the A/C system and purifier for a closed-loop mechanism.

(4) The control feedback interface of the air purification controller can be CAN, LIN, Ethernet, etc.

3. Current pain spot

At present, IAQS is often expensive, while users are not aware of air quality and safety and lack intuitive visual impact on consumers. For this reason, IAQS is not widely used.

On-board fragrance system

1. Function introduction

Nowadays, most luxury cars are equipped with an on-board fragrance system to enhance vehicle luxury as a whole and enhance the ride experience.

The working principle of the on-board fragrance device is to uniformly release perfume into the vehicle through A/C. At the same time, fragrance intensity can be adjusted according to the gear position. Generally, the manufacturer will originally introduce some perfume appropriate to that vehicle, and the owner can also replace or add perfumes according to preference. The role of the on-board fragrance device is to keep inside air clean, play a certain role in purifying the air, create a more comfortable atmosphere in the vehicle, and enhance the texture and luxury of the whole vehicle. Generally, the perfume box is placed in the glove box, which is convenient for connecting with the A/C system and occupies a defined space. Most manufacturers provide fragrances with multiple aromas for owners to choose from. Some models may install two fragrance boxes at the same time, and the two fragrances can be used alternately or mixed inside the vehicle.

2. Technical architecture

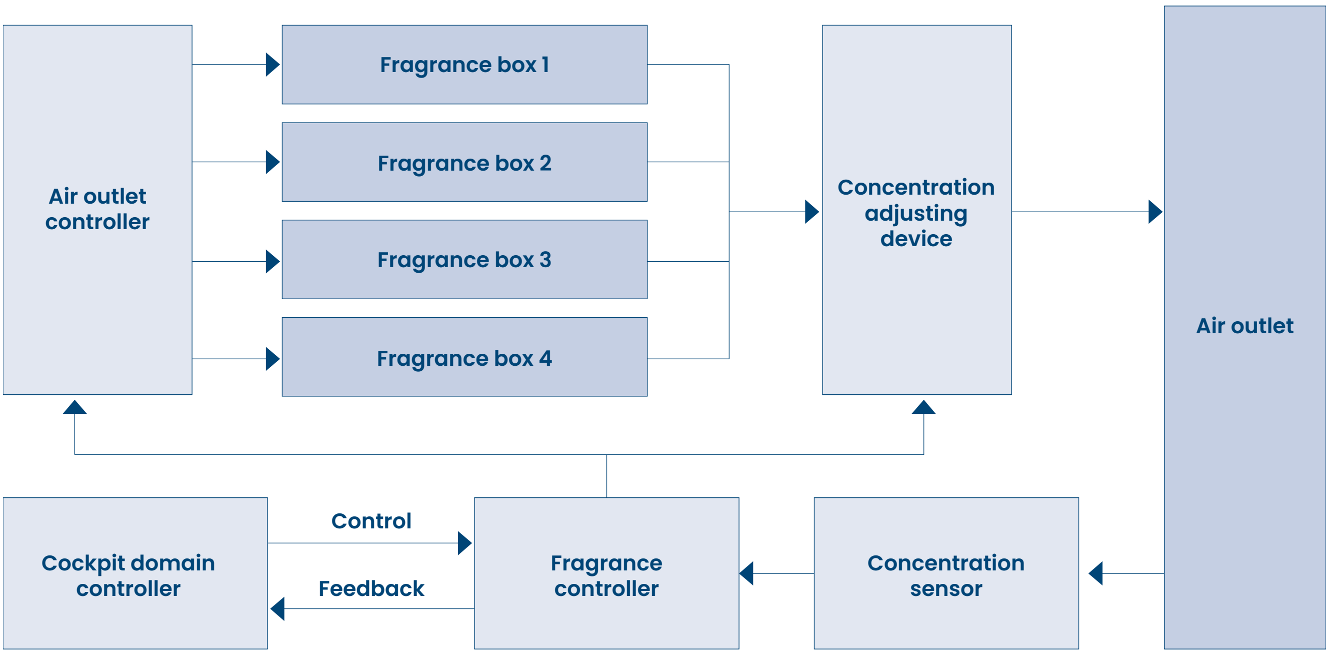


Figure 16 Reference architecture for the on-board fragrance system

Below are the descriptions of the reference architecture:

(1) The core components of the on-board fragrance system include a fragrance controller, a concentration sensor, an air outlet controller, a fragrance box and a concentration adjusting device.

(2) The fragrance controller is responsible for receiving instructions from the cockpit domain controller and adjusting the fragrance.

(3) The air outlet controller selects the corresponding fragrance box and automatically control the air-out through the concentration adjusting device.

(4) The concentration sensor detects the current fragrance concentration inside the vehicle and informs the fragrance controller to dynamically adjust the concentration to form a closed-loop mechanism.

(5) The control feedback interface of the fragrance controller can be CAN, LIN, Ethernet, etc.

3. Current pain spot

The front fragrance system is not sufficiently popular:

(1) Strict vehicle safety standards make the cost of compliant vehicle products high. In addition to the safety regulations for raw materials (such as IFRA regulations and MSDS testing) that must be observed for household fragrances, it is also necessary to pass vehicle safety tests, e.g. for high and low temperatures, durability and collision. This threshold is beyond the reach of ordinary small workshops that produce household fragrances, and the cost is much higher than that of ordinary vehicle perfumes with a retail price of tens of dollars.

(2) The traditional single application scenario does not stimulate the purchase impulse of users. The single odour emitted by a system cannot meet the needs of all passengers or scenarios, and there are only a handful of scents to choose from – let alone personalised and customised scents.

(3) The interfaces of fragrance boxes in different OEMs are not uniform and the brands available for fragrance boxes are limited. Many of them drip essential oils without changing the boxes, which can easily result in odours from different essential oils.

4. Standardisation prospect

The front on-board fragrance can be standardised on the communication interface, including the communication interface with cockpit domain control and replacement interface of the fragrance box.

The front on-board fragrance can be standardised in terms of parameters, including odour, temperature (heat-resistant and safe), volatilisation speed, usage time, etc.

Auto audio system

1. Function introduction

Auto audio is a playback device set up to relieve the boredom of drivers and passengers during their journey. Vehicle AM radio was used initially. This was followed by AM/FM radio and tape player, which evolved to the CD player and digital audio compatible with DCC and DAT. Currently, auto audio has reached a high standard in terms of timbre, operation and anti-vibration, etc., which can cope with bumps of the vehicle on rough road and ensure the stability of performance and perfection of sound quality.

Functions of the auto audio system:

(1) Power amplification, which outputs the audio output by the head unit to each speaker of the vehicle body with amplification gain.

(2) Tuning distribution: the audio source of the multimedia output is distributed to different types of speakers in various

positions inside the vehicle body according to different tuning, forming a specific sound field effect.

(3) Mixing strategy: different audio will be mixed in different ways according to the mixing strategy of the whole vehicle factory.

(4) Simulation of sound effects: in line with the definition provided by the OEM, the power amplifier produces different sounds according to the real-time data of the vehicle. For example, the effect of simulating engine sound waves or reverse noise reduction.

2. Technical architecture

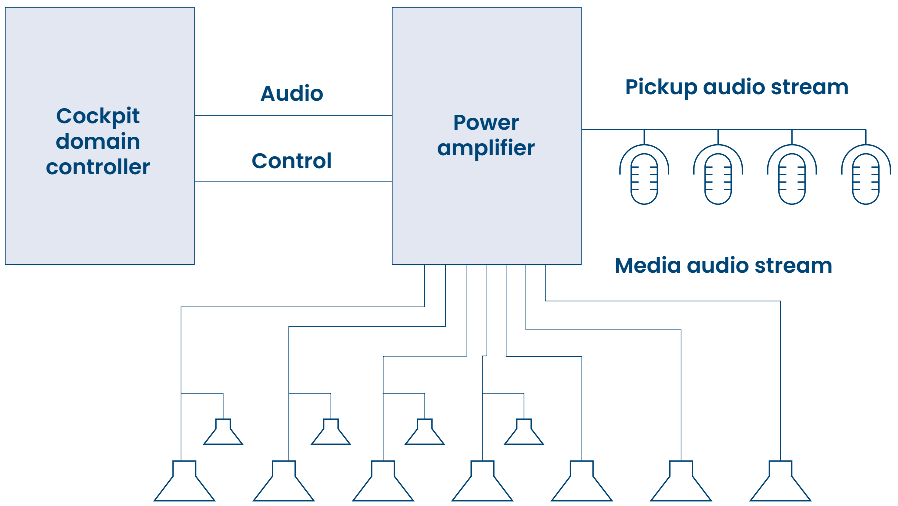


Figure 17 Reference architecture for the auto audio system (both internal and external power amplifiers are applicable)

Below are the descriptions of the reference architecture:

(1) The core components of the auto audio system include power amplifier, pickup and speaker.

(2) Audio stream interfaces supported by the power amplifier include A2B, SPIDIF, MOST, etc.

(3) The external power amplifier control feedback interfaces can be CAN, LIN, Ethernet, etc.

(4) The internal power amplifier control feedback interface can be SPI, I2C, UART, etc.

3. Current pain spot

Evaluation standards for auto audio in the industry vary, and evaluation ability is insufficient, relying in part on the influence of big brand audio. Changes in functions are subject to supplier standards, and there is only low capacity for users to customise and personalise.

4. Standardisation prospect

The parameters and evaluation of auto audio can be standardised. This includes factors such as sound out time, noise floor, signal-to-noise ratio, frequency response and overall delay, as well as subjective and objective evaluation.

Below are the key environmental terminal parameters for the cockpit:

Air quality detection

Module	Detection range	Main indicator parameters
AQS sensor	Mainly monitor the temperature, humidity, air pressure, illumination, PM2.5, PM10, TVOC and other values in the air, as well as the concentrations of gases such as oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO) and formaldehyde (CH_2O).	Accuracy Linear range Sensitivity Stability Frequency response

Air purification

Type	Purification range	Main indicator parameters
Strainer air cleaner Electrostatic dust-collecting air cleaner Ozone air cleaner Clean ion group air cleaner Water filter air cleaner	PM2.5 Toxic and harmful gas (formaldehyde, benzene series, TVOC etc.) Abnormal odour Bacterial and virus	Clean air delivery rate (CADR) Cleaning energy efficiency Noise Effective room size Cumulate clean mass (CCM) Cleaning life span Standby power Hazardous substance emission Microbe removal (antibacterial, mildew-proof and sterilisation)

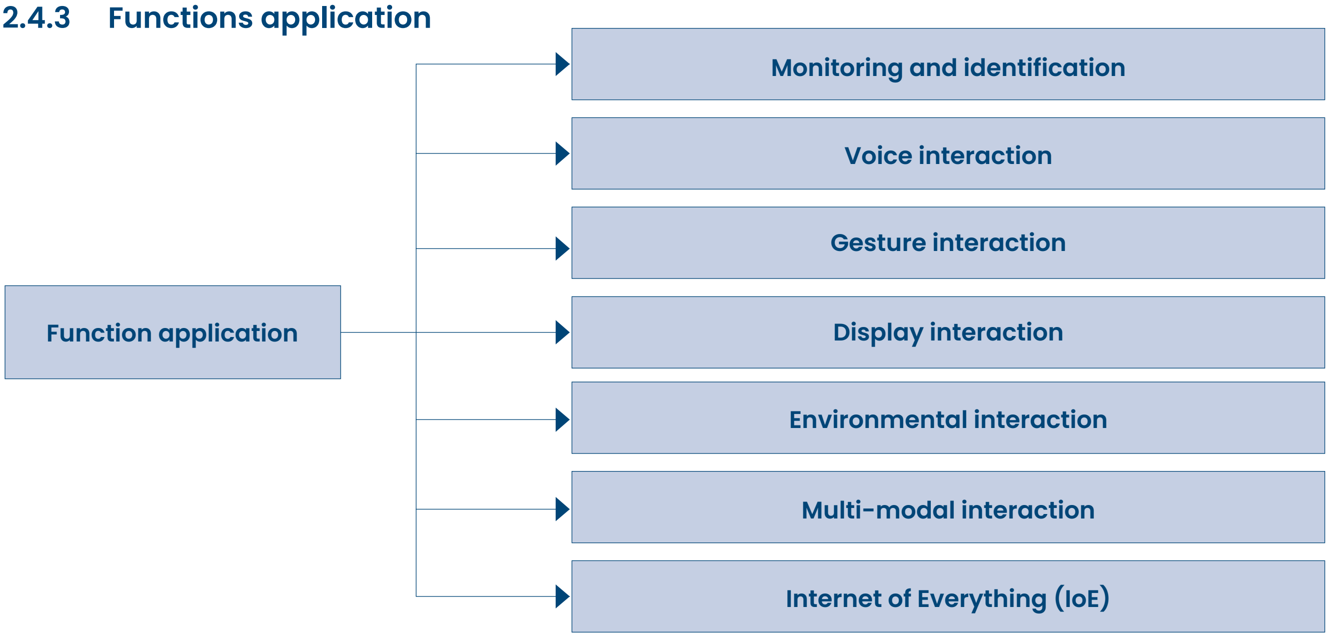
Power amplifier

Type	Output Capability	Main indicator parameters
A/B/AB/D type power amplifiers Built-in/external power amplifier Analog/digital Special power amplifier: noise reduction power amplifier/headrest power amplifier, etc.	Number of channels: 8, 16, 24 and 32 channels Stereo/surround algorithm/ panoramic sound algorithm Acoustic fidelity rendition Noise reduction algorithm Virtual engine sound algorithm	Background noise Output power Frequency response curve Total harmonic distortion plus noise (THD+N) Signal noise ratio (SNR)

