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Build Innovation System of Third Generation of Agricultural Machinery in China

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Abstract

Agricultural mechanization and intelligent agricultural machinery equipment are important basis for improving agricultural production efficiency and rural productivity, and changing the mode of agricultural development. In the past 70 years, China's agricultural machinery industry has made remarkable achievements. It has become the largest agricultural machinery country in the world, though the backwardness before liberation. Nevertheless, there is still a huge technical gap between China and established powers in the field of agricultural machinery. "Big but not strong" has become the main feature at this stage. To realize the breakthrough "from big to strong" in agricultural machinery industry, the fundamental path is to establish an agricultural machinery innovation system suitable for China's agricultural production operation mode. This study takes tractor as a typical representative of agricultural machinery industry, and reviews the development process of agricultural machinery industry system in China. Then we divide the agricultural machinery industry system of new China into different generations according to the technological development and the reform of land system. The aim and content of the new generation (third generation) agricultural machinery innovation system are described emphatically. We also discuss the application of new technology innovation system in the Yellow River Delta, and introduce how to build the application system of the third-generation agricultural machinery. Finally, some suggestions are given for the construction of the independent and controllable third generation agricultural machinery innovation system of China.

Keywords

intelligent agricultural machinery; industrial distribution; the Third Generation of Agricultural Machinery Innovation System of China; intelligent agriculture; development suggestion

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Abstract: Agricultural mechanization and intelligent agricultural machinery equipment are important basis for improving agricultural production efficiency and rural productivity and changing the mode of agricultural development. In the past 70 years, China's agricultural machinery industry has made remarkable achievements. It has become the largest agricultural machinery country in the world, despite the backwardness before 1949. Nevertheless, there is still a huge technical gap between China and established powers in the field of agricultural machinery. "Big but not strong" has become the main feature at this stage. To realize the breakthrough "from big to strong" in agricultural machinery industry, the fundamental path is to establish an agricultural machinery innovation system suitable for China's agricultural production operation mode. This study takes tractor as a typical representative of agricultural machinery industry and reviews the development process of agricultural machinery industry system in China. Then we divide the agricultural machinery industry system of China into different generations according to the technological development and the reform of land system. The aim and content of the new generation (third generation) agricultural machinery innovation system are described emphatically. We also discuss the application of new technology innovation system in the Yellow River Delta and introduce how to build the application system of the third-generation agricultural machinery. Finally, some suggestions are given for the construction of the independent and controllable third generation agricultural machinery innovation system of China.
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General Secretary Xi Jinping pointed out that it is necessary to vigorously promote agricultural mechanization, intelligentization, and modernization through science and technology. With the progress of science and technology, agricultural production has gradually shown a trend of "industrialization." At present, the granularity in the agricultural production process is getting finer and finer. The data-driven production organization and management model has been widely recognized, and the organization mode of agricultural production preliminarily has the characteristics of industrialized process production. It is foreseeable that this production mode will greatly liberate manpower, improve agricultural production efficiency, and profoundly affect the upstream and downstream industries of the agricultural industry. Similar to industrial production, "equipment" and "information" are the cores that run through the upstream and downstream parts of agricultural production, especially the "intelligent agricultural machinery" that is a fusion of the two, which should have the capability of information data processing and intelligent operation. Judging from the technical layout of the global agricultural machinery giants, this trend is already very obvious. However, under the situation that China's traditional agricultural machinery technology is far behind developed countries, the construction of China's agricultural machinery innovation system will inevitably always be backward if the "catch-up strategy" is still adopted. Therefore, at the beginning of the establishment of a new generation of agricultural machinery innovation system by the global agricultural machinery industry powers, it is an important exploration that China's agricultural machinery industry takes advantages in the field of information technology to build an independent and controllable agricultural machinery innovation system with information technology as the core.

Agricultural machinery generally refers to all kinds of machinery used in production processes of farming and animal husbandry as well as the initial processing and processing of agricultural and livestock products. The tractor with the main feature of providing power output is regarded as the representative product of agricultural machinery, and its technological development level reflects the overall technological level of a country's agricultural machinery industry to a large extent. Therefore, this paper will use the tractor as a representative to explain the construction ideas of the innovation system of China's agricultural machinery industry.

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1 China's agricultural machinery innovation system has long relied on "introduction, digestion, and absorption"

1.1 History of innovation and development of China's agricultural machinery innovation system

Before 1949, China did not have its own agricultural machinery industry system. After that year, the development process of China's agricultural machinery industry can be roughly divided into two stages.

The first stage began in the 1950s. During this period, China was based on the collective agricultural production model and introduced Soviet Union technology during the "First Five-Year Plan" period. For example, the construction of the "Dongfanghong Luoyang Tractor Factory" and the production of the "Dongfanghong 54" metal crawler tractor based on the KharKov Tractor Factory "DT-54," which marked the beginning of China's entry into agricultural mechanization process from iron plow. At the same time, there were also Tianjin Tractor Factory and "Tie Niu" tractors officially named in 1956, "Shangyou" tractors produced by Changchun Tractor Factory established in 1958, and the first "Hongqi" tractor produced by Shanghai Tractor Factory in 1958, as well as the tractor factories in Jiangxi, Qingjiang, Xingtai, Hubei, and Xinjiang. These tractor manufacturing enterprises represent the technological level of an era and become the top ten agricultural machinery manufacturing factories at that time, which also lays the foundation for the development of China's agricultural machinery industry to enter a new era.

