Talent cultivation method of aerospace manufacturing engineering incorporating new aerospace technology

Rongqiang Liu[1,*], *Guanxin* Chi[1], *Fei* Wang[1], *Lijun* Yang[1], *Honghao* Yue[1], and *Yifan* Lu[1]

[1]Department of Aeronautics and Astronautics Manufacturing Engineering, School of Mechatronics Engineering, Harbin Institute of Technology, Harbin, 150001, P.R. China

Abstract. In order to meet the needs of the state and society for improving the quality of undergraduate education and cultivating innovative talents, individualized training mode has gradually become the direction of higher education reform. In China, there is a long-standing situation that talent cultivation is out of touch with industrial demand. In order to explore the training mode of innovative talents in the new era, the idea of cultivating individualized talents with scientific research as feedback to teaching is established in this paper. The latest research results of aerospace are incorporated into the training process of aircraft manufacturing engineering professionals and professional knowledge system are optimized. By building high-level courses with overseas scholars and domestic industry experts, an off-campus practice training base for personalized talent training is established, and the teaching contents and methods is reformed. The practice has proved that the personalized talent training mode and method proposed in this paper have achieved good results.

1 Development and evolution of the major

The foundation of aircraft manufacturing engineering major in Harbin Institute of Technology (HIT) is the automated mechanical design and manufacturing major of HIT, and its origin can be traced back to 1958. Harbin Institute of Aviation Technology was merged into HIT to set up the department of aviation engineering. In 1963, the department of aviation moved out to support the professional construction of several national characteristic colleges and universities, then this major was closed. In 1993, it began to prepare for the establishment of new postgraduate training in the aerospace manufacturing engineering discipline, and it has been 17 years since 2004. To promote the construction and development of aircraft manufacturing engineering major, the Department of Aerospace Manufacturing Engineering was established in 2008. In 2009, this major became a key discipline in Heilongjiang Province, and in 2019, it entered the provincial first-class professional construction list. In 2021, it entered the national first-class professional construction list. The major, 'based on aerospace and serving national defence', is a multidisciplinary integration major integrating aircraft manufacturing technology, computer application technology, and mechatronics technology. Meanwhile, this major trains compound senior professionals for the design and manufacture of mechanical and electrical products, production organization management, basic theory, and applied technology research and development in aerospace and related fields.

*e-mail: liurq@hit.edu.cn

2 Teaching staff and research direction

There are 42 full-time backbone teachers in this major, including 19 professors, 8 associate professors, and 9 lecturers. Among them, there is one academician of the Chinese Academy of Engineering, one national famous teaching teacher award of colleges and universities, 11 people who were selected into the national talent support program, and 18 people who have studied abroad for more than one year. There are several teaching and research platforms, such as the National Defence Key Discipline Laboratory of Aerospace Space Agency and Control Technology, the National Innovation and Intelligence Introduction Base of Equipment Design and Manufacturing Science and Technology, and the Joint Laboratory of Space Machinery Science and Technology of China Academy of Space Technology—Harbin Institute of Technology.

This major has many strong professional directions, such as planetary surface movement systems, large-scale space folding, and exhibition mechanism, space docking and unlocking, planetary surface sampling and detection, and intelligent manufacturing of equipment. In 1999, under the leadership of Professor Zongquan Deng, the professional founder, we took the lead in researching the key technologies of the lunar rover's mobile system in China, and innovatively designed eight configurations of the lunar rover's mobile suspension. Among them, the 6-wheel rocker arm type mobile configuration is determined as the mobile system configuration of China's Chang'e III "Yutu" lunar rover [1]. The invention of the horizontal pendulum linkage lunar rover transfer mechanism has realized the reliable transfer of the 2.4 m drop of the "Yutu" lunar rover, which has become a highlight of the Chang'e III mission. The configuration of an active-passive hybrid rover mobile system with a peristalsis function was proposed. It has the functions of sinking and climbing, and was adopted by the "Tianwen-I" rover. Completed the overall scheme design and key technology research of lunar surface sampling in China, and jointly developed the "Chang'e-V" drilling and sampling model product with the engineering department [2].

