

Application, Management and Industrialization of Aerospace Science and Technology of Beijing 2022 Winter Olympics

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Abstract: In February 2021, the successful hosting of the Beijing Winter Olympic Games once again made the world witness the strength of China, and also made more people impressed by "China's aerospace power". It is of pioneering significance for the application of the "aerospace development pattern" in industrial projects and the application of systems engineering management methods in the Winter Olympics. Faced with tight schedule, epidemic situation and other practical difficulties, the Winter Olympics aerospace team used scientific ideas, methods and paths to break the bottleneck. It once again proved the effectiveness and reliability of the "aerospace development pattern" in major national activities. In this paper, the application of aerospace science and technology in Beijing Winter Olympic is introduced, the aerospace science and technology in engineering projects and the characteristics of aerospace engineering management methods are analysed, and the industrialization of aerospace science and technology is explored to how better serve the people at home and abroad, the industrial projects, civil and commercial enterprises, and to provide ideas for the related people.

1. Introduction

The 2022 Winter Olympic, officially called the XXIV Olympic Winter Games and commonly known as Beijing 2022, has been held from February 4, 2022 to February 20, 2022 in Beijing and Zhangjiakou city, Hebei Province.

It was the first time in Chinese history that the Winter Olympic Games were held. Beijing and Zhangjiakou were both host cities. It was also the third time that China hosted the Olympic Games following the 2008 Beijing Summer Olympics and 2014 Nanjing Youth Olympic Games. Beijing became the first city in Olympic history to host both the summer and winter Olympic Games, and the second capital city to host the Winter Olympic Games after Oslo, Norway in 1952. Beijing 2022 set seven (7) major events, fifteen (15) sub-events, one hundred and nine (109) minor events. Beijing hosted all the ice events, while Yanqing district and Zhangjiakou hosted all the snow events.

The Modern Olympic Games are becoming an important stage for the host countries to show their scientific and technological prowess. In 2019, the Beijing Winter Olympic and Paralympic Games Organizing Committee decided to select a team with aerospace experience as one of the technical support units for the opening ceremony of Beijing 2022. The aerospace administration set up a specific research team to formulate scientific and technological strategies, and carry out project layout in advance. Then the research team started the three-year winter Olympic preparations.

The advanced aerospace technology in the Winter Olympics has played a unique role in technical support for the opening and closing ceremonies, venue guarantee, event live broadcast, weather support and other aspects. Thanks to aerospace science and technology, the Chinese platform at the Opening ceremony of the Winter Olympics was as safe and accurate as launching a rocket and the athletes' movements in the competition are measured like satellite launches.

2. Application of Aerospace Science and Technology in Beijing 2022

Based on the actual needs of the Winter Olympic Games, the aerospace research team implemented a series of aerospace technologies and systems through theoretical analysis, field research, case analysis, model experiments, data mining, prototype construction, system development and integration, demonstration and application, forming various technical support platforms for the Winter Olympic Games.

The aerospace technologies involved in the opening ceremony of the Winter Olympic Games include ground stage (including flagpole equipment), Lifting wire, torch, ice cube (including the five rings), command monitoring, communication system, ground display system, icefall, command centre, media video playback and VR, video rendering room and other major projects. The technical installation runs smoothly, exceeding the expectations and imagination of the director's team.

2.1. Ice Cube and Five Rings Presented Like a Dream

The ice cube, 22 meters long, 7 meters wide and 10 meters high, weighs 400 tons and has a lifting weight of 180 tons. The lifting load is 8 times more than that of lifting platform in general theatres. It is the most powerful driving equipment for the whole opening and closing ceremonies. Before it was raised, ice cube was hidden in a huge underground chamber measuring 84 meters long, 42 meters wide and 10 meters deep. The multistage folding structure enables ice cube to rise and fall at a maximum speed of 0.28 meters per second, and in a minimum of 43 seconds for the whole lifting process. The process of the five rings rising from ice cube is shown in Figure 1. Under the condition of limited space, the research team controlled the lifting and positioning accuracy of the giant ice cube within ± 1 mm by precisely controlling the motor to drive the four sets of synchronous transmission units consisting of 16 chains and 16 wire ropes.



Figure 1: Ice Cube and Five Olympic Rings in the Opening Ceremony of Beijing 2022

After the ice cube rises, the Five Olympic Rings slowly appear. The lifting of the fifth rings is difficult, such as the strict weight limit. As we know that it's huge, but it's really thin. So the research team did many simulations and tests, and finally completed the perfect debut of the Five Olympic Rings. They are 18 meters wide, 11.75 meters high and 5 meters in diameter. The display time can be used for performances of more than 60 minutes.

In the design of stage machinery control system, digital simulation software and hardware equipment used in the aerospace system are added to it. During the design process, the control