The second stage began with reform and opening up. In this period, the agricultural production model changes from a collective production model to household contract responsibility system. The agricultural machinery technology system based on Soviet Union technology has been unable to meet the complex and changeable use needs in the individualized agricultural production processes, so the top ten agricultural machinery manufacturers have launched agricultural machinery products such as small four-wheel type tractor and small hand-held tractor that meet rural reforms. However, these short-lived independent innovation products belong to "indigenous manufacturing" and are insufficient to form a "system." Under the guidance of "techniques for market motives," China introduced the Italian Fiat's medium- and high-horsepower wheeled agricultural machinery system as a complete set in the late 1980s and started the industrial development process of "introduction–digestion–absorption–re-innovation" of the second generation of agricultural machinery system represented by the European and American technology system, which has given birth to agricultural machinery industry clusters and new agricultural machinery brands featuring industrial supporting facilities. Nowadays, three major agricultural machinery manufacturing bases, mainly in Luoyang in Henan, Weifang in Shandong, and Changzhou in Jiangsu, have been formed. In addition, a certain scale of agricultural machinery industry clusters has also formed in eastern Zhejiang, Wuhu in Anhui, Jilin, Hebei, and some other regions.

1.2 Periodization of China's agricultural machinery innovation system

The establishment of the system includes not only the technology system but also the manufacturing system, standard system, business system, and talent system. From the perspective of technology system alone, the above two historical stages obviously belong to two different generations of technology systems, and the temporal duration is about 30 years. From a global perspective, with the world's first unmanned intelligent agricultural machine developed by Case Corp of the United States in 2016 as a symbol, the world's agricultural machinery development has reached the threshold of a new generation of agricultural machinery system with information technology as the core.

The periodization of technological development (sorting, differentiation, and establishment of generations) is of great significance for clarifying ideas and guiding research and development (R&D). Therefore, it is necessary to divide China's agricultural machinery technology system into different generations. In the world, agricultural machinery officially originated in the first industrial revolution in the 1760s, but China did not begin to build its own agricultural machinery industry system until 1949. Therefore, the development process of China's agricultural machinery industry represented by tractors is divided into three stages, namely the three-generation system (Figure 1): ① the first- generation system—the Soviet Union technology system (1956–1986), with differential steering technology, power system, and the wet main clutch as the core; ② the second-generation system—the European and American technology system (1986–2016), with electric fuel injection, high-pressure common-rail fuel engine, and power shift as the core; ③ the third-generation system—the information technology system (2016–2046), a new generation of agricultural machinery technology system with clean energy, unmanned technology, and intelligent operations as the main features.

Both the first generation and the second generation of agricultural machinery systems have roughly gone through 30 years of development, and especially the agricultural machinery industry based on the second generation of system has made remarkable achievements since the reform and opening up. Since the National People's Congress passed the *Law of the People's Republic of China on Promotion of Agricultural Mechanization* on June 25, 2004, China's agricultural machinery industry has experienced a rapid development of a "golden decade." In 2018, the industrial operation data released by the National Bureau of Statistics of China showed that the industry's main business income was 260.132 billion CNY, and China has become the world's largest agricultural machinery manufacturing country [1].

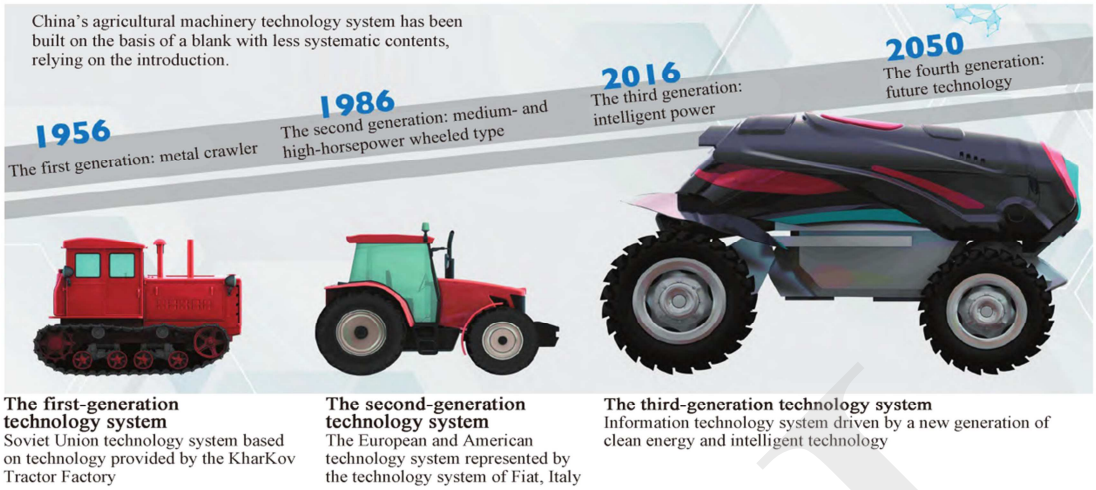

Figure 1 Periodization of the innovation system of China's agricultural machinery technology

1.3 Core problems of China's agricultural machinery industry

Since the first two generations of technology systems of China's agricultural machinery rely on technology introduction, they are chasers. This is one of the core reasons that cause China's agricultural machinery industry to be behind for a long time. Taken together, the core problems of China's agricultural machinery industry are mainly reflected in three aspects.