Loudspeaker

Location	Type	Main indicator parameters
Front Door Headrest Ceiling Footwell Rear platform	Distribution by frequency: high/ medium/bass/mega bass Material classification: ferrite and NdFeB	Short-term maximum power/long-term maximum power/rated sinusoidal power Frequency characteristic Directional property Nominal impedance Total harmonic distortion Sensitivity Anti-interference Frequency range

2.4.3 Functions application



2.4.3.1 Monitoring and identification

1. Technical classification

Biometric technology can be divided into identity recognition and status monitoring from the functional dimension. The current mainstream technology can refer to the figure below.

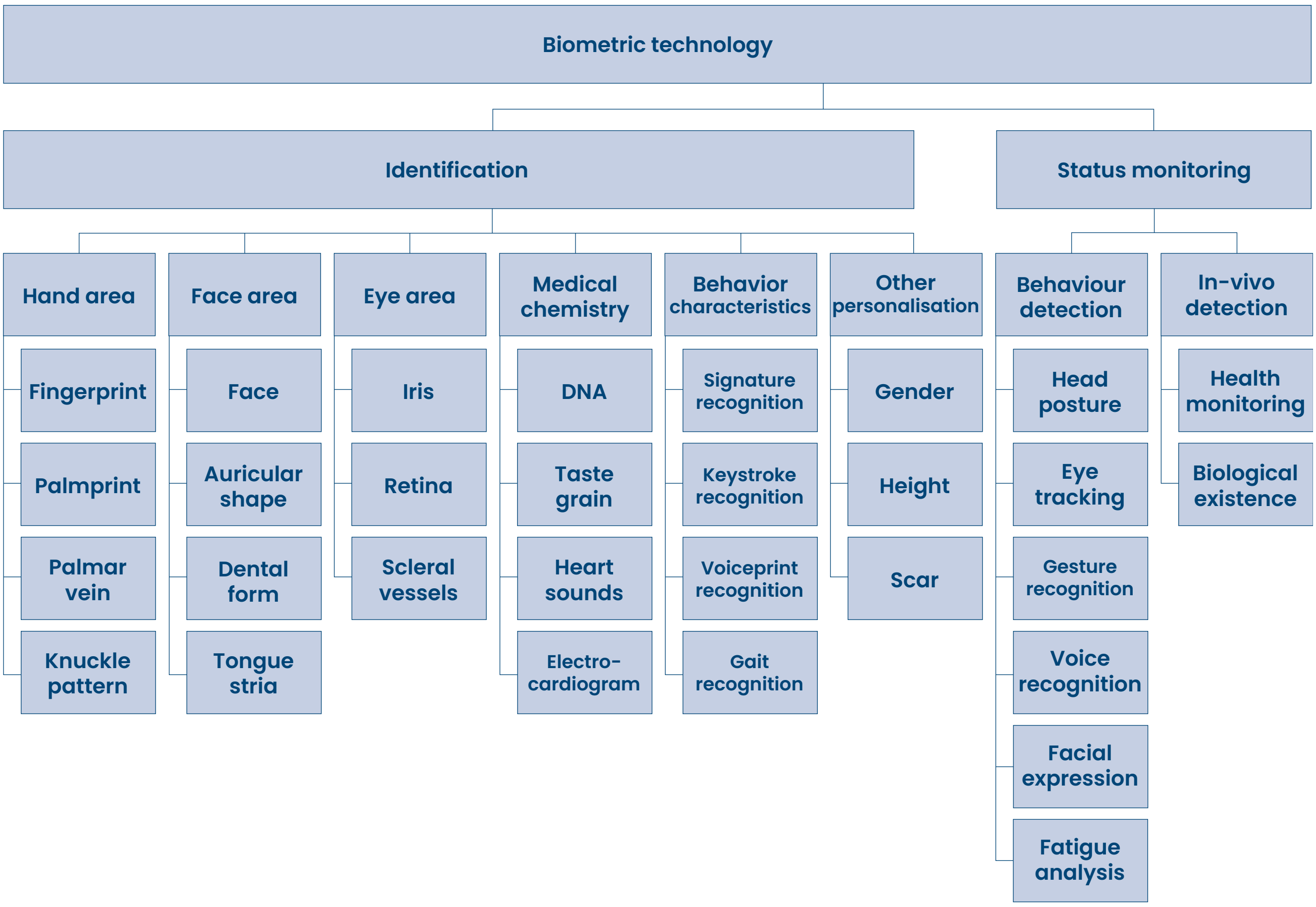


Figure 18 Classification reference of biometric technology

Identity recognition technology mainly includes, but is not limited to, face recognition, fingerprint recognition, voiceprint recognition and iris recognition. Following identity registration via the head unit or vehicle control APP, the driver can unlock the vehicle by face/fingerprint/voiceprint/iris and log in to the cockpit account system and other scenario applications.

Status monitoring technology mainly includes, but is not limited to, the driver monitoring system (DMS), occupants monitoring system (OMS) and extra-vehicle detection.

The design of intelligent and connected vehicles focuses on user safety and user experience, so a large number of on-board apps will collect biometric user data. Here are some typical application scenarios:

Identity authentication: Based on fingerprint, face, voice and other identification devices installed in the steering wheel, B pillar, rearview mirror and other places near the main driving position, the driver's identity is confirmed by means of face scanning, iris scanning, voiceprint recognition and fingerprint tracking. After identity is confirmed, the door, trunk and head unit system can be unlocked.

Personalised service: Once the vehicle has recognised the user's identity, the vehicle is personalised according to the memory function. This includes interior seats, music, A/C, navigation and other equipment. Through face recognition technology, it is possible to analyse changes in facial expression to identify emotions and play different music.

Driver monitoring: Facial recognition detection is the main technology used to detect the degree of fatigue and physical condition of the driver in the vehicle. Eye tracking technology is used to detect whether or not the driver is distracted and assess whether he/she is able to take control of the vehicle from the automatic driving system, thus ensuring driving safety.

Health monitoring: A series of sensors on the steering wheel and safety belt are used to monitor the driver's health. For example, the piezoelectric sensor on the safety belt captures breathing, the infrared sensor measures body temperature and the conductive sensor measures heart rate. By analysing the driver's heart rate, blood pressure and other information, the vehicle can adjust the emotional lighting system to help reduce stress or provide health reminders. If it is detected that the driver has a medical emergency, the vehicle will send out a voice reminder to prompt the driver to slow down or take the initiative to call for emergency help.

Biological presence detection: Through direct or indirect sensing technology, this function detects the existence of living creatures in the vehicle, such as children or pets left behind in the vehicle. If it detects that a creature has been left in the car, the system will prevent the door from locking and send an alarm to remind the driver, passengers or people around, thus preventing a potential in-vehicle accident.

In the future, the automobile will gradually implement a multi-modal biometric function by integrating various biometric technologies, and recognition methods and application scenarios will become more and more diversified. This will include behaviour measurement (predicting future actions of vehicle occupants and verifying them by recognising moving speed, strength, inclination and other factors), DNA recognition, biometric burglar alarm, etc. As the technology develops, more humanised on-board interactive functions will increasingly be applied to automobiles.

2. Pain spot analysis

Camera imaging: No matter what kind of camera or technical scheme, changes in external lighting and other environmental factors may cause the overall image to be too dark, too bright or yin-yang in nature. If the user wears glasses, a hat, mask or other accessories, the local area of the face is obscured, which means the face cannot be recognised or facial features are not clear in the final imaging. This invalidates the product function. At present, in order to solve this pain point, image quality is usually adjusted by hardware ISP or software ISP. However, there remain certain limitations in similar methods that attempt to repair image quality; in particular, it is difficult to guarantee the scenario effect in extreme light. In the future, it is expected this problem will be solved by multi-technology integration.

In-vivo attack: Face or fingerprint recognition is faced with the risk of forgery, replay and other attacks when applied to authentication and authorisation. Compared with face recognition, fingerprint duplication and forgery technology are simpler and faster. To solve this pain point, in addition to establishing relevant technical protection mechanisms, targeted tests should be conducted to verify and finally improve the anti-attack capability of related products.

Building test sets: Similar to product sampling, the method of building test sets assumes not only that the sample size of the test set is enough to cover all use scenarios as far as possible, but also that cost can be controlled when building a test set. However, due to the different hardware principles and varying biometric algorithm calculation principles, it is difficult for the industry to build a common test set. The hardware principle for fingerprint identification is single and less affected by the external environment, sensor selection is single and less affected by illumination, therefore some public test sets can be constructed. By contrast, under the influence of sensors, modules and illumination, the pain point for vision-based face recognition in this respect is more obvious. To solve this pain point, we can reduce the related risks and cost of dealing with the pain point by standardising the relevant test methods, clarifying the corresponding camera imaging quality and specifying the information comparison test set scheme during verification.

Passenger monitoring: Based on the traditional sensor scheme, recognition accuracy is high, but the pain point lies in the single function. If more functions are realised, it will inevitably require the installation of more sensors, resulting in higher costs. In most cases, the camera-based scheme can cover the whole vehicle scenario and multiple functions as long as one or two cameras are installed, but its recognition accuracy for seat position is low. If the cost is acceptable, not only can multiple sensors be installed to ensure their stability, but also any related deficiencies can be compensated for by multi-sensor fusion. If cost is limited, key areas can be covered by adjusting the installation position of sensors or cameras.

Biological presence detection: The evaluation method of indirect detection technology is relatively clear, and different processes – such as opening and closing doors, positioning a child, driving and locking the vehicle – are carried out in accordance with the vehicle use scenario of a child left behind that needs to send an alarm or prevent a false alarm. However, indirect detection requires users to strictly follow the relevant methods: if an intermediate step conflicts with the indirect detection system, there will be a certain misjudgment.

Health monitoring: At present, for the function of occupant health monitoring, the main sensors used are the visual camera, infrared camera, etc. Meanwhile, ultrasonic-based non-contact blood flow sensing is also in the research stage. However, there is room for further cost reduction in system hardware because it has not currently been rolled out in large quantities. In the aspect of software algorithm, the further understanding of human body state also needs a lot of actual data to support and enrich the training data set, so as to improve the recognition ability of human body state. At present, this is the main technology used to assess the use of each seat in the vehicle by pressure sensor/capacitance sensor, and to evaluate the situation inside the vehicle by the camera facing passengers. The hardware cost of the former is relatively high, although it can determine people's position with a high degree of accuracy; nevertheless, it is easy to produce a false alarm for contents relating to heavy objects. Camera accuracy is higher when objects are visible, and the hardware cost is lower, but accuracy when an object is invisible is lower than that provided by the hardware sensor.