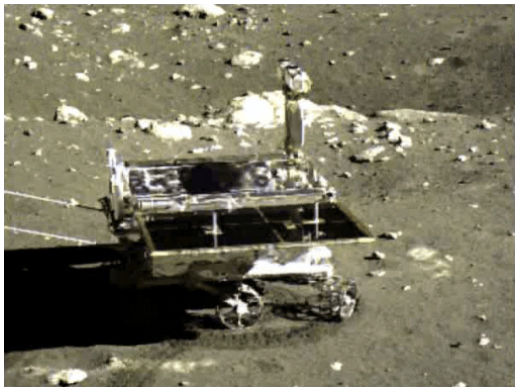

Figure 1. Yutu lunar rover

Figure 2. Lunar surface sampling device of Chang'e-V

We closely integrate the aerospace scientific research results with student training, so that the students can apply what they have learnt in their career and dedicate to China's aerospace industry. Meanwhile, a large number of "Yutu" lunar rover mobile system, "Zhurong" Mars rover mobile system, Chang'e V lunar surface drilling sampling and packaging system, large space extension arm, hexapod mobile robot, and large-scale low gravity simulation system are introduced in the teaching and graduation dissertation.

3 Professional and personalized talent training concept

This major is oriented to aerospace manufacturing, with distinctive national defence characteristics. In the major curriculum, the idea of "thick foundation and wide calibre" is fully implemented, the students' generous basic knowledge of natural science, technical science, and mechanical design and manufacturing is emphasized, the cultivation of generous basic theories such as mathematics, mechanics, basic theories of mechanical design and manufacturing, aircraft manufacturing technology and the ability to apply advanced and reasonable knowledge is reinforced.

The major of aircraft manufacturing engineering pays attention to the cultivation of excellent ideological quality, scientific quality, humanistic quality, and good ability to analyse, express, and solve engineering problems, and focus on the cultivation of self-study ability, innovative consciousness, practical ability, organization and coordination ability, patriotism and dedication, honesty and pragmatism, and physical and mental health.

Broaden the innovative practice teaching links and build innovative practice base clusters with aerospace engineering departments. Turn scientific research achievements into teaching content, and turn scientific research strength and discipline advantages into teaching advantages. In combination with the development of aerospace technology, the course content will be updated in real-time, and relying on specialized course laboratories in the school, the independent, appointment-based and open experimental teaching will be realized. Improve the decentralized and personalized graduation practice base construction, build the practice management and evaluation system, and explore the establishment of a school-enterprise integration practice teaching system suitable for first-class undergraduate majors. Based on professional advantageous scientific research direction, we build 1–2 scientific research and practice platforms with display degrees and fully exercise students' practical ability. Actively update laboratory equipment, strengthen the challenge and innovation of the course experiment, establish 5 national and provincial teaching practice bases.