(1) China's agricultural machinery industry has long relied on the introduction, digestion, and absorption of agricultural machinery technologies of other countries, and lacks independent innovation technology capabilities and basic technology research, which has caused China's agricultural machinery industry to be "big but not strong." From the perspective of the overall level of agricultural machinery equipment, due to the lack of a large amount of basic common technology research, core components have long been dependent on imports. Although China has become the world's largest agricultural machinery manufacturing and consumer country, as for the overall level of equipment technology, there is still more than 30 years gap compared with the global agricultural machinery powers [2] (Table 1). From the perspective of the scale of industry leaders, the agricultural machinery industry has a fragmented competition pattern in China, and the market concentration needs to be improved. Besides, there is a serious shortage of large enterprise groups with international competitiveness and brand influence. Although the total output value of China's agricultural machinery manufacturers in 2018 was more than 260 billion CNY [3] (excluding enterprises manufacturing parts and components), the total amount was only about 1.3 times the output value (29.3 billion US dollars) of the global agricultural machinery giant John Deere. During the same period, the total output value of China's largest agricultural machinery company was less than 10 billion CNY, which is the difference of magnitude compared with the world agricultural machinery giants. The root cause is a lack of innovation. The R&D expenses of China's agricultural machinery companies account for less than 2% of corporate sales, while those of the main agricultural machinery companies in other countries are basically 4%–6%. Modern design methods and test conditions are lagging behind, and the product development cycle is 2–3 times the international level [4]. In terms of disciplines, the top 20 universities in the world for agricultural equipment disciplines are all located in Europe, the United States, and Japan, and none of the universities in China are shortlisted. In terms of talents, China's agricultural machinery industry has a talent gap of 169 000 by 2020, and the gap will be as high as 440 000 by 2025 [5].

(2) The demand for agricultural machinery products in China is diversified, but the actual situation is that there are few types of agricultural machinery, low-level repetition, and serious vicious competition. China has a vast territory and a large span of latitude and longitude, which has led to the diversified characteristics of agricultural production, such as paddy fields in the middle and lower reaches of the Yangtze River, large-scale agriculture on black soil in the northeast, dryland agriculture in Ningxia and Qinghai, hilly and mountain agriculture in the southwest, and saline-alkali land agriculture in the Bohai Bay area. The complex terrain, landforms, and climatic characteristics lead to the diversification of crop varieties and diversified operation methods, so the required agricultural equipment is also diversified. However, because the basic technology system of agricultural machinery is not in our own hands, the new product development cycle is long and the level is low. Moreover, the basic investment of core technology is insufficient. These make the products of China's agricultural machinery enterprises lack the innovation, showing low-level duplication and vicious competition. At present, China's agricultural machinery varieties are still focused on the cultivation and harvesting of the three major staple crops, and there is a lack of agricultural machinery supply for cotton, bast fiber crops, oil, sugar, and other crops. From a global perspective, there are more than 7 000 varieties of agricultural machinery products

in the world, while there are only more than 4 000 varieties of agricultural machinery products in China [6]. The phenomenon of "no machine available" in China will exist for a long time, and there is an urgent need to develop personalized agricultural machinery customization on the basis of regional production characteristics.

(3) Relying on the existing agricultural machinery system cannot meet the needs of China such as rural revitalization and the "Belt and Road" construction. All labor tools spawned by technology are the inevitable result of the interaction between productivity and production relations, and the innovation process of agricultural machinery is also a reflection of the social development process. From the perspective of social development, with the acceleration of China's urbanization process, the rural population has gradually turned into urban population. The shortage of rural labor forces has led to the phenomenon of land "abandonment." It is difficult for "post-2000s generation" and "post-2010s generation" to engage in traditional agricultural production "facing the loess and backing the sky" like their ancestors. Therefore, the implementation of the rural revitalization strategy needs to attract more middle- and high-end technical talents to return to the countryside to become professional farmers in the new era, so as to realize the development of urbanization and rural revitalization to complement each other and their benign interaction. These "new farmers" need to use high-end intelligent agricultural machinery to engage in modern agricultural production just like operating mobile phones and computers. From the perspective of the socialist land system in the new era, land belongs to the country and the collective, but in the process of the transformation of production relations, the land system also changes. From the People's Commune system after 1949, to the "household contract responsibility system" after the reform and opening up, and then to the "separation of the three rights" in land rights confirmation today, all are accompanied by changes in the degree of land intensification. The small-scale peasant economy's intensive cultivation and precision and high efficiency of large-scale production will be reflected in the innovation and transformation of production tools. The moderate scale operation of land in China and the people's demand for high-quality agricultural products will give birth to intelligent agricultural production equipment, but the current production tools cannot adapt to such development trends and requirements. In addition, the agricultural production efficiency and production level of developing countries along the "Belt and Road" are relatively low, and there is an urgent need for small- and medium-sized agricultural machinery equipment. For small- and medium-sized agricultural machinery equipment, developed countries are unwilling to manufacture, and countries along the "Belt and Road" are not capable of manufacturing. Under such circumstances, China's agricultural machinery industry contains huge development opportunities. However, the tractors currently exported to the markets of Central Asia and Africa cannot even compete with agricultural machinery companies such as Mahindra in India. Therefore, China's agricultural machinery industry urgently needs to develop third generation of agricultural machinery with advanced technology and excellent quality.

China's development is facing "a great change unseen in a century," and Sino-US economic and trade frictions are only the beginning of this major change. As one of the three major basic national securities, food security has become more and more important in the context of Sino-US economic and trade frictions. The United States regards the import of a large number of agricultural products as the main demand of the negotiation every time, and the import of a large number of agricultural products will gradually weaken China's food self-security ability. The era of relying on the third generation of agricultural machinery to promote the transformation of China's agricultural production methods has come. Just as China's mobile communications industry has gone through the historical leap of "2G follow-3G breakthrough-4G synchronization-5G lead," it is necessary to build an independent and controllable Third Generation of Agricultural Machinery Innovation System of China in the agricultural machinery industry, and find a new road of agricultural machinery industry innovation and development.