2.4.3.2 Voice interaction

Voice interaction is the simplest, most natural and safest in-vehicle interaction mode and has become the most important in-vehicle interaction mode.

Intelligent voice interaction mainly covers voice wake-up, ASR (Automatic Speech Recognition), NLP (Natural Language Processing), speech synthesis and other technologies. NLP includes NLU (Natural Language Understanding) technology and NLG (Natural Language Generation).

The ASR installation rate in the intelligent cockpit was about 67% in 2020 and is expected to reach 84% by 2024.

In the era of unmanned driving, technologies such as recognition of different sound types (including ambulance and fire service vehicles), sound source recognition, voice emotion recognition and voiceprint recognition will be added.

The main application scenarios of the on-board voice assistant occur in high-frequency applications. These include making phone calls, asking for directions, sending short messages, playing music, finding radio stations, asking about the weather and finding restaurants.

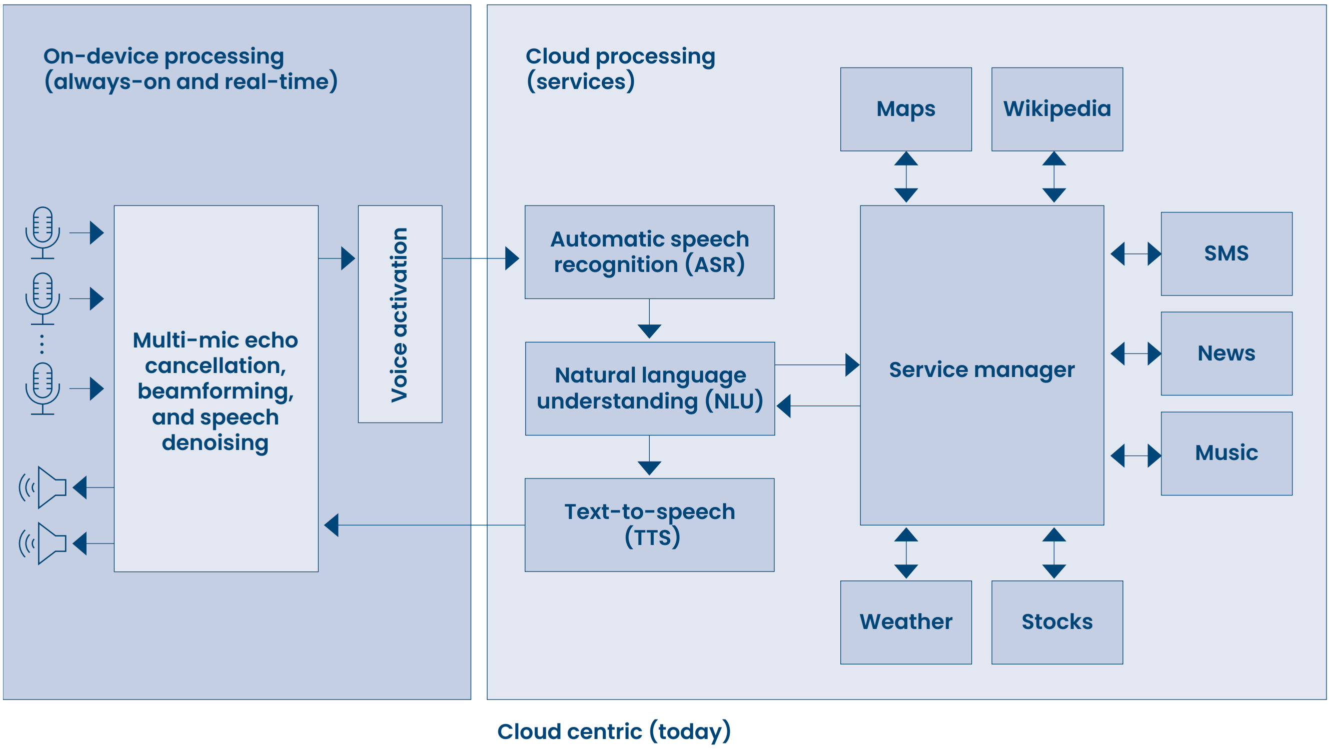


Figure 19 Online mode of voice assistant (source: Texas Instruments)

On-board voice assistants for low-end and mid-end vehicles are mostly online; those for a few luxury vehicles are a combination of offline and online.

The online process operates as follows: at the ground end, the microphone array picks up the human voice, carries out ADC analog-digital conversion, then filters out noise, background sound and signals far away from the pickup area, before uploading the filtered signals to the cloud. The cloud server mainly performs ASR and NLU, and after identification, it returns to the original channel and converts the signals into commands or plans for the automobile MCU.

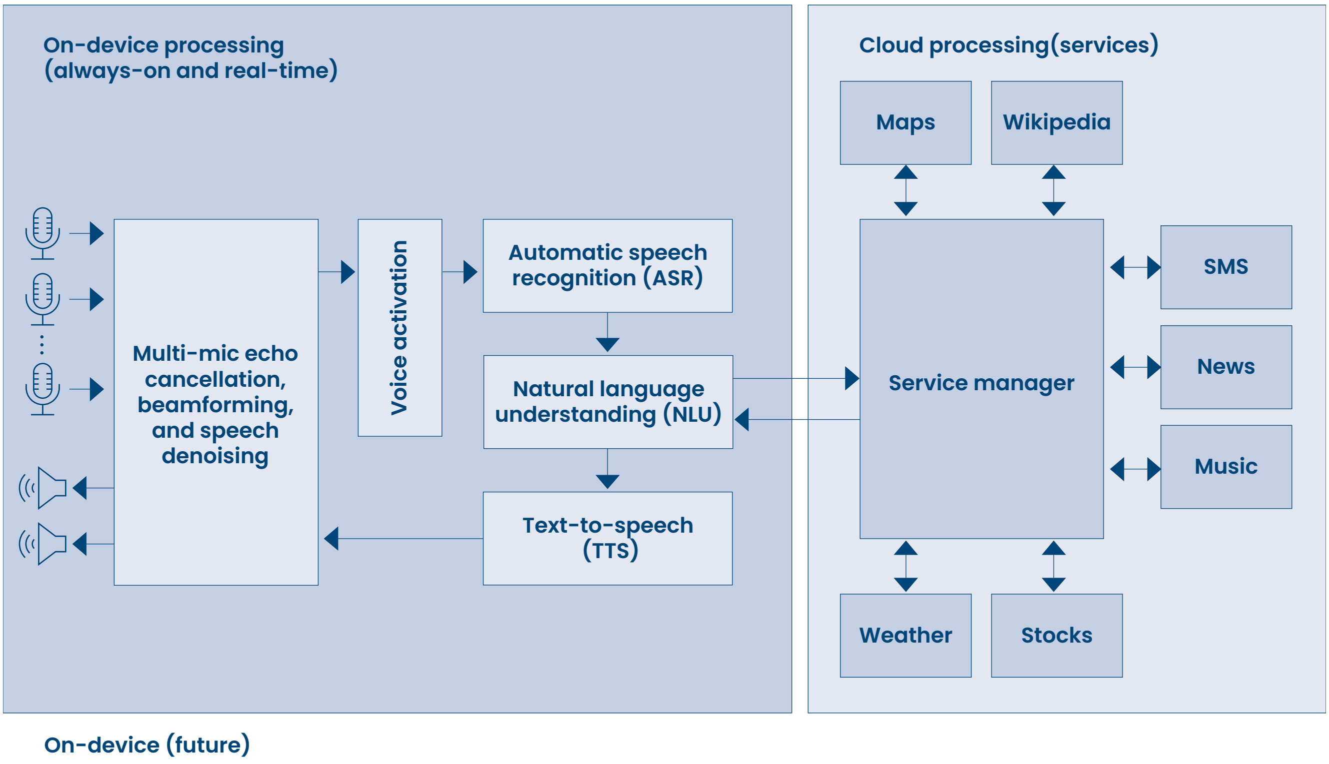


Figure 20 Combination of offline and online voice assistants (source: Texas Instruments)

The process of combining offline with online operates as follows: ASR and NLU are also added to the vehicle head unit. The cloud server is used in the case of networking, or it can be used locally offline without networking. Offline use can also maximise privacy and ensure data security. Other advantages are short delay time and stable performance.

There are three technical difficulties with the voice assistant: first, accurate pickup and noise elimination, namely SSE (Speech Signal Enhancement); secondly, the corpus for a deep learning training model; thirdly, the parallel calculation for a speech recognition feature extraction model.

The corpus is the training data for voice recognition. It is different from that for home use, requires special consideration of the on-board environment, and is an on-board environment of different models. For example, there is a significant difference between the interior noise in electric vehicles compared with fuel vehicles. There is also a major difference between the interior noise of diesel vehicles and gasoline vehicles. It is therefore necessary to collect relevant data for vehicle models. This leads to high development costs and a long development cycle.

Finally, the parallel computing problem. In-vehicle voice assistants require deep learning in four links, namely SSE, ASR, NLU and TTS. Different from image-based deep learning, LSTM (Long Short-Term Memory) requires the largest amount of computation, which is a kind of RNN (Recurrent Neural Network). At present, RNN is the most mature and mainstream technology, but the sequence-dependent structure of RNN itself is quite unfriendly to large-scale parallel computing.

On-board computing resources are mainly parallel computing resources, such as GPU. Serial computing is usually done by CPU or special NPU. A powerful CPU means high cost. Most NPUs in the chip are aimed at image deep learning, or CNN, which is why everyone is reluctant to create offline solutions.

2.4.3.3 Gesture interaction

Gesture interaction is an interactive technology from a distance. This can reduce the risk of a driver manipulating the screen to improve driving convenience and safety.
The gesture interaction technology used in the intelligent cockpit can be divided into simple gesture and complex gesture.
Simple gestures use sensors such as the camera or infrared light source to recognise two-dimensional gestures – up, down, left and right or waving.

Complex gestures use the 3D camera and a fast modulation infrared light source to measure the flight time, which can recognise 3D gestures.

2.4.3.4 Display interaction

The display interaction of the intelligent cockpit is based on the user's vision and presented via the display device. These functional services include travel service, social life, personalised service, owner service and infotainment.

Travel services do more than just provide services to drivers or passengers during sport or rest. These services can be visits to transportation tools such as vehicles, or the delivery of content or services such as vehicle sharing services, parking spaces or electric vehicle charging stations. Travel services also include a combination of various means of transportation to help users reach their destination. These services are driven by digital lifestyle, IoV and the sharing economy.

Social life opens up the communication between vehicle owners and the outside world, including but not limited to a vehicle friends circle, group trip, online chat, payment, ordering food and hotel reservation.
Personalised services combine the behaviour habits of drivers and passengers to generate personalised needs, including but not limited to personalised care, intelligent scenarios and situational patterns.

Vehicle owner services refer to the vehicle owner service in the non-travel state, including but not limited to intelligent reminders (maintenance reminders, fuel consumption/power consumption management, insurance, etc.), vehicle safety alarm (container monitoring, fuel tank anti-theft, etc.) and remote diagnosis.

Entertainment is the information window of the intelligent cockpit for drivers and passengers, and also provides cockpit leisure and entertainment functions, including but not limited to vehicle information, body control, navigation, multimedia, games and online APPs.

2.4.3.5 Environmental interaction

The environmental interaction technology used in the intelligent cockpit includes the interaction between the internal and external environment of the cockpit, including but not limited to air quality, smell control (fragrance, etc.), sound effect control, noise detection, ambient temperature perception and intelligent lighting language.

The air quality is improved by detecting whether the cockpit environment contains pollutants as well as through purification and filtration.
At present, smell control is mainly realised by fragrance, which can be manually or automatically adjusted to enhance the smell experience of drivers and passengers.
The sound effect control improves the sense of space and 3D sense of cockpit sound through sound IC, power amplifier and acoustics, and increases the audio experience of drivers and passengers.

Cockpit noise is reduced by detecting the noise index in the cockpit and through active and passive noise reduction methods.
Ambient temperature sensing can dynamically adjust the A/C controller by detecting the temperature in the cockpit to keep the cockpit at a comfortable temperature.