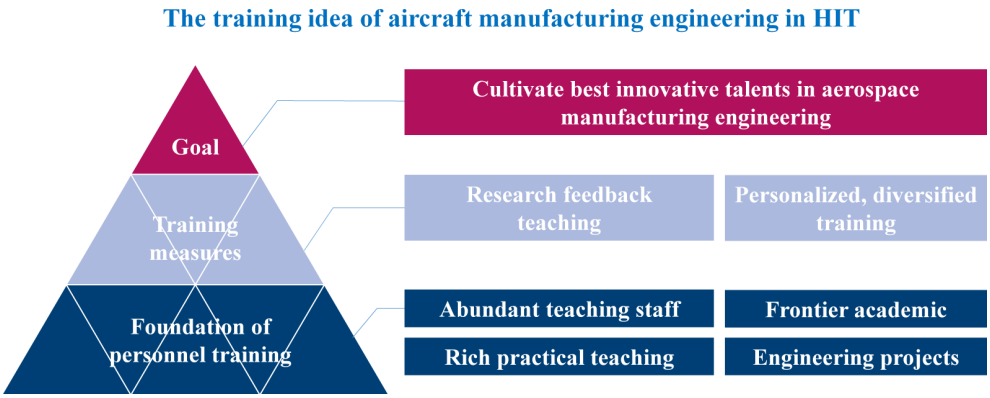

Figure 3. Training ideas of aircraft manufacturing engineering professionals in Harbin Institute of Technology

Figure 3 shows the training idea of aircraft manufacturing engineering major in HIT. Relying on HIT's abundant teaching staff, rich practical teaching foundation and scientific research advantages, the aircraft manufacturing engineering major builds a personalized training system suitable for research universities through personalized, diversified training, research feedback teaching, and other measures.

Figure 4 shows the practical teaching process of aircraft manufacturing engineering major in Harbin Institute of Technology, which embodies the training concept of "strong practice and innovation" in aircraft manufacturing engineering major.

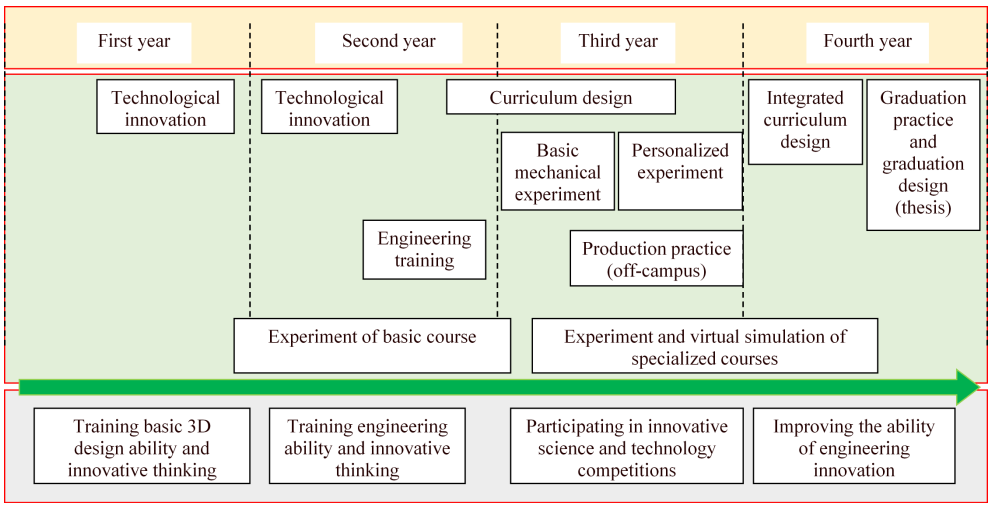

Figure 4. Practical teaching history diagram of aircraft manufacturing engineering major in Harbin Institute of Technology

Establishing the talent education concept of "being responsible for students' personalized growth and tapping students' personalized potential", and building the personalized talent training concept of research universities that "everyone has their particularity and uniqueness, and needs the expertise to show their individuality under the universal knowledge system". Establishing an undergraduate tutorial system implementation mode of mutual selection and interaction between teachers and students, from enrollment to graduation to follow-up career, with 100% students participating and significant gains.

In the aspect of curriculum system, specialized module courses are decomposed, and students choose courses according to their interests and development points; In the aspect of scientific and technological innovation practice, set up tutorial system, arrange students to enter the laboratory to follow their tutors to engage in scientific research activities in sophomore year; In the aspect of graduation practice, decentralized practice is adopted, and major aerospace units are selected as practice places. Then students can enter workshops, teams, and groups, enter the production line and participate in the actual production process.