Table 1 Comparison of key technical indicators of agricultural machinery in China and other countries

Key technical indicator	Other countries	China	Gap
Mechanization level	United States: mechanization was fully realized in 1954 Canada and the former West Germany: mechanization was fully realized at the end of the 1960s Japan: mechanization was fully realized in 1982 South Korea: mechanization was fully realized in 1996	China will basically realize mechanization in 2025 and fully realize mechanization in 2035	More than half a century
Power shift technology	The United States began to adopt in 1970	R&D started in 2014	44 years
Closed center hydraulic system	The United States began to use in 1961	China started to apply in 2010	39 years
High-horsepower tractor	In 1980, the United States began to produce 250 horsepower tractors	China started the production of 240 horsepower tractors in 2015	35 years
Grain harvester with longitudinal axial flow	The United States started the production in 1976, with the cutting width of 6 m and the power of 230 horsepower	China started the production in 2011, with the cutting width of 5.3 m and the power of 220 horsepower	35 years
Mean time between failures (MTBF)	The MTBF of Italian Fiat tractors reached 350 hours in the 1980s	In 2017, the MTBF of products from a large enterprise only reached 330 hours	30–40 years
Operating efficiency of agricultural machinery	The average power per mu in the United States in 2016 was 0.06–0.07 kW	In the same period, China's average power per mu is 0.41 kW	About 6 times

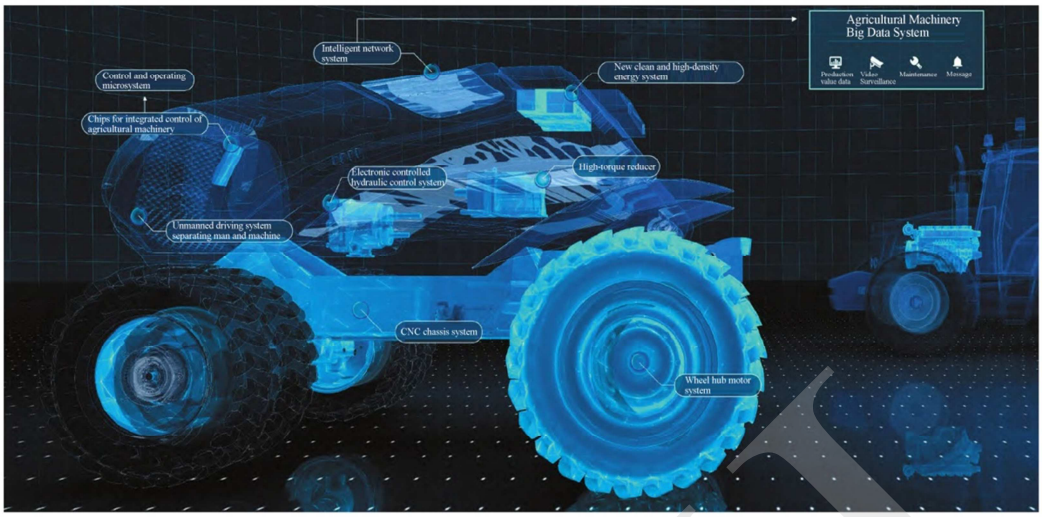

Figure 2 Core content of the third generation of agricultural machinery system

2 Establishment of independent and controllable Third Generation of Agricultural Machinery Innovation System of China

2.1 Characteristics of the Third Generation of Agricultural Machinery Innovation System of China

Marked by the world's first unmanned intelligent agricultural machine developed by the Case Corp of the United States in 2016, the world's agricultural machinery development has reached the key link of the third generation of agricultural machinery system with information technology as the core. The third generation of agricultural machinery innovation system driven by information technology has three specific characteristics: digital control of agricultural machinery through electronic technology, interconnection of agricultural machinery through networking, and unmanned operation of agricultural machinery through intelligence. Specifically, it is to use mechanical equipment as the carrier to integrate electronics, information, biology, environment, materials, modern manufacturing, and other technologies to continuously enhance the adaptability of equipment technology, expand precision operation functions, ensure the reliability of seasonal labor operations, improve the efficiency of manufacturing of complex structures, increase the coordination degree among soil, animals and plants, machines, humans, and the ecological environment, and achieve "safety and multi-function, automation and efficiency, precision and intelligence."

2.2 Core route of the Third Generation of Agricultural Machinery Innovation System of China

Since the third generation of agricultural machinery innovation technology has brought traditional agricultural machinery from mechanical control to a new stage of integration of "mechanic, control, communication, and computing," it is necessary for related units in the field of information such as the Institute of Computing Technology of the Chinese Academy of Sciences (CAS) to enter the field and actively promote the establishment of a new system, so as to establish a division of labor similar to the information industry. Taking the information industry as an example, companies in the information field such as Apple and Huawei focus on building systems, conquering key technologies, outputting solutions, and providing services. The real manufacturing is done by Foxconn, BYD, and other foundry companies. Therefore, the core thinking mode of the Third Generation of Agricultural Machinery Innovation System of China is to transform agricultural machinery into high-tech intelligent agricultural equipment with information technology as the core. The realization of intelligent agricultural equipment needs to rely on the discipline of agricultural machinery equipment with the integration of the Internet of Things, mobile communications, cloud computing, big data, artificial intelligence, and other information technologies to achieve leapfrog development. In the R&D system, an open standard system (Figure 2) needs to be constructed to maximize the respective advantages of universities, research institutes, and enterprises to jointly tackle key problems.