Intelligent lighting language includes the interaction between interior ambient lights and exterior lights:

(1) Exterior light interaction conveys information to the outside world by

means of lamp projection, lamp group display screen, etc. on the premise of complying with regulations; the light interaction provides a channel for the driver to interact with the outside world. While the commercialisation of automatic driving, intelligent light language enables auto-driving vehicles to communicate with the surrounding environment.

(2) Interior ambient light is a type of lighting fixture that can play a decorative role. Its brightness and colour can be changed according to vehicle state, environment and personal preference to improve the ride experience for vehicle occupants. The control circuit for rhythmic ambient light outputs the corresponding data of the LED working state to the driving MOS tube in the form of a PWM signal through the controller, and controls each RGB colour by pulse width modulation (refer to B11B full colour gamut colour scheme V010C for specific colours), ultimately realising matching and dimming for the RGB LED three-colour mix, and achieving the multi-functional effects of monochromatic stillness, monochromatic breathing, colour-changing breathing and rhythm for the colourful ambient light. The light source for the interior ambient light is generally a RGB-LED light source. Based on the additive light mixing principle of red, green and blue, red light, green light and blue light are mixed to obtain different lighting colours, thus realising colour changes of the light source. Through the PWM of the output waveform, i.e. by adjusting the duty ratio of LED conduction, different degrees of illumination brightness can be obtained and the change of light source brightness can be realised, thus achieving the colour and brightness required by users.

2.4.3.6 Multi-modal interaction

The multi-modal interaction technology used in the intelligent cockpit serves to generate intelligent scenarios by fusing multiple single-modal interactions and combining cockpit functions. In the field of the intelligent cockpit, an evolving key research branch is to improve intelligent cockpit interaction by calling up all the senses of vision, voice, hearing, touch and smell.

Common multimodal interactions include 'voice + sight' and 'voice + lip language'.

(1) 'Voice + sight': the recognition ability of fuzzy pronouns, including 'this, that' by voice interaction is almost zero. In this case, if we add sight tracking, we can lock the direction of sight and then issue instructions through voice, which can greatly improve the response rate of instructions.

(2) 'Voice + lip language': voice interaction combined with lip movement recognition will greatly improve the performance of speech recognition. Lip movements are different in different languages. In the noisy cockpit environment, even if the sound received by the system is minimal, the combination of lip movements can guarantee a high speech recognition rate.

2.4.3.7 IoE

By integrating mobile terminals with traditional vehicles, IoE technology makes use of the large-scale application ecology of mobile terminals to provide richer information service content and value-added services to traditional vehicle users.

IoE technologies used in the intelligent cockpit include, but are not limited to, mobile phone screen projection, digital key, health monitoring, Bluetooth music, AR/VR glasses, vehicle-cloud cooperation and mobile-vehicle interconnection.

(1) Mobile phone screen projection

At present, all mobile phone manufacturers, mobile phone system suppliers and software suppliers have put forward their own mobile phone screen projection schemes, which are mature, widely used and strongly bound with their own products to enhance the competitiveness of mobile phone product lines. These include Google's Android Auto, Huawei's HiCar, Baidu's Carlife and Apple's CarPlay. At this year's WWDC22 Apple Developers Conference, Apple has greatly upgraded CarPlay, so that CarPlay is no longer a simple projection of the iOS system on the centre console system, but makes iOS fill the entire interior screen.

Mobile phone screen projection connects mobile devices with automobiles through underlying connection technologies such as USB/Bluetooth/Wi-Fi. By leveraging the powerful attributes of automobiles, mobile devices and multi-device interconnection capability, mobile phone applications and services can be extended to automobiles to realise a whole scenario experience with mobile phones as the core. Users can access navigation, music, telephone and other services provided by the mobile phone via the touch screen, physical buttons, voice receiving devices, etc.

Mobile phone screen projections include but are not limited to Miracast, MirrorLink, Apple Carplay, Android Auto, Carlife and HiCar.

Android Auto as example:

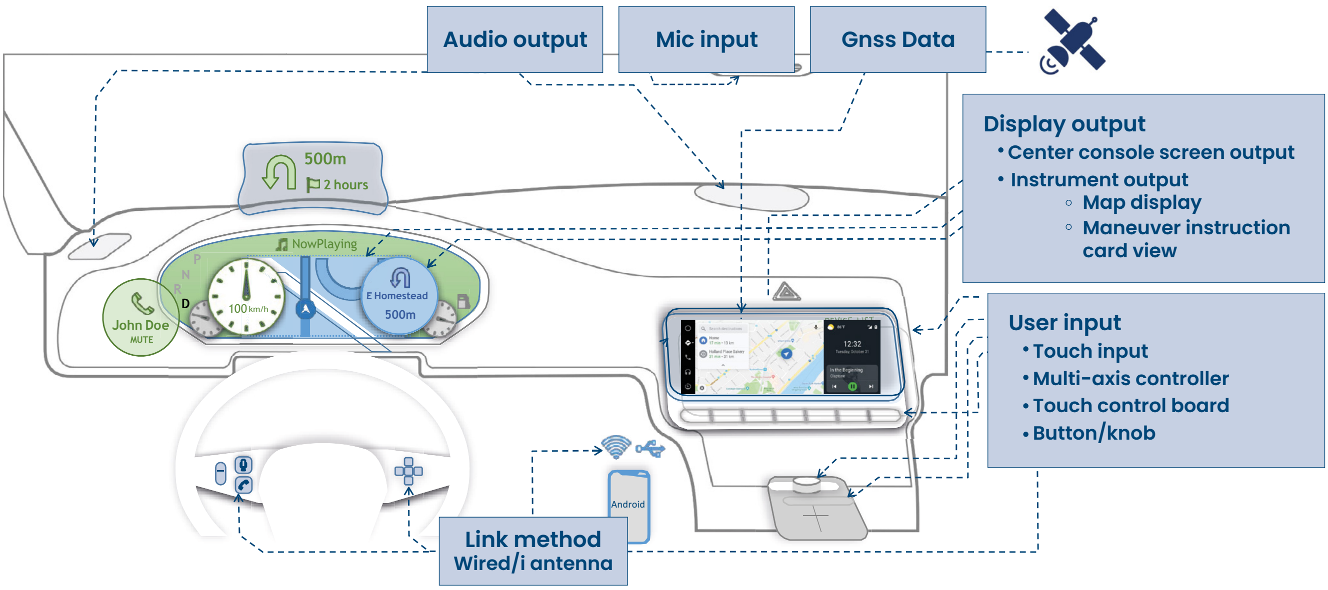


Figure 21 Principles of mobile phone screen projection technology

Mobile phone screen projection has the following pain points:

a. the mobile phone screen projection scheme must correspond to each mobile phone manufacturer, with high development cost;

b. different mobile phone projection schemes all need to be certified, with high certification cost.

Taking mobile phone screen projection as the focus of differentiated development by mobile phone manufacturers is one of the main directions of innovation. Standardisation hinders their enthusiasm for innovation and vested interests are expected to have a low degree of cooperation. However, other mobile phone manufacturers are trying to break the current situation and promote standardisation. For example, the Intelligent Car Connectivity Open Alliance (ICCOA) initiated by Xiaomi, oppo and vivo is making efforts in this regard.

(2) Digital key

Hitherto, digital keys have been applied in mass production and the technology is relatively mature. At the same time, standards relating to digital keys have been formulated by ICCE and CCC and applied in the industry.

The digital key makes use of the features of precise positioning and high security, so that the smart terminal with smart phone as the media can realise the digital key, which can implement remote start-up of the vehicle, personalised settings, ADAS settings, owner authentication and other scenarios.

(3) Health monitoring

Some vehicles will be equipped with corresponding bracelets to obtain physiological information about drivers, including heart rate, respiratory rate, blood pressure saturation, etc., to assess whether drivers are in a state of fatigue, dangerous driving or shock.

(4) Bluetooth music

Based on Bluetooth® A2DP/AVRCP Profile, Bluetooth music projects the audio stream played on the smart phone terminal to the head unit system. The technology is mature and reliable and its penetration rate is extremely high. It is already widely used in the head unit system and smart phone system.

Bluetooth SIG (Bluetooth Technology Alliance) is a multinational organisation responsible for promoting Bluetooth technology. It owns the Bluetooth trademark and is responsible for certifying manufacturers and authorising them to use Bluetooth technology and the Bluetooth logo, but it is not responsible for the design, production and sale of Bluetooth devices.

Bluetooth music wirelessly transmits multimedia sound played on the intelligent devices of vehicle occupants to the cockpit system and outputs it from the cockpit sound.

Drivers and passengers can control multimedia playback of remote intelligent devices through voice input/user interface operation/steering wheel buttons and other input methods in cockpit system.

(5) AR/VR glasses

The introduction of corresponding AR and VR glasses into the cockpit will eliminate some screen information and navigation status of the vehicle and enhance the interactive experience inside and outside the vehicle. Depending on the needs of drivers or passengers, the vehicle can feed route information, road conditions, information outside the vehicle, etc. to drivers or passengers in real time, thus enhancing enjoyment of the driving experience. Passengers can also experience the enjoyment of driving through AR/VR glasses and encounter the driving experience and technology of vehicles in virtual reality.

(6) Vehicle-cloud cooperation

Automobile EE architecture is evolving towards vehicle centralisation + zone and vehicle centralisation. The domain controller undertakes the main logic for the vehicle as a whole, and the application of service communication protocol based on the SOA design idea in the field of the automobile has become a new technical trend. SOA not only realises the cross-domain integration of vehicle capabilities, but also realises the service communication capability between vehicles and clouds.

Vehicle-cloud cooperation is based on the standardised vehicle-cloud unified interface and builds a cloud-end digital vehicle, supports remote access and interacts with other IoE devices. In the application scenario, service communication between vehicle and cloud can achieve the efficient collaboration of capabilities between vehicle and cloud. It is also possible to enhance the intelligent experience of the whole vehicle by freely combining the capabilities between vehicle and cloud.

At present, the main pain points of vehicle-cloud cooperation are that vehicle-cloud interface standards are not uniform, considerable adaptation work is needed to access the IoT platform, and there remains a question about how to realise controlled access once access has been achieved. Through standardisation, a lot of the adaptation work resulting from non-uniform standards can be reduced and the highly fragmented problem of similar IoT protocols and standards can be avoided.

Domestic vehicle-cloud cooperation can define a unified standard vehicle-cloud interface on standardisation and cooperate with the existing IoT platform to realise IoE. These include the Vehicle Signal Specification (VSS) formulated by COVESA abroad, WoT Specification and Vehicle Information Service Specification (VISS) formulated by W3C.

(7) Mobile phone vehicle interconnection

At present, mobile phone vehicle interconnection is mostly in the stage of screen projection and one-way utilisation of head unit resources by mobile phones (such as Miracast, Mirrorlink, AndroidAuto, CarPlay, CarLife). Few mobile phones and vehicles can achieve hardware and software coordination. Some of those which implement similar functions (such as Huawei's HarmonyOS) use their own private internal protocols.

Mobile phone vehicle interconnection involves high-security and high-speed protocol communication, device discovery and service discovery, device hardware resource sharing, standardised application services and other technologies, and has the following advantages:

a. mobile phones use the rich hardware resources of vehicles through interconnection, such as large screen, multi-zone microphone, extensive vehicle sensors, etc.;

b. head units use the rich software ecology of mobile phones, the hash rate of AI chips, 5G communication rate and the unique content services of mobile phone manufacturers through interconnection.

Mobile phone vehicle interconnection has the following pain points:

a. there are many hardware models for the head unit, OS versions, OS differences and customisation of software protocols;

b. a mobile phone OS has many versions, fast update frequency and many interconnection protocols.

Due to the long R&D cycle and slow updating times for the head unit, vehicle intelligence can continue to be achieved for a long time through docking with interconnection standards and by means of mobile terminals with fast updating, iteration and rapid hardware upgrading.

Mobile phone and head unit manufacturers can cooperate to develop interconnection protocols, open up the boundaries between mobile phones, head unit and IoT devices, and realise the IoE. At present, some domestic manufacturers have spontaneously formed similar alliances, such as ICCOA and ICCE.