Determining the goal orientation, adhering to the combination of talent demand orientation and traditional characteristics of running a school, and taking the related technologies of aerospace intelligent equipment system as the object, and establishing the talent training framework as follows:

1. One goal: to train high-end talents in the field of aircraft manufacturing engineering for "Made in China 2025" and future development.
2. Two ways: classroom teaching and practical training.
3. Three foundations: mechanics, electricity, and mechanics.
4. Four series: design, manufacturing, measurement and control, management course series.

4 Talent cultivation method integrating new aerospace technology

4.1 Teaching methods

On the research of professional teaching methods, the teaching link of aircraft manufacturing engineering major vigorously promotes the reform of the 'research-based learning' method. Based on professional courses with relatively independent knowledge and no lack of interdisciplinary points, several research directions under the connotation of the courses are established, with grouped research topics throughout the teaching process as the assessment object, teaching, and research are combined. Let students walk into the classroom with questions, take the realization of project research objectives as the driving force, and fully, actively acquire courses and related knowledge; Actively organize teamwork after class, use professional knowledge to carry out innovative design and practice, maximize the role of individuals in the project team, and jointly complete the project research content.

The individualized professional teaching mode of "research-based learning" requires that group practice in class be the mainline, the curriculum objectives, curriculum structure, and teaching content be optimized, and a full-cycle teaching design of "teaching preparation-teaching project design-concrete implementation-effectiveness feedback" be formed.

4.1.1 Teaching preparation

Using constructivism and metacognition theory, carrying out the investigation and analysis of students' cognitive status. Get the basic state of students' autonomous learning subjects and their subjective understanding of the planning of scientific research projects in the curriculum system, which provides the basic basis for effective teaching activities and data for teaching effect evaluation.

4.1.2 Instructional design

Setting the curriculum objectives in the 'research-based learning' system, planning the curriculum structure and organizing teaching materials in combination with teaching, materials, such as lecture notes, expanding knowledge, designing cases, typical applications and scientific research projects that students need to complete in groups, and finally, form a systematic teaching document and curriculum system.

4.1.3 Classroom teaching

Combined with the professional characteristics and academic direction of the course, group research demonstration and implementation combined with classroom teaching content are carried out. Establishing a scientific research team in the teaching cycle by self-selecting topics or grouping propositions, and establishing process management mechanisms such as internal discussion, state feedback, and teacher guidance. The examination method of the course is changed from proposition examination to project completion reply.

4.1.4 Extended development

Establishing a long-term tracking and encouraging plan for the achievements of grouped projects, selecting the research team of the teachers from the students who have completed the teaching process, and digging deep into the research direction confirmed in the course. Furthermore, students can master scientific knowledge and the steps and methods of scientific research more deeply, develop the ability of scientific argumentation and cultivate research skills.

4.1.5 Perfection of evaluation

Establishing the evaluation system of teaching effectiveness of "research-based learning", comprehensively evaluating the tightness of the combination of the teaching mode and the

Figure 5. Innovative training courses taught in groups

curriculum and its influence on students from various aspects such as students' satisfaction with classroom learning, the degree of investment in scientific research projects, the academic level of scientific research achievements, the cohesion of teamwork and self-evaluation after the completion of the curriculum.

4.2 Application of scientific research results in teaching

The application of scientific research results in teaching directly enriches the teaching content, broadens students' horizons, deepens students' understanding of professional technology prospects, and enhances their professional identity. The vivid examples of the integration

Table 1. Scientific research examples are directly used in the list of teaching contents

No.	Transformation of scientific research achievements	Teaching application (course name, experiment name, etc.)	Application initiation time
1	Test bed of planetary wheel soil interaction characteristics	Integrated curriculum design II	2009 present
2	The mobile system of the six-wheel planetary rover with hybrid adaptive suspension	Course experiment (robot technology and application course)	2010 present
3	Folding and unfolding mechanism of spacecraft	Bar mechanism (mechanical principle course)	2003 present
4	Missile control mechanism	Separation mechanism (aircraft structure design)	2014 present
5	Spatial connection and separation mechanism	Low impact separation device (space intelligent structure and mechanism)	2016 present

of science and education show the students a rich and colourful technological world, allowing them to get in touch with practical cases from engineering practice.