2.3 Key points for the construction of the Third Generation of Agricultural Machinery Innovation System of China

2.3.1 Open standards of the Third Generation of Agricultural Machinery Innovation System of China and the basic reference framework to form agricultural machinery openness

Facing the transformation of agricultural production mode, the three generation of agricultural machinery system is necessary to build a new overall framework with information technology as the support on the basis of physical

systems such as power system, transmission system, walking system, suspension system, hydraulic system, and harvesting system of traditional agricultural machinery framework. It includes distributed motor power system, centralized high-density energy system, electronic controlled deceleration system, modular harvesting system, and intelligent network system. With the standard framework and common technology platform, the development of customized agricultural machinery products is realized, and a complete set of technologies, standards, and technological processes for agricultural production services is formed to meet the management needs of future agricultural production in the full life cycle. The realization of the third generation of agricultural machinery system requires the concentration of core R&D teams in relevant fields in China to build a unified and open standard framework. Through the layering of functions and the unification of interface standards, the entire industry chain is coordinated to complete the deep integration of development and manufacturing of agricultural machinery products with information technology, promoting the collaborative upgrading of manufacturing, information industry, and agriculture.

2.3.2 R&D of core information components for agricultural machinery intelligentization

Intelligentization is the core of the Third Generation of Agricultural Machinery Innovation System of China. For this reason, it is necessary to focus on the layout of five core components to realize the intelligentization of agricultural machinery.

(1) Chip for integrated control of agricultural machinery. In response to the needs of agricultural machinery informatization, it realizes the centralized control of electronic systems of agricultural machinery and provides millisecond-level data processing and communication platforms for agricultural machinery operations, automatic driving, and other functions.

(2) Control and operating microsystem. It satisfies the core scheduling and intelligent control algorithm of agricultural machinery application diversification and completes the automatic precision control of sub-meter level in agricultural machinery operation processes.

(3) Intelligent network system. On the basis of space-earth integration network technology, the traditional agricultural machinery is upgraded to a new type of intelligent terminal with computing, communication, and control capabilities, and it supports clustering, collaboration, and wide-area communication capabilities to meet the GB-level integrated data transmission demand in agricultural machinery control processes.

(4) Unmanned driving system separating man and machine. It achieves assisted driving, remote control driving, intelligent autonomous driving in stages, with the ability to remember agricultural production and self-execution capability, and can execute autonomously on the basis of historical experience in a specific farm.

(5) Agricultural machinery big data system. It realizes EB-level storage and processing of agricultural machinery data, data-driven agricultural machinery operation control, and fault prediction and provides data and control interfaces for agricultural production applications.

2.3.3 Realizing "changing lanes and overtaking" of basic platforms of agricultural machinery on the basis of new energy technology

After years of development, China has obtained good technological accumulation in the field of new energy technology, which provides a good foundation for China to develop basic platforms of agricultural machinery with the help of new energy technology. In addition, new energy technology and information technology have natural affinity. Therefore, achieving a leap in basic platforms of agricultural machinery on the basis of new energy technology is an important idea to build the Third Generation of Agricultural Machinery Innovation System of China. The R&D of basic platforms of agricultural machinery mainly includes six aspects.

(1) Wheel hub motor system. The high-horsepower power system is improved through distributed control of wheel hub motors, including the deployment of single-machine distributed motors, the linear superposition of single-machine power, and multi-machine cluster driving relying on communication system, which improves the operation efficiency.

(2) New clean and high-density energy system. New clean energy is introduced to drive agricultural equipment in stages, from lithium battery to methane, and then to hydrogen energy power, steadily achieving 500 Wh/kg energy density, and completing the replacement of the main energy system of agricultural machinery from fuel to clean energy.

(3) Distributed control system. Aiming at the scalable wheel hub motor framework, through distributed wheel hub motor control, the distributed control of low-speed off-road walking is realized.

(4) High-torque reducer. The design and material selection of low-speed and high-torque agricultural machinery reducer is completed, and the stable control of high-horsepower agricultural machinery platform is realized.

(5) Electronic controlled hydraulic control system. Through precise control of hydraulic system with an electronic control method, it can provide more accurate control for centimeter-level agricultural machinery precision operation.

(6) CNC chassis system. In response to the needs of unmanned intelligent driving, a high-horsepower CNC chassis is designed to realize functions such as automatic steering and speed increase.

2.3.4 Conducting customized R&D and building new agricultural production services on the basis of China's geographic and geomorphic characteristics

The agricultural production of China is rich in regional

characteristics. The eastern and western regions are bounded by 400 mm annual precipitation. The eastern region has relatively good coordination of heat, water, and soil conditions and dense population, which is the concentration area with the vast majority of crops, forests, fishing, and sideline. The climate in the western region is arid, and there are big defects in the coordination of heat, water, and soil conditions, and the population is sparse. Most areas are dominated by animal husbandry, supplemented by planting. Therefore, customized agricultural equipment has a very realistic demand.

In response to the agricultural production needs of different regions, different climates, and different crops in China, diversified sets of intelligent agricultural equipment and information solutions should be provided. The long-term goal is to create an Internet-based agricultural machinery service system with the integration of agriculture, manufacturing, and service industries, to realize the "Alibaba mode" of agricultural production services with agricultural machinery as the entrance, to build a new type of business that combines the agricultural machinery industry with modern service industries, and to promote comprehensive recycling of resources and the construction of agricultural ecological environment protection, so as to support the sustainable development of agriculture.