2.5 Intelligent cockpit evaluation

In the development of the intelligent cockpit, different participants are trying to evaluate the intelligent cockpit from different angles and methods. Based on different evaluation purposes, the category and content of intelligent cockpit experience evaluation also vary.

1. From the perspective of the OEM: intelligent cockpit experience evaluation is carried out based on design and R&D.

Some OEMs will set up test benches and equipment in accordance with the goals they need to achieve for various R&D and design stages in order to carry out experience evaluation for the intelligent cockpit. The content of the evaluation mainly includes interactive experience evaluation and performance experience evaluation.

2. From the perspective of automotive software suppliers: the intelligent cockpit scheme is evaluated based on usability.

Some automotive software suppliers will verify and iterate the scheme through usability testing when designing the project scheme. For example, Thoughtworks launched the HMI usability evaluation system, which focuses on the influence of common functions on driving and evaluates this quantitatively.

3. From the perspective of automobile media: subjective evaluation is carried out with a focus on the perspective of consumers.

In recent years, various automobile media have published evaluation articles and videos on automobile forums, websites and WeChat video official accounts to evaluate experience of the intelligent cockpit for listed vehicles from a perspective that focuses on consumers. For example, the XCX-IC test evaluation system was introduced by New Mobility Company. This conducts subjective evaluation of the voice, map, entertainment and other systems in the interior instrument and centre console and directly presents actual experience results without scoring. CHEYUN.COM launched the CC-1000T evaluation system, which combines scoring and subjective evaluation to evaluate the experience of instruments, IVI and vehicle scenarios from the aspects of intelligent performance, usability and digital innovation.

4. From the perspective of third-party evaluation agencies: comprehensive, objective and quantitative evaluation is carried out for the intelligent cockpit experience.

As a third-party evaluation organisation, it is necessary to stand between consumers and automobile manufacturer clients, with both consumer and automobile professional perspectives, and conduct a comprehensive, objective and quantitative experience evaluation of the intelligent cockpit. On the one hand, the subjective and objective experience evaluation of HMI, voice interaction, scenario function, etc. is carried out in terms of safety, usefulness, efficiency and intelligence. On the other hand, other content that impacts the user experience in the intelligent cockpit, such as odour, material and image display effect, are evaluated objectively. This helps automobile customer enterprises to identify experience problems during the R&D process at an early stage and provide professional advice on cockpit experience for consumers in terms of vehicle selection and purchase.

Table 1 Research on evaluation systems for the intelligent cockpit experience

Experience evaluation system	Evaluation object	Items for evaluation	Evaluation sub-item	Evaluation method
New Mobility **XCX-IC Test**	Dashboard Console	Voice interaction system Map navigation system Entertainment system Ecological interconnection	Dashboard Wake-up mode Voice recognition rate Navigation preferences	Subjective evaluation
CHEYUN.COM **CC-1000T**	IVI Dashboard Vehicle use scenario	Intelligent performance Ease of use Appearance Digital innovation	Function diversification Speed Head unit UX Voice control	Scoring Subjective evaluation
Thoughtworks **HMI availability evaluation**	HMI	Availability	Task completion time Total scanning time Single scanning time	Scoring Objective evaluation
CAERI **CN95 Intelligent & healthy cockpit evaluation**	Voice interaction performance Interior air quality	Voice interaction effectiveness Voice interaction accuracy Voc	Voice recognition rate Voice interruption success rate	Scoring Objective evaluation
CAERI **Interactive experience evaluation of intelligent cockpit**	Performance experience HMI interaction Screen contents scenario-based function	Safe Useful High efficiency Intelligent	Stability Sight deviation Task time Logic structure	Scoring Subjective evaluation Objective evaluation

Experience evaluation of the intelligent cockpit mainly includes evaluation method, evaluation object, evaluation system and evaluation process.

1) Evaluation method

Evaluation methods include subjective evaluation and objective evaluation:

	Subjective evaluation	Objective evaluation
Measurement means	Human body	Instrument
Measurement process	Psychological and physiological feelings	Physical method
Output	Language description	Value
Accuracy	Low	High
Correction	Difficult	Easy
Sensitivity	Good	Limited
Reproducibility	Low	High
Fatigue and adaptation	Large	Small
Training effect	Large	Small
Environmental impact	Large	Small
Ease of implementation	Simple and quick	There must be instruments
Measurement range	Large (can measure satisfaction)	Small (cannot measure satisfaction)
Comprehensive judgement	Easy	Difficult

Evaluation methods include, but are not limited to, traditional methods, psychological methods and physiological methods:

Method	Description
Traditional	Including, but not limited to, questionnaire survey, interview, user diary and observation
Psychological	Including, but not limited to, SUS questionnaire, PANAS scale, PrEmo measurement method, Mood Board, Probe detection method and PPP measurement method
Physiological	Including, but not limited to, behavioural recording, facial expression measurement and eye tracking

2) Evaluation object

Evaluation objects include, but are not limited to, colour, space, atmosphere, interaction, texture, odour, layout and sound effects.

3) Evaluation system

No.	Dimension	Indicator items
1	**Visual attraction**	1. Aesthetics 2. Colour 3. Creativity
2	**Service perception**	1. Visibility 2. Attention 3. Perceptual guidance 4. Experience expectation 5. Identifiability 6. Feedback
3	**Cognitive concentration**	1. Memory load 2. Thought 3. Chart recognition 4. Operation understanding
4	**Availability**	1. Functionality 2. Safety 3. Satisfaction
5	**Emotional experience**	1. Fun in using 2. Willingness to use 3. Sensory enjoyment

4) Evaluation process

1	**Establishment of evaluation system**	Object confirmation Dimension confirmation Index confirmation Evaluation standard confirmation
2	**Scenario task design**	Test scenario design Test task design Recruitment of subjects Equipment arrangement
3	**Conduct of tests**	Arrangement of test personnel Test process design Conduct of tests User interview
4	**Data collection and analysis**	Data sorting Data analysis Results output

3 Development roadmap for intelligent cockpit standards

3.1 Thoughts on development of intelligent cockpit standards

3.1.1 Standards requirement analysis for the intelligent cockpit

3.1.1.1 Research on standardisation requirements for the intelligent cockpit

In order to fully understand the application status of intelligent cockpit technology in the Chinese market at present the project team conducted two rounds of research on the intelligent cockpit, covering the automobile, electronics, information communication and other industries. All OEMs, parts companies and testing institutions participated in the questionnaire and gave feedback.

The first round of the questionnaire included a definition of the intelligent cockpit, intelligent cockpit products in mass production and planning, standardisation requirements for the intelligent cockpit, and the technical and functional categories of the intelligent cockpit. Based on the principle of industry status quo, the intelligent cockpit is divided into three levels: 1) the basic technologies like cockpit chip, operating system, cloud platform, network transmission, etc.; 2) the equipment terminals including sensor controller, interactive communication environment terminal, etc.; 3) the functional applications such as monitoring and identification, IoE and interaction.

Based on the results of the first round of research and after three rounds of discussions, the project team initially formed the technical categories and standardisation requirements of the intelligent cockpit for basic technologies, equipment terminals and functional applications. The team then carried out a second round of questions, which investigated 66 functions and technologies of the intelligent cockpit. The questionnaire dimensions mainly included technical cost, technical maturity, consumer acceptance and standardisation requirements. These provided an important basis for completing the roadmap of technical standards for the intelligent cockpit. Specific scoring methods are shown in Table 1.

Table 1 Scoring methods

Research project	Scoring method
Technical cost	1: very high cost 2: high cost 3: average cost 4: low cost 5: very low cost
Technology maturity	1: still in conceptual stage, mass production is expected to be made over 5 years; 2: technology is not yet mature, mass production is expected to be achieved within 3~5 years; 3: technology is relatively mature, mass production is expected to be achieved in 1~3 years; 4: technology is mature, small scale mass production has been achieved; 5: technology is very mature, large scale mass production has been achieved
Consumer acceptance	1: unaccepted 2: barely accepted 3: not bad 4: favorable 5: highly favorable
Standardisation requirement time	1: in and after 2027 2: 2026 3: 2025 4: 2024 5: 2023

3.1.1.2 Questionnaire analysis

The application status evaluation of intelligent cockpit technology comprehensively considers cost, technology maturity, consumer acceptance and standardisation demand time, and selects different weight coefficients according to their importance in calculating the overall score. Technology maturity is a comprehensive evaluation of the product technology development level; the degree of product production reflects the technology development level, which is a primary consideration for technology application. Standardisation reflects the industry's attention to intelligent cockpit technology, as well as the industry's demand for unified standards. This is also a primary consideration for technology application. The cost of technology has much influence on whether or not companies put technology onto the market and could be an important factor in deciding whether products can actually be applied. However, the cost may vary depending on the different technical routes taken by companies, so which is regarded as the secondary consideration index of technology application. Consumer acceptance determines the actual application state and life cycle of products. But since this has certain subjective factors, it is again regarded as a secondary consideration index, similar to cost.

According to the above analysis, the order of importance of the four indicators of intelligent cockpit research is as follows: technology maturity (coefficient 0.3) = standardisation demand (coefficient 0.3) > technology cost (coefficient 0.2) = consumer acceptance (0.2). The evaluation factors of intelligent cockpit technology application are weighted in accordance with the above weighting coefficients.

According to the above analysis, the basic calculation formula is: technology application status score for the intelligent cockpit = weighted average of each evaluation factor score.

According to the above analysis, the basic calculation formula is:

Technology application status score for the intelligent cockpit = weighted average of each evaluation factor score - weighted average of variance of each evaluation factor score.

The scoring results for each item calculated by the above formula are shown in Table 2.

Table 2 Comprehensive scoring results for intelligent cockpit technology application status

No.	Research object	Score	No.	Research object	Score
1	Automobile Bluetooth communication terminal	4.4790	34	Intelligent headlamp	3.6779
2	Bluetooth music	4.4595	35	Remote vehicle diagnosis	3.6772
3	Automobile WLAN communication terminal	4.3818	36	Gesture recognition and interactive functions	3.6459
4	Reading lamp	4.3151	37	Noise monitoring and control	3.6090
5	Wireless phone charging	4.3141	38	Odour control	3.5836
6	Instrument screen	4.3038	39	AI assistant	3.5820
7	Mobile phone - head unit interconnection	4.2865	40	On-board fingerprint identification	3.5439
8	Centre console screen	4.2268	41	Sound field control (intelligent speaker)	3.5240
9	Remote vehicle startup	4.2040	42	Rear row screen	3.5150

No.	Research object	Score	No.	Research object	Score
10	Ambient light	4.1978	43	AR-HUD	3.4828
11	Ambient temperature control (intelligent A/C system)	4.1879	44	Armrest screen	3.4784
12	Intelligent navigation (trip planning)	4.1550	45	CMS screen	3.4615
13	Voice recognition and interactive functions	4.1426	46	Health monitoring (heart rate etc.)	3.4583
14	Digital key	4.1311	47	Cockpit domain controller	3.3865
15	Cockpit account	4.1269	48	Automobile UWB communication terminal	3.3337
16	Automobile NFC communication terminal	4.0854	49	On-board voiceprint identification	3.3153
17	Driver monitoring	4.0748	50	Ceiling screen	3.2908
18	Mobile phone - head unit mapping	4.0634	51	Digital signal lamp	3.2887
19	Air quality monitoring	4.0554	52	3D display	3.2425
20	Cellular communication terminal	4.0001	53	Multi-modal interaction function	3.2416
21	Cloud services (e.g., networked third-party services)	3.9824	54	Emotion recognition	3.2269
22	On-board face identification	3.9216	55	Intelligent light language	3.1244
23	Automobile satellite positioning communication terminal	3.9078	56	Eye identification	3.0234
24	Automobile direct connection communication terminal	3.9024	57	On-board iris identification	2.9227

No.	Research object	Score	No.	Research object	Score
25	Intelligent reminder (maintenance reminder, personalised recommendation)	3.8940	58	Intelligent surface	2.7667
26	Co-driver screen	3.8570	59	Transparent A pillar	2.7458
27	Automobile ETC communication terminal	3.8333	60	Lip language identification	2.7441
28	Occupants monitoring	3.8157	61	Front-projected holographic display	2.3867
29	Ambient humidity control	3.7842	62	Virtual reality display (AR/VR glasses)	2.3733
30	Biological presence monitoring (detention of children and pets)	3.7738	63	Window display	2.1408
31	Interior rearview mirror screen	3.7487	64	Subjective evaluation	2
32	Cockpit security	3.7330	65	Objective evaluation	2
33	Intelligent seat	3.6944			

3.2 Research status of intelligent cockpit standards at home and abroad

3.2.1 Existing relevant standards for the intelligent cockpit abroad

At present, the existing relevant standards for the intelligent cockpit abroad are mainly presented by and under the jurisdiction of the Branch Technical Committee of UN ECE WP.29 and the ISO TC22 Road Vehicles Technical Committee.