The seemingly out-of-reach cutting-edge technology is interpreted by teachers in the form of self-presentation. In these cases, there are mechanical arms in space stations, folding and unfolding mechanisms in spacecraft, and metal rubber components in buffer devices of the lunar lander. These contents not only show the scientific research characteristics of the college 'based on aerospace and serving national defence', but also show the professional and strong scientific research strength and solid technical foundation. This content of promoting teaching through research and integrating science and education has been widely praised by students.

4.3 School-enterprise linkage practice and practice

Production practice and graduation practice are important to practice links of college students' training. In recent years, due to the continuous expansion of enrolment scale, taking the Institute of Mechanical and Electrical Engineering as an example, the number of interns reaches 3–400 every year, all of whom go to Changchun FAW Factory for internships. Due to the limitation of internship enterprises' acceptance ability, the original participatory internship has become a visiting internship, and the effect of going out for an internship is getting worse and worse. For the sake of production management and confidentiality management, internship enterprises are generally unwilling to accept college students' internships and provide support and assistance for internships. The aircraft manufacturing engineering major of Harbin Institute of Technology established the orientation of individualized, elite personnel training, and put forward the decentralized internship method for the first time in the internship session. Students majoring in aircraft manufacturing engineering were dispersed to several aerospace enterprises for internships, and new internship bases such as Beijing Satellite Manufacturing Factory, Beijing Aerospace Aircraft General Design Department, Tianjin Aerospace Electromechanical Research Institute, Hafei Group, etc. were opened. These bases are important national spacecraft and aircraft design and manufacturing bases, and professional students were grouped according to internship bases. Each group has no more than 20 people. We divide the students of an internship base into several groups according to the type of work, such as numerical control, inspection, assembly, surface treatment, etc. Distributing the internship students to workshops and work stations, and conducting specific operations under the guidance of the master, and rotating according to the type of work every week to ensure that every student can get exercises of various types of work.

Figure 6. Students' Internship in Tianjin Aerospace Electromechanical Research Institute

Figure 7. Students' Internship in Aerospace Test Base

To enable postgraduates majoring in aircraft manufacturing engineering to get more engineering training and exercise opportunities, and promote technological innovation, school-enterprise scientific research cooperation, and transformation of technological achievements. Relying on the decades-long scientific research cooperation foundation between Harbin Institute of Technology and China Academy of Space Technology, in 2012, a joint training base for graduate students in mechanical engineering was established in China Academy of Space Technology.

The General Design Department of Beijing Spacecraft, a subsidiary of the Academy, is the overall spacecraft research and development unit with the largest overall spacecraft field and the most complete professional technology in China. Beijing Satellite Factory is a high-tech enterprise specializing in the research and production of spacecraft. The two units represent the highest level of domestic spacecraft design, R&D, and manufacturing. In 2017, the base was selected as the national joint training demonstration base for graduate students with professional degrees. The Institute of Mechanical and Electrical Engineering of Harbin Institute of Technology sends 20–30 graduate students to the joint training base every year to engage in internship practice activities, and the internship practice time is 6–10 months.