Through the key layout of the above four aspects, a complete Third Generation of Agricultural Machinery Innovation System of China can be constructed, which covers different links such as technological innovation, product innovation, equipment innovation, standard innovation, and business model innovation. On this basis, the current production-sales model of agricultural equipment is able to change fundamentally and the transformation and upgrading of the agricultural machinery industry can be driven through information technology and intelligent technology, so as to be on par with the world's agricultural machinery powers.

3 Exploration of the Third Generation of Agricultural Machinery Innovation System of China and intelligent agriculture in the Yellow River Delta

The construction, improvement, and maturity of the Third Generation of Agricultural Machinery Innovation System of China require a development process, and a large number of tests and verifications are essential links. Therefore, in accordance with the idea of "Industry 4.0," for special terrain and landforms and special crop varieties, to achieve personalized agricultural machinery customization and to carry out technology, complete machines, and demonstration verifications are particularly important to promote the development of the third generation of agricultural machinery industry.

At present, the area of arable land in China is about 1.8 billion *mu*, but the alkalized area accounts for 6.62%. In addition, according to statistics, China has nearly 1.5 billion *mu* of saline-alkali land, accounting for about 1/10 of the world's saline-alkali land. Among them, 200 million *mu* of saline-alkali land is considered to have potential for agricultural use. As an important reserve arable land resource in China, improving and using saline-alkali land is of great significance for compensating for the decreasing area of arable land and ensuring national food security. In terms of agricultural equipment, due to the particularity of saline-alkali soil and crops, there is almost no agricultural equipment special for saline-alkali soil operations, let alone the full mechanization of "cultivation, planting, management, and harvesting."

The Yellow River Delta Agricultural High-tech Industry Demonstration Zone is the first national agricultural high-tech industry demonstration zone established in the 21st century to focus on the comprehensive management of saline-alkali land. The major tasks assigned by the State Council of China to the Yellow River Delta Agricultural High-tech Industry Demonstration Zone are as follows. The innovation-driven development strategy should be deeply implemented, and pioneering trials and demonstrations should be conducted in the comprehensive management of saline-alkali land, international scientific and technological exchanges and cooperation, institutional mechanism and policy innovation, and the simultaneous development of the "four modernizations" (i.e., modernizations of industry, agriculture, national defense, and science & technology). The replicable and extendable innovation-driven new urban-rural integrated development model should be constructed, which would become an important carrier to promote agricultural scientific and technological progress and enhance independent innovation capabilities, and a powerful engine to drive the adjustment of agricultural structure and the transformation of development methods in the eastern coastal areas. In particular, the current ecological protection and high-quality development of the Yellow River Basin have risen to a major national strategy. The Yellow River Delta Agricultural High-tech Industry Demonstration Zone has established the Yellow River Delta Agricultural High-tech Innovation Center with the active support of the CAS and the Shandong Provincial Government. The third generation of agricultural machinery technology system has become an important support point for future agricultural farming models. Therefore, the demonstration of the comprehensive application of saline-alkali land agriculture in the Yellow River Delta will be taken as an example to explore the construction of the third generation of agricultural machinery system and future agricultural farming models and establish a replicable and extendable agricultural machinery business model. The specific work includes three aspects.

3.1 Construction of pilot R&D platform for the new generation of intelligent agricultural machinery in the Yellow River Delta Agricultural High-tech Industry Demonstration Zone via resource integration

In November 2019, approved by the CAS, led by the Institute of Computing Technology of the CAS, and seven units of CAS including the Institute of Botany, the Institute of Microelectronics, and the Shenyang Institute of Automation jointly established the CAS Engineering Laboratory for Intelligent Agricultural Machinery Equipment (hereinafter referred to as "Engineering Laboratory"). After years of deployment and R&D, the Engineering Laboratory has successfully developed the first control chip of China special for intelligent agricultural machinery, intelligent networked terminal controller, agricultural machinery big data platform, and unmanned driving technology, and has taken the lead in proposing and successfully developing the world's first intelligent agricultural equipment based on the third generation of technology system. At present, the Engineering Laboratory team is in the leading domestic and world-class level in the field of new-generation intelligent agricultural equipment.

In order to further promote the development of China's new generation of intelligent agricultural machinery, the Engineering Laboratory together with the National Agricultural Machinery Equipment Innovation Center, China University of Petroleum, and University of Electronic Science and Technology of China, with the Yellow River Delta Agricultural High-tech Industry Demonstration Zone as the base, establishes Shandong Zhongke Intelligent Agricultural Machinery Equipment Technology Innovation Center. At present, the center has completed the construction of the third generation of agricultural machinery pilot R&D platform. Aiming at the key technologies of the Third Generation of Agricultural Machinery Innovation System of China, ten key technology platforms are built, including the application development platform for smart agricultural robots, the big data platform for intelligent agricultural machinery applications, the application development platform for agricultural transmission networks of super base station, the monitoring and application platform for intelligent farming facilities, and the R&D platform for super-horsepower intelligent agricultural machinery, the variable operation technology development and verification platform for agricultural machinery, the agricultural aviation system development platform with the integration of communication, navigation, and remote control, the detection and development platform for intelligent agricultural equipment production process, the perception recognition technology development platform for intelligent agriculture, and full-process unmanned operation demonstration application development platform.