After investigation, it was found, as shown in Figure 22, that the main relevant standards for the international intelligent cockpit at present are active and passive safety for driving; there are relatively few standards related to driving comfort. At the same time, international standards are relatively concentrated in various functional areas, including the driver monitoring system, centre console screen function, human-machine interaction, E-call, etc., and there is no unified standards system. Of the five senses data for the intelligent cockpit – vision, touch, hearing, smell and taste – the standards mainly involve vision, hearing and touch.

International standard for intelligent cockpit		Intelligent cockpit function				Five-sense data					Active/ passive safety	
		Driver monitoring	Human-machine interaction	Center console screen	Emergency call	Vision	Touch	Hearing	Smell	Taste	Active	Passive
ISO series												
16505	Road vehicles Ergonomic and performance aspects of Camera Monitor SystemsRequirements and test procedures	○				○					○	
22736	Taxonomy and definitions for terms related to driving automation systems foron-road motor vehicles	○				○					○	
21956	Road Vehicles -Ergonomic Aspects of Transport Information And Control Systems - Human Machine Interface Specifications For Keyless Ignition Systems		○				○				○	
16352	Road Vehicles -Ergonomic Aspects of In-vehicle Presentation For Transport Information And Control Systems -Warning Systems		○			○	○	○			○	
17361	Intelligent transport systems - Lane departure warning systems -Performance requirements and test procedures		○			○					○	
22411	Ergonomics data for use in the application of ISOMEC Guide 71:2014		○			○	○	○			○	
20071-15	Information technology- User interface component accessibility - Part 15.Guidance on scanning visual information for presentation as text in various modalities		○			○					○	
80416-4	Basic principles for graphica symbols for use on equipment -- Part 4:Guidelines for the adaptation of graphical symbols for use on screens anddisplays (icons)			○		○						○
15638-10	Intelligent transport systems - Framework for oooperative telematicsapplications for regulated commercial freight vehicles (TARV)- Part 10 Emergency messaging system/eCall				○							○
20530-1	Intelligent transport systems - Information for emergency service support viapersonal ITS station - Part 1: General requirements and technical definition				○							○
29341 -26-10	Information technology - UPnP Device Architecture- Part 26-10: Telephonydevice oontrol protoool - Level 2 - Cal management servioe				○							○
IEC series	Audio/video, information and communication technology equipment											
63246	Multimedia systems and equipment for cars - Configurable Car InfotainmentServices (CCIS) - Part 4: Protocol	○				○						○
63033	2022 RLV Redline version Multimedia Systems and equipment for vehicles Surround view system - Part 2: Recording methods of the surround view system	○				○					○	
EN series												
614	Safety of machinery - Ergonomic design principles		○			○	○					○
62368-1	Audio/video, information and communication technology equipment			○								○
55032	Electromagnetic compatibility of multimedia equipment - Emission			○								○
62311	Assessment of electronic and electrical equipment related to human exposurerestrictions for electromagnetic fields (0 Hz - 300 GHz)			○								○

Figure 22 List of international standards for the intelligent cockpit

(1) Biometric identification/monitoring

There are four international standards related to biometric identification/monitoring:

ISO 16505-2015 Road vehicles – ergonomic and performance aspects of Camera Monitor Systems – requirements and test procedures

The standards mainly involve: CMS structure (camera, display screen, power supply, digital status output), functional structure (image acquisition, processing and display), horizontal and vertical viewing angles, camera magnification factor, angular resolution, signal-to-noise ratio, point light source, glare scenario, parking status, modulation transfer function.

ISO/SAE PAS 22736:2021 Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles.

The standard mainly involves: definition of active safety system and automatic driving system, definition of dispatching and driving automation, driver support function, unmanned task, unmanned operation, fault mitigation strategy, vehicle horizontal and vertical control, minimum risk condition, system fault, object and event detection, monitor setting and operation domain, remote driving and assistance, intervention request and supervision, where the L2-L3 automatic driving system requires monitoring in order to compare the driver's current state with the set threshold state and decide whether intervention is necessary. The intervention will end once the driver's state is improved to the threshold, thus forming a closed loop.

IEC TR 63246-4 ED1 Multimedia systems and equipment for cars – Configurable Car Infotainment Services (CCIS) – Part 4: Protocol

The standard mainly involves: system model, users and service processes (user types, service processes of various customers)
IEC 63033:2022 RLV Redline version Multimedia Systems and equipment for vehicles – Surround view system – Part 2: Recording methods of the surround view system

The standards mainly involve: video recording, recording, observer, camera picture quality (resolution, image quality), camera calibration, FOV, time characteristics (start-up time, frame rate and delay).

(2) Human-machine interaction

ISO 21956:2019 Road vehicles — Ergonomic aspects of transport information and control systems — Human machine interface specifications for keyless ignition systems

The standard mainly involves: human-machine interaction of keyless ignition, which complements SAE J2948with the goal of helping to minimize user-initiated errors, including the inability to start and stop the vehicle propulsion system, exiting the vehicle when the automatic transmission is in the non-parking position, exiting the vehicle when the vehicle propulsion system is activated, and exiting the vehicle when the vehicle propulsion system is disabled but the accessories or electrical system are activated, actuation of the keyless ignition control with automatic start/stop system, actuation to start or stop the vehicle propulsion system in case of emergency, actuation to start the propulsion system when the key battery is low, actuation of keyless ignition control of the key carrying device is started, and recommendations for determining detailed alarms and status indications using specific use case examples.

ISO/TR 16352:2005 Road vehicles — Ergonomic aspects of in-vehicle presentation for transport information and control systems — Warning systems

The standards mainly involve: alarm signals (effects, types of invalid signals, emergency mapping, alarm theory and design suggestions), psychological and physiological factors (human process of handling alarm signals, workload, sensory patterns, differences in expectations and individualisation), visual warning signals (physiological and psychological basis, types of visual display, design parameters), auditory warning (physiological and psychological basis, advantages of hearing, tone signals and auditory icons, and voice output, comparison of output signal and tone signal), action alarm (tactile advantage, design parameters), information redundancy (visual/auditory/tactile combination, visual/auditory quality and indication of display, main alarm), comparison of warning types (non-verbal coded visual/auditory performance, abstract and spatial information, etc.), warning of assistant driving system (distance warning, collision, side obstacle, lane departure, assistant driving of low-speed operation, information availability).

ISO 17361:2017 Intelligent transport systems — Lane departure warning systems — Performance requirements and test procedures

The standards mainly involve: system functions, system classification, optional functions, test environment conditions (test process conditions, test vehicle conditions, test system installation and configuration, test procedures and passing standards), parameters recoverable from data records, warning generation test, repeatability test and false alarm test.

ISO/TR 22411:2021 Ergonomics data for use in the application of ISO/IEC Guide 71:2014

The standards mainly involve: data selection and format, sensory characteristics and abilities (sight, hearing, touch and heat), physical characteristics and abilities (body shape, hands, upper body, lower body and muscles), cognitive characteristics and abilities (attention, information processing, memory, language and writing).

ISO/IEC TS 20071-15:2017 Information technology — User interface component accessibility — Part 15: Guidance on scanning visual information for presentation as text in various modalities.

The standards mainly involve: visual information scanning (content, frame, equipment, software, scanning mode, equipment type, software type), scanning information display mode (selection setting, scanning information processing) and text presentation (barcode recognition, short text recognition, printed text recognition, object colour recognition, specific object recognition, shape and number recognition, logo recognition).

EN 614 Safety of machinery – Ergonomic design principles

The standards mainly involve: design principles (barrier-free design for disabled people, design taking into account people's body size and movement, people's psychological ability, and the influence of the physical working environment on people) and mechanical design based on ergonomics.

(3) Display screen

ISO 80416-4:2005 Basic principles for graphical symbols for use on equipment — Part 4: Guidelines for the adaptation of graphical symbols for use on screens and displays (icons)
The standards mainly involve: design principles of screens and graphic displays (icon types, graphical symbols, colours), icon construction (cell size, location, line drawing, resolution, filled area, distinguishability, arrow) and icon behavior (status indication, animated icon, dynamic icon).

EN 62368-1:2020 Audio/video, information and communication technology equipment

The standards mainly involve: protection types of multimedia equipment (electrical, mechanical and thermal damage), protection measures and equipment for technicians, electrical fire model, protection measures (fire source, temperature, voltage and current), energy classification, explosion-proof requirements, etc.

EN 55032 2012-07 Electromagnetic compatibility of multimedia equipment – Emission

The standards mainly involve: electromagnetic radiation of multimedia equipment (conduction, radiation combination, floor measurement, desk measurement), cable layout, measuring instruments and procedures, decision tree model of detectors, voltage source matching network, cable insulation and shielding.

EN 62311 2020 Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)

The standards mainly involve: evaluation methods (radiation frequency range, evaluation process), uncertainty and compliance, non-uniform field and multi-frequency source, limit compliance evaluation (evaluation items, evaluation methods, results analysis) and equipment using external antennae.

(4) eCall

ISO 15638-10:2017(en) Intelligent transport systems — Framework for cooperative telematics applications for regulated commercial freight vehicles (TARV) — Part 10: Emergency messaging system/eCall

The standards mainly involve: vehicle data service requirements, data application services (quality requirements, testing requirements, labels), supervised service features (general principles, common features, operation sequence, service quality, information security, data naming content and quality, software engineering quality system, quality monitoring station, audit, data access policy) and emergency call for help (service description and scope, operation concept, operation sequence of named content).

ISO 20530-1:2020(en) Intelligent transport systems — Information for emergency service support via personal ITS station — Part 1: General requirements and technical definition

The standards mainly involve: the overall framework, implementation of application cases (application clusters and cases), and the definition of data exchange messages (collision detection, vehicle speed, airbag deployment inspection, rollover inspection and accident data transmission).

ISO/IEC 29341-26-10:2017 Information technology — UPnP Device architecture — Part 26-10: Telephony device control protocol — Level 2 — Call management service

The standards mainly involve: symbols and regulations (text, data type, vendor definition) of telephone call service, definition of service scale (service type, call management service architecture, state variables, events and adjustments, operation and service behaviour model) and XML service description attachments.

3.2.2 Existing relevant standards for the domestic intelligent cockpit

At present, the existing relevant standards for the intelligent cockpit in China are mainly presented by and come under the jurisdiction of the Branch Technical Committee of TC 114 National Technical Committee of Auto Standardisation.

The main existing standards under the jurisdiction of NTCAS include (under preparation and published): GB 15084-XXXX Performance and Installation Requirements of Devices for Indirect Vision on Motor Vehicles, GB/T Road Vehicles – Performance Requirements and Test Methods of Navigation and Positioning System – Satellite Navigation, GB/T Passenger Vehicle Head-up Display System Performance Requirements and Test Methods, GB/T 38892-2020 On-board Driving Video Recording System, GB/T 26775-2011 On-board Audio and Video System, GB/T Performance Requirements and Test Methods for Driver Attention Monitoring System, QC/T 1166-2022 Automobile Streaming Media Rearview Mirror, GB/T Road Vehicles – Performance Requirements and Test Methods for Hands-Free Call and Voice Interaction, GB/T 41484-2022 Automobile Ultrasonic Sensor Assembly, GB/T Automotive Active Infrared Detection System, GB/T Automotive Passive Infrared Detection System, GB/T Visual Signals in Automobiles – Technical Requirements and Test Methods, and GB/T Intelligent and Connected Vehicles – Technical Requirements and Test Methods for On-board Operating System.