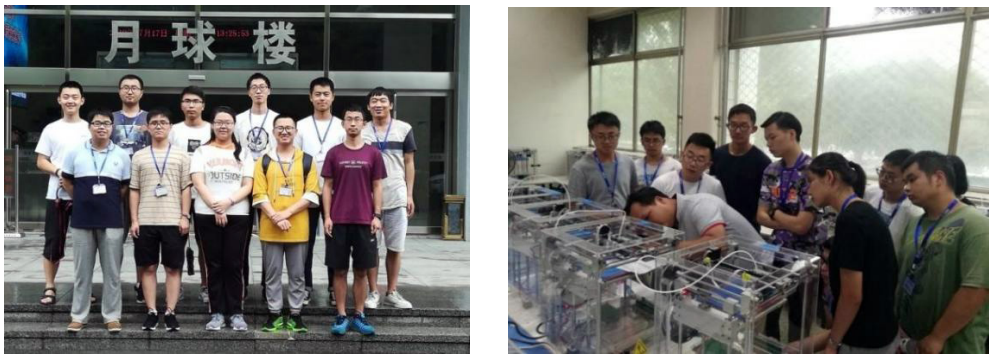

Figure 8. Students' carry out practical activities in the off-campus joint training base

The joint training graduate students have participated in the research work of model product research and development and forward-looking basic pre-research projects jointly undertaken by both parties with high quality. The research topics include space manipulator, lunar sampling, large-scale deployable antenna, spacecraft connection, and separation, etc. In terms of training process management, both schools and enterprises jointly complete the teaching and management of graduate students stationed in the joint training base using 'sectional responsibility and collaborative management', and establish a joint training mode of dual tutor system for graduate students. Through the construction of a joint training base, the comprehensive quality and engineering practice ability of joint training graduate students have been greatly improved. Zhengwang Yu, a graduate student, won the 'Fifth National Master of Engineering Internship Excellent Achievement Award'. In addition, the employment competitiveness and career development potential of graduates are superior to the traditional training model, which further promotes the deep cooperation of scientific research between schools and enterprises, and improves the basic and innovative research level of enterprises.

4.4 Off-campus expert courses and innovative course construction

To broaden student's academic horizons and understand the development frontier of this major at home and abroad, we will jointly build advanced high-level undergraduate courses with domestic industry experts and well-known foreign scholars.

From the General Department of the Fifth Academy of Aerospace Engineering, the researcher Jianzhong Yang, an expert in the lunar exploration engineering structure institution, was hired to teach the spacecraft mechanism technology course. This course tells the basic contents of spacecraft mechanism and its design, spacecraft mechanism design and production process quality management, simulation analysis of spacecraft mechanism, and ground test of spacecraft mechanism from the perspective of engineering design and practice. Jianzhong Yang, based on his research and development experience of the landing buffer mechanism of Chang "e-IV", and closely combined with the engineering background of the space mission, taught the students the knowledge of the overall development of spacecraft, the research and development of key components, the ground test and the overall test verification, and introduced the common simulation methods of space flight and the future space simulation methods, which laid a good foundation for students to carry out aerospace engineering and technical work in the future.

Prof. Hornsen Tzou, an expert in structural electronics from the University of Kentucky, USA, taught the undergraduate students about the course of intelligent structure and intelligent control. This course introduced the mechanical basis of an intelligent structure, set up topics around the spatial application of intelligent structure, and students were divided into groups to research topics, gave design schemes, wrote analysis programs, and made physical prototypes. Organizing students to answer the final questions, and combining theoretical knowledge with solving practical problems through open course teaching. Cultivated students' innovative thinking in scientific research and ability to solve engineering problems.

The discipline gives full play to the advantages of aerospace engineering research, offers innovative training courses with aerospace characteristics for senior students, and offers 8 innovative training courses around the cutting-edge directions of planetary movement detection, planetary sample collection, large-scale space development, additive manufacturing, and space robots. The innovative practice was carried out on weekends in the laboratory with small class flexible teaching of 5–15 students, and we extract training objects from scientific research projects, clarified course contents, and objectives. The innovative work is carried out in groups, so that every student can have the opportunity to participate in the work of scheme design, modelling analysis, material production, etc., and evaluate the students' completion through the final reply. Training students' ability to solve practical problems by using what they have learned, and then laying a scientific research foundation for graduate students to study and participate in work.