3.2 Construction of a pilot assembly base around the third generation of ultra-high-horsepower intelligent networked agricultural machinery equipment

China's agricultural machinery industry must not only break through the predicament of "emphasizing the main engine and neglecting the components" but also inherit the historical experience of "main engine breakthrough and component follow-up" to drive the overall innovation and development of the industry. Therefore, while completing the core technology and core component layout of the Third Generation of Agricultural Machinery Innovation System of China, the core competitiveness is formed by gathering superior scientific and technological strength in China, including providing the core control chip of the third generation of agricultural machinery, operating system, electronic control unit (ECU), and other core components, so as to completely break the monopoly of other countries on agricultural machinery related fields. The project team will work with relevant units of CAS to carry out major equipment research around the "Honghu" series of super-horsepower intelligent networked agricultural machinery, and break through the complex system control and system integration problems of super-horsepower agricultural machinery in the Yellow River Delta Agricultural High-tech Industry Demonstration Zone, forming a series of "full-process unmanned" agricultural equipment with functions of space-earth integration network connection, intelligent operation, and autonomous operation path planning (Figure 3).

3.3 Creating a new data-driven agricultural production model with the third generation of agricultural machinery as the core

Thirty years ago, China's mobile communication field formed an industrial pattern relying on the three major telecom operators with Julong Communications, Datang Telecom, ZTE, and Huawei as the main communication equipment manufacturers. Thirty years have passed and mobile communications have entered the 5G era. Communication equipment manufacturers represented by Huawei and operators represented by China Mobile, China Unicom, and China Telecom continue to lead China's communications industry. The same situation will happen in future agricultural production. It should be realized that the core of the future business model of the Third Generation of Agricultural Machinery Innovation System of China is "service." Therefore, in addition to manufacturing of the third generation of agricultural machinery equipment, the "intelligent network" capability of agricultural machinery equipment should also be relied on to realize the service operation of agricultural machinery equipment and break the current traditional model of relying on government subsidies to sell agricultural

Figure 3 Schematic diagram of intelligent agricultural machinery based on the third generation of system

machinery to farmers. Besides agricultural machinery, intelligent agricultural production technology and intelligent services are also involved, leading to a new type of agricultural production model transformation in the intelligent era.

In order to achieve comprehensive "three-dimensional" intelligent agricultural production (Figure 4), the project team will conduct the integration of information technology and agricultural production of saline-alkali land in the five levels of "perception end, communication network, cloud, big data, and application" on the basis of 10 000 *mu* of standard test field provided by the Yellow River Delta Agricultural High-tech Industry Demonstration Zone in Shandong in accordance with the standards of the Third Generation of Agricultural Machinery Innovation System of China. ① On the perception end, the needs of soil, weather, crops, and animal husbandry production are combined to build a terminal data acquisition system with sensor technology as the core. The sensor terminal is deployed with 50 *mu* as a grid unit to realize the digital portrait of the entire agricultural production process. ② In the level of communication network, combined with the characteristics of large-scale agricultural production, Bluetooth, WiFi, 5G, and satellite combined communication methods are provided to realize the space-air-ground integrated communication and serve the agricultural production communication requirements of scenes over 10 000 *mu*. ③ In the level of "cloud" and "big data," a big data center is built around the agricultural production of saline-alkali land, and cloud computing and other technical means are combined for data analysis and mining. Through the aggregation of agricultural production data of about 10 GB (video data is processed and transmitted back) every day and the realization of comprehensive data processing of 10 000 *mu* of standard demonstration fields, the digitization of the production experience of saline-alkali land agriculture is formed. ④ In terms of application, the value of agricultural production data in saline-alkali land is explored, and the unmanned operation of the third generation of agricultural machinery equipment involving ploughing, planting, plant protection, harvesting, drying, storage, transportation, and deep processing is reversely controlled. The Yellow River Delta Agricultural High-tech Industry Demonstration Zone takes scientific and technological innovation as its mission and has the foundation and innovative advantages of large-scale and intelligent operations with the help of the scale of the land. Once a standard production model of the saline-alkali land smart agriculture application demonstration at the level of 10 000 *mu* is formed, it can gradually replicate and be promoted in the 500 million *mu* of saline-alkali land in China, so as to promote the maturity of the Third Generation of Agricultural Machinery Innovation System of China.

The saline-alkali land in Yellow River Delta Agricultural High-tech Industry Demonstration Zone is a testing ground for the Third Generation of Agricultural Machinery Innovation System of China and commercial innovation system. In the future, the standard test fields at the level of 10 000 *mu* as a template, combined with China's complex terrain, landforms, climate, and crop characteristics, will be used to create a unified business model that meets the diversified characteristics of China's agriculture. Supported by the third generation of agricultural machinery system, and on the basis of the "CAS Agricultural Science and Technology Overall Solution," a series of 10 000-*mu*-level samples will be achieved nationwide. They will be made into a national food "stabilizer" to guarantee that "China's bowl" contains "Chinese food." Furthermore, a complete system for countries along the "Belt and Road" will be provided to implement the great concept of "community with a shared future for mankind" proposed by General Secretary Xi Jinping.

4 Prospects and suggestions

Building an independent and controllable Third Generation of Agricultural Machinery Innovation System of China is an important starting point to change the long-term backward situation of China's agricultural machinery industry, and it is also the key to improving China's agricultural productivity. Focusing on the core goal of "building the Third Generation of Agricultural Machinery Innovation System of China," three suggestions are put forward as follows.