At the same time, TC 485 aims at standards relating to the IoV, and mainly carries out standardisation work for the application of the IoV enhanced by the public telecommunication network, vehicle communication equipment, etc. TC 268 carries out standardisation work for vehicle information interaction, navigation and positioning, driving assistance, traffic information collection, electronic toll collection, communication and information security covering ITS. TC 576 carries out standardisation work in fields including traffic information collection and road condition monitoring. TC 28 carries out standardisation work for electronic and electrical equipment, software technology, data application, platform and service specifications relating to vehicle networking. TC 242 carries out standardisation work in the fields of vehicle audio and video equipment. TC 260 aims to carry out standardisation work around the network security of automotive electronic systems and the security of on-board information services.

3.2.3 Applicability analysis of existing relevant standards

There are a large number of domestic and foreign standards related to the intelligent cockpit, so applicability between these and the intelligent cockpit is not analysed on an individual basis due to space limitations. However, whether the concept and its main technical characteristics within the scope of the 'intelligent cockpit' are considered, and whether technical requirements and test methods are put forward based on the related functions of the 'intelligent cockpit' can be roughly analysed according to the standardisation process time period for standard items. In accordance with the time node of industry development and technological progress post 2020, standard items in the stage of standardisation work – such as pre-research, drafting and technical verification – can be regarded as standard items with high applicability to the intelligent cockpit. However, standard items that have completed technical work prior to 2020 can be regarded having poor applicability to the intelligent cockpit, and their applicability to the intelligent cockpit still needs to be independently assessed.

3.3 Standard formulation principles

3.3.1 Basic principles

Based on China's national conditions and overall planning, and based on China's intelligent cockpit technology, development status and future planning, if the development of intelligent cockpit standards technology and product realisation is to be supported, the competent authorities must play a leading role in top-level design, organisation and coordination, policy formulation and other aspects, and establish an automobile intelligent cockpit standards system appropriate to China's national conditions.

Taking full account of the characteristics of technologies and standardisation, the development of basic standards and the standards on key technologies is to speed up to support the establishment of intelligent cockpit standard system. In line with the technical maturity and application requirements for the intelligent cockpit, the work plan and timetable for related standardisation projects is to be rationally programmed to vigorously advance the research and formulation of urgently needed standards.

Strengthen cross-field and cross-industry cooperation, fully mobilise resources for the automobile, communication and other industries, and drive vehicle manufacturers, suppliers and testing institutions to jointly participate in the development of standards relating to the intelligent cockpit with a view to promoting industrial development.

Carry out relevant standards research around products or functional items that affect users' safety and health, have high frequency of user use and have obvious user experience perception. Establishing a standards system will drive technical development of intelligent cockpit products and improve user satisfaction.

Combining the current situation of intelligent cockpit standards at home and abroad, we will give priority to the layout of vacant intelligent cockpit standards in international standards, enhance our country's right to speak in the field of the intelligent cockpit, and at the same time strengthen the transformation and simultaneous formulation of advanced international standards based on the consideration of international standards coordination.

3.3.2 Priority principles for standard formulation

Based on basic universality, technology application status, safety relevance and policy promotion, the priority order of intelligent cockpit standards formulation is comprehensively evaluated and the four factors are defined as follows:

(1) Basic universality: to evaluate whether this standard is a basic universal standard, please refer to the basic and universal standards in the standards system table for intelligent and connected vehicles in the Guidelines for Construction of National Standards System for Internet of Vehicles (IoV) Industry (intelligent and connected vehicles).

(2) Technology application status: this comes from 'Table 16 Comprehensive scoring results of intelligent cockpit technology application status' in this paper, in which the top 50% of items in the table are rated as 'good application status'.

(3) Safety relevance: evaluate whether this standard is strongly related to driving safety, mainly taking into consideration whether use of this technology/function will affect driving safety.

(4) Policy promotion: this comes from related mandatory installation projects involved in GB 7258-2017, etc.

Priority evaluation follows the following logic: the quantity marked with ✓ is 0: low; the quantity marked with ✓ is 1: medium; the quantity marked with ✓ is greater than 1: high.

The intelligent cockpit standards plan is formulated in accordance with the priority order; projects with high priority will start standards formulation before 2022. Projects with medium priority will start standards formulation in 2023. Projects with low priority will start standards setting in 2024 and beyond. The pre-research cycle of each project is flexibly adjusted in line with the complexity of each project.

3.4 Standards system architecture for the intelligent cockpit

3.4.1 System architecture

The framework of the intelligent cockpit standards system is defined as having four parts: Basic, General, Product and Technology Application, and Related Standards. At the same time, in line with the similarities and differences in content scope and technical level of the specific standards, the four parts are further subdivided, as shown in Figure 23.

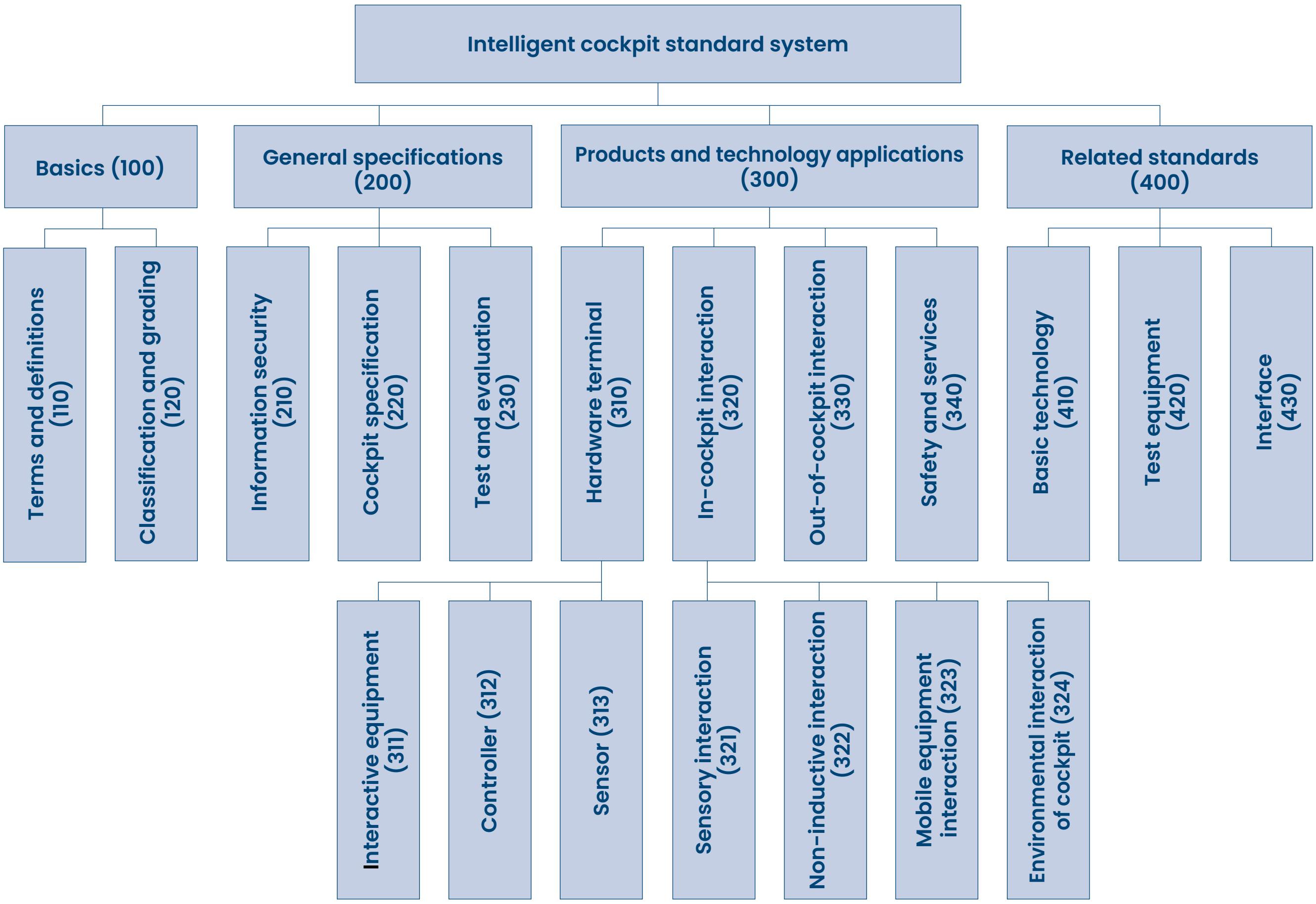


Figure 23 Standards system framework for the intelligent cockpit

3.4.2 System contents

1. Basic (100)

Basic standards include two basic standards: terms and definitions, classification and grading of the intelligent cockpit. Terms and definition standards are used to unify the basic concepts relating to the hardware, software and functions of the intelligent cockpit, provide a common language relating to the intelligent cockpit for the industry, and provide support for the formulation of other parts of the standards. Classification and grading standards are mainly used to classify and grade the interactive functions of the intelligent cockpit and are used for subsequent functional evaluation and safety requirements.

2. General (200)

General standards are classified into information security, cockpit specification and test and evaluation standards. Information security mainly aims at the communication security that supports the function of the intelligent cockpit, data collection of the cockpit system, the security of stored user (environment) data and the protection of personal privacy. Cockpit specifications include safety specifications for visual and auditory display with drivers or other occupants when using non-driving functions or supporting functions. Test and evaluation: a unified test and evaluation method is proposed for the safety and usability of cockpit functions.

3. Products and technology applications (300)

Product and technical application standards include hardware terminal, in-cockpit interaction and out-of-cockpit interaction.

Hardware terminal standards mainly refer to the performance requirements and test methods of equipment terminals and related controllers that realise the interactive function of the intelligent cockpit. In-cockpit interaction mainly refers to the relevant specifications of non-driving interaction functions in the vehicle, including non-sensory interaction functions based on biological information identification such as blood pressure, ECG, EEG, iris and limb behaviours, sensory interaction functions based on eye movements, gestures, voice and touch, interactive functions using hand-held and wearable intelligent mobile terminals, and environmental interaction functions such as sound field and air quality (temperature, humidity and odour) in the cockpit. Out-of-cockpit interaction mainly refers to the interactive functions generated by vehicles and external traffic participants through light, sound and wireless connection. Out-of-cockpit interaction mainly refers to the interactive functions generated by vehicles and external traffic participants.

4. Related standards (400)

Related standards refer to the basic technology and interface standards that support the realisation of intelligent cockpit functions, the test equipment standards that assist in functional testing and evaluation, and the interior decoration and material standards relating to cockpit hardware.