5 Achievements in talent training

In recent years, remarkable achievements have been made in the cultivation of professional talents with students as the centre, research and teaching as the way, and personalized cultivation as the mainline. After application and practice in the aircraft manufacturing engineering major of HIT, remarkable results have been achieved.

5.1 Theoretical research of personalized training system

In 2017, "Construction and Implementation of Innovative Practice System of Combining Reality with Reality for High-end Equipment Manufacturing Talents Training" and "Research

and Practice of Graphics Curriculum System for New Engineering Talents Training" won the second prize of teaching achievement in Heilongjiang Province respectively. In 2018, "Construction of Basic Course System of Mechanical Design for New Engineering Based on Ability Orientation" and 'Exploration and Practice of Training Mode for New Engineering Talents of Mechanical Major Oriented to Intelligent Manufacturing' were approved by the Ministry of Education for New Engineering.

5.2 Teachers and students' innovative ability training

The effectiveness of research feedback teaching has gradually become prominent, and the interaction between teachers and students has promoted the improvement of professional teachers' scientific research ability and comprehensive level, also significantly improved students' innovative practice ability. In 2016, the virtual simulation team of high-end equipment manufacturing was selected as the research-oriented teaching innovation team of the Ministry of Industry and Information Technology. In 2018, the aerospace agency and control team were rated as the national key field innovation team. In recent 3 years, students of this major have won 32 national and provincial competition awards, including the Gold Award in the International Vertex Design Competition, the National University Student robot contest Special Prize and other awards representing the highest level of domestic undergraduates.

5.3 Improving the quality of graduates

The quality of personnel training is highly praised and favoured by domestic and foreign universities, domestic research institutes, aerospace enterprises, and well-known private enterprises. A sample survey of 123 undergraduate graduates of aircraft manufacturing engineering in recent three years shows that there are currently 51 graduates studying for master's degree in domestic universities, accounting for 41.5%, all of whom have achieved excellent results during their master's degree studies. 13 graduates are studying for master's degree abroad, accounting for 10.6%, among whom 5 have studied for the doctoral degree. Graduates are engaged in product development, scientific research, and management in the fields of aircraft, robotics, vehicle engineering, information, nanotechnology, etc., and the employment rate of graduates reaches 100%. In recent years, 59 people have worked in scientific research institutes, aerospace enterprises, Sino-foreign joint ventures, and government aircraft, among them, nearly 10 people have served as project managers and business backbones in aerospace enterprises, and some graduates have become backbone members of major national aerospace projects and key models of new generation fighters.

6 Conclusion and prospect

Aiming at building the first-class major of aircraft manufacturing engineering, we have strengthened the comprehensive major reforming idea of "personalized talent training", established the concept of personalized talent training integrated with new aerospace technologies, popularized and applied the teaching method of "research-based learning", and constantly strengthened the training objectives for aerospace, serving national defence and aiming at major national equipment. We have also optimized the professional knowledge system, built high-level courses with overseas scholars and domestic industry experts, set up an off-campus practice training base for personalized talent training, fed back teaching with scientific research, strengthened the cultivation of practice and innovation ability, and taken various measures to promote comprehensive professional reform, thus steadily improved the quality of talent training.

In the future, we will continue to improve and deepen the personalized personnel training method system, seize the historical opportunity of HIT to build a national laboratory of aerospace technology, further integrate the latest aerospace technology into the teaching and training system, and put aerospace technology into the whole chain of personnel training of teaching-scientific research-practice-entrepreneurship. We will strengthen the joint training of talents with similar international universities and majors, and establish the "2 + 3" talent training mechanism. After studying basic courses for two years in China, students will go abroad for three years of professional course study and practical training. Mutual recognition of courses and credits, exchanges of students and teachers will be realized. After graduation, students will be awarded diplomas and degree certificates from Harbin Institute of Technology and foreign universities, respectively. We will continue to explore the new curriculum system and training mode of new aerospace technology, and cultivate a new generation of aircraft manufacturing professionals with international vision and pioneering spirit.

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