(1) The top-level design should be strengthened. It is recommended that the CAS carries out strategic research in this direction. Combining the development strategies of innovative countries, the development plans to 2025, 2035, and 2050 should be formulated, respectively. In addition, the research on the application and promotion of agricultural machinery industry for countries along the "Belt and Road" should be carried out. At the same time, on the basis of the linkage with the Ministry of Science and Technology, the Ministry of Industry and Information Technology, the

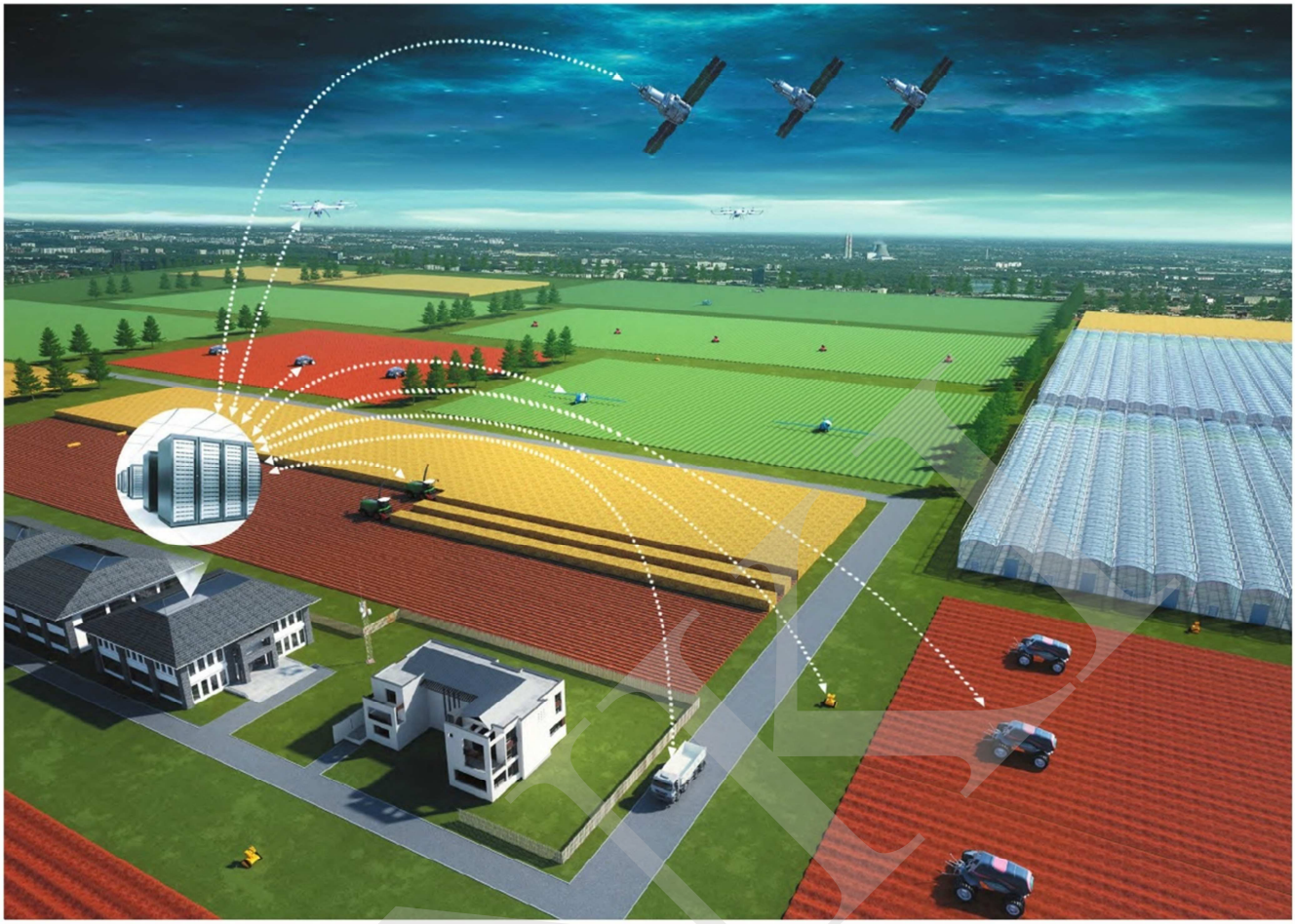

Figure 4 Schematic diagram of comprehensive "three- dimensional" intelligent agricultural production

National Development and Reform Commission, the Ministry of Agriculture and Rural Affairs, the Ministry of Education and other ministries and commissions of China, the integrated top-level design of the technology system, manufacturing system, industrial system, application system, and talent system should be carried out to optimize resource allocation for achieving the goal of the Third Generation of Agricultural Machinery Innovation System of China.

(2) A national platform should be established. The innovation of agricultural machinery equipment involves basic theoretical innovation, key technology innovation, integrated equipment innovation, and business model innovation. Therefore, it is recommended to build simulation and emulation test grounds on the basis of the complex agricultural machinery system theory of agricultural machinery- agronomy integration and agricultural machinery dynamic modeling under different soil resistance models, so as to provide support for major national infrastructure scientific and technological facilities. At the same time, the Engineering Laboratory and the "CAS Future Agricultural Scientific and Technological Innovation and Industrialization Alliance" in preparation are relied on to strive to build the "National Technology Innovation Center for Intelligent Agricultural Machinery" during the "14th Five-Year Plan" period.

(3) The model exploration should be supported. An agricultural machinery innovation system that integrates technology, industry, capital, scientific research, and policies should be established, and the positioning and tasks of various entities in the agricultural machinery innovation system should be clarified. Special support for the strategic pilot science and technology within the CAS should be set with these goals, and the CAS agricultural science and technology system solutions should be formed. Moreover, leading companies should be incubated on this basis, so as to create world-class leading enterprises in the field of agricultural machinery that match the major and powerful agricultural machinery countries and a group of invisible champions in subdivision areas of core technology.

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