Table 3 Standard system framework of the intelligent cockpit

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
Basics (100)						
Terms and definitions (110)						
110-1	Term and definition of the automobile intelligent cockpit	National standard	Recommended	To be started		High
Classification and grading (120)						
120-1	Intelligent classification of the automobile cockpit	National standard	Recommended	To be started		High
General (200)						
Information security (210)						
210-1	Technical requirements for information security of intelligent cockpit communication	National standard	Recommended	To be started		High

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
Cockpit specification (220)						
220-1	Intelligent and connected vehicle – General safety specification for users to use non-driving task functions	National standard	Recommended	To be started		High
220-2	Intelligent and connected vehicle – General specification for signaling prompt	Industrial standard	Recommended	To be started		High
220-3	Intelligent and connected vehicle – Interaction specification between driving automation system and external traffic participants	National standard	Recommended	To be started		Medium
220-4	Specification for visual display of the automobile intelligent cockpit	National standard	Recommended	To be started		High
220-5	Specification for hearing display of the automobile intelligent cockpit	National standard	Recommended	To be started		High
Test and evaluation (230)						
	Specification for functional evaluation of the automobile intelligent cockpit	Industrial standard	Recommended	To be started		Medium
Products and technology applications (300)						
Hardware terminal (310)						
Interactive equipment (311)						
311-1	Performance requirements and test methods for on-board display system	National standard	Recommended	In pre-research	ISO/AWI TS 8231	High
311-2	General technical requirements and test methods for cockpit display screen	National standard	Recommended	To be started		Medium

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
311-3	Intelligent and connected vehicle – General requirements and test methods for 3D display	Industrial standard	Recommended	To be started		Low
311-4	Intelligent and connected vehicle – General requirements and test methods for projection display	Industrial standard	Recommended	To be started		Low
311-5	Intelligent and connected vehicle – Technical requirements and test methods of virtual reality display	Industrial standard	Recommended	To be started		Low
311-6	General requirements and test methods for intelligent surface display of automobiles	National standard	Recommended	To be started		Low
311-7	Performance requirements and test methods for passenger vehicle head-up display system	National standard	Recommended	In pre-research	ISO/AWI TS 21957	High
311-8	Performance requirements and test methods for intelligent head-mounted display equipment	Industrial standard	Recommended	To be started		Low
311-9	Performance requirements and test methods for automobile transparent column A display system	National standard	Recommended	To be started		Low
311-10	Automobile streaming media rearview mirror	Industrial standard	Recommended	Published QC/T1166-2022		High
311-11	Performance requirements and test methods for intelligent headlight	National standard	Recommended	To be started		Medium
311-12	Performance requirements and test methods for digital signal lamp	National standard	Recommended	To be started		Low
311-13	Performance requirements and test methods for power amplifier	National standard	Recommended	To be started		Low

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
311-14	Performance requirements and test methods for loudspeaker	National standard	Recommended	To be started		Low
311-15	On-board wireless communication terminal	National standard	Recommended	Project approved 20193386-T-339		High
311-16	Technical requirements and test methods for automotive Bluetooth communication terminal	Industrial standard	Recommended	To be started		Medium
311-17	Technical requirements and test methods for automotive WLAN communication terminal	Industrial standard	Recommended	To be started		Medium
311-18	Technical requirements and test methods for automotive NFC communication terminal	Industrial standard	Recommended	To be started		Medium
311-19	Technical requirements and test methods for cellular communication terminal	Industrial standard	Recommended	To be started		Medium
311-20	Technical requirements and test methods for automotive UWB communication terminal	Industrial standard	Recommended	To be started		Low
311-21	Technical requirements and test methods for on-board information interaction system based on LTE-V2X direct communication	National standard	Recommended	Application for project approval		High
311-22	Technical requirements and test methods for on-board information interaction system based on 5G-V2X direct communication	National standard	Recommended	In pre-research		Medium

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
311-23	Technical requirements and test methods for on-board positioning system Part 1: Satellite positioning Part 2: Inertial navigation	National standard	Recommended	Part 1 Application for project approval Part 2 In pre-research		High
311-24	ETC system – On-board electronic unit	National standard	Recommended	Published		High
Controller (312)						
312-1	General technical requirements and test methods for cockpit domain controller	National standard	Recommended	To be started		Low
312-2	General technical requirements and test methods for door controller	National standard	Recommended	To be started		Low
312-3	General technical requirements and test methods for seat controller	National standard	Recommended	To be started		Low
312-4	General technical requirements and test methods for A/C controller	National standard	Recommended	To be started		Low
Sensor (313)						
313-1	Vehicle camera	Industrial standard	Recommended	Published		High
313-2	Performance requirements and test methods of millimeter wave radar for automobiles	National standard	Recommended	In pre-research		Low
313-3	Performance requirements and test methods for air quality sensor	National standard	Recommended	To be started		Low
In-cockpit interaction (320)						
Sensory interaction (321)						

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
321-1	Intelligent and connected vehicle – Performance requirements and test methods for gesture interaction system	National standard	Recommended	To be started		Low
321-2	Performance requirements and test methods for hands-free call and voice interaction of road vehicles	National standard	Recommended	Project approved 20213581-T-339		High
321-3	Performance requirements for haptic interaction system of intelligent and connected vehicle	National standard	Recommended	To be started		Low
321-4	Performance requirements and test methods for multi-modal interaction system	Industrial standard	Recommended	To be started		Low
321-5	Performance requirements and test methods for intelligent seat system	National standard	Recommended	To be started		Low
321-6	Technical requirements and test methods for ecological application of on-board games	Industrial standard	Recommended	To be started		Low
Non-inductive interaction (322)						
322-1	Intelligent and connected vehicle – Technical requirements and test methods for on-board face identification system	National standard	Recommended	In pre-research		Medium
322-2	Intelligent and connected vehicle – Technical requirements and test methods for on-board palmprint identification system	National standard	Recommended	In pre-research		Low
322-3	Intelligent and connected vehicle – Technical requirements and test methods for on-board fingerprint identification system	National standard	Recommended	In pre-research		Low

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
322-4	Intelligent and connected vehicle – Technical requirements and test methods for on-board voiceprint identification system	National standard	Recommended	In pre-research		Low
322-5	Intelligent and connected vehicle – Technical requirements and test methods for on-board iris identification system	National standard	Recommended	In pre-research		Low
322-6	Performance requirements and test methods for driver attention monitoring system	National standard	Recommended	Published GB/T 41797-2022		High
322-7	Intelligent and connected vehicle – Performance requirements and test methods for biological retention monitoring system	National standard	Recommended	To be started		High
322-8	Performance requirements and test methods for automobile occupant emotion recognition system	National standard	Recommended	To be started		Low
322-9	Performance requirements and test methods for automobile occupant health monitoring system	National standard	Recommended	To be started		Low
Mobile equipment interaction (323)						
323-1	Intelligent and connected vehicle – Performance requirements and test methods for digital key	National standard	Recommended	In pre-research		High
323-2	Wireless charging performance requirements of in-cockpit mobile equipment	National standard	Recommended	To be started		Medium

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
323-3	Performance requirements and evaluation specification of interconnection between mobile terminal and on-board equipment	National standard	Recommended	To be started		Medium
Environmental interaction of cockpit (324)						
324-1	Technical requirements and test methods for in-cockpit sound field partition	National standard	Recommended	To be started		Low
324-2	Technical requirements and test methods for in-cockpit active noise reduction system	National standard	Recommended	To be started		Low
324-3	Technical requirements and test methods for in-cockpit air quality diagnosis system	National standard	Recommended	To be started		Medium
324-4	Technical requirements and test methods of in-cockpit space sound	National standard	Recommended	To be started		Low
324-5	Performance requirements and test methods for in-cockpit lighting	National standard	Recommended	To be started		Medium
324-6	Technical requirements and test methods for in-cockpit intelligent temperature control	National standard	Recommended	To be started		Medium
324-7	Technical requirements and test methods for in-cockpit intelligent humidity control	National standard	Recommended	To be started		Medium
324-8	Technical requirements and test methods for vehicle remote control system	National standard	Recommended	To be started		Medium
324-9	Performance requirements and test methods for odour control of intelligent and connected vehicle	Industrial standard	Recommended	To be started		Low

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
Out-of-cockpit interaction (330)						
330-1	Performance requirements and test methods for intelligent vehicle light language	Industrial standard	Recommended	To be started		Low
330-2	Technical requirements and test methods for exterior sound system	National standard	Recommended	To be started		Low
330-3	Technical requirements and test methods for exterior voice recognition system	National standard	Recommended	To be started		Low
Safety and services (340)						
340-1	Application requirements and evaluation methods for vehicle maps	National standard	Recommended	To be started		High
340-2	Information security requirements for cockpit account	Industrial standard	Recommended	To be started		High
340-3	Performance requirements and test methods for automobile cockpit security system	National standard	Recommended	To be started		High
340-4	Technical requirements and test methods for vehicle remote diagnosis	National standard	Recommended	To be started		Low
Related standards (400)						
Basic technology (410)						
410-1	General technical requirements for communication protocols	Industrial standard	Recommended	To be started		Low
410-2	Technical specification for cloud service platform of intelligent and connected vehicle	Industrial standard	Recommended	To be started		Medium
410-3	Functional requirements and test methods for IoV operation platform	Industrial standard	Recommended	To be started		Medium

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
410-4	General technical requirements for software upgrade	National standard	Compulsory	Advice solicitation		High
410-5	Technical requirements and test methods for computing chips of the automotive intelligent cockpit	Industrial standard	Recommended	To be started		Low
410-6	Technical requirements and test methods for control chips of the entertainment system in the automotive centre console	Industrial standard	Recommended	To be started		Low
410-7	General technical requirements and test methods for automobile gateways	National standard	Recommended	To be started		Low
410-8	General technical requirements and test methods for T-box	National standard	Recommended	To be started		Low
Test equipment (420)						
420-1	Road vehicles – Networked function test equipment for the intelligent and connected vehicle	National standard	Recommended	To be started		Medium
420-2	Road vehicles -–Technical specification for test object monitoring and control of intelligent and connected vehicle Part 1: Functional requirements, specifications and communication protocols Part 2: Description format of test scenario	National standard	Guided by	To be started		Medium
Interface (430)						
440-1	Electrical interface requirements and test methods for hardware	National standard	Recommended	To be started		Low

Standard project and classification		Standard type	Standard nature	Status	Alternative standard/ adopted standard	Priority
440-2	Functional interface requirements and test methods for software	National standard	Recommended	To be started		Low
440-3	Requirements and test methods for interface between TSP platform and terminal	National standard	Recommended	To be started		Low
440-4	Intelligent and connected vehicle – Technical specification for application software	Industrial standard	Recommended	To be started		Low
440-5	Intelligent and connected vehicle – Technical specification for interactive data receiving interface	National standard	Recommended	To be started		Low
440-6	Interface requirements and test methods for vehicle controller and display terminal	National standard	Recommended	To be started		Low
440-7	Interface requirements and test methods for entertainment peripherals of automobiles	National standard	Recommended	To be started		Low
440-8	Communication interface requirements and specifications for child seats	National standard	Recommended	To be started		Low

3.5 Standard planning for the intelligent cockpit

Based on the intelligent cockpit standard system framework, combined with the standard formulation priority conclusion, the suggested formulation time for subsequent intelligent cockpit standards is shown in Table 4.

Table 4 Recommended national standard planning for the intelligent cockpit

No.	Standard item	2022	2023	2024	2025	2026
1	Term and definition of the automobile intelligent cockpit		■	■		
2	Intelligent classification of the automobile cockpit		■	■		
3	Technical requirements for information security of intelligent cockpit communication		■	■		
4	General safety specification for users to use non-driving task functions		■	■		
5	Interaction specification between driving automation system and external traffic participants		■	■		
6	Specification for visual display in the automobile intelligent cockpit		■	■		
7	Specification for hearing display in the automobile intelligent cockpit		■	■		
8	General requirements and test methods for intelligent surface display in automobiles				■	■
9	Performance requirements and test methods for the gesture interaction system				■	■
10	Performance requirements for the haptic interaction system of intelligent and connected vehicles				■	■
11	Performance requirements and test methods for the intelligent seat system				■	■

No.	Standard item	2022	2023	2024	2025	2026
12	Technical requirements and test methods for the biological identification system					
13	Performance requirements and test methods for the driver attention monitoring system					
14	Performance requirements and test methods for the biological presence system					
15	Performance requirements and test methods for the automobile occupant emotion recognition system					
16	Performance requirements and test methods for the automobile occupant health monitoring system					
17	Performance requirements and evaluation specification for interconnection between the mobile terminal and on-board equipment					
18	Performance requirements and test methods for the digital key					
19	Technical requirements and test methods for the in-cockpit air quality diagnosis system					
20	Technical requirements and test methods for the in-cockpit intelligent temperature control					
21	Technical requirements and test methods for the in-cockpit intelligent humidity control					
22	Road vehicles – networked function test equipment for the intelligent and connected vehicle					

No.	Standard item	2022	2023	2024	2025	2026
23	Road vehicles – technical specification for test object monitoring and control of intelligent and connected vehicle Part 1: Functional requirements, specifications and communication protocols Part 2: Description format of test scenario			■	■	
24	Intelligent and connected vehicle – technical specification for interactive data receiving interface				■	■

Appendix references

1 Peng Siyu. Intelligent cockpit race has a bright future [N]. China Securities Journal, 2022-07-19(A07).

2 Su Xiaomin. White paper on research of intelligent cockpit market and technology development trend. IHS Markit, 2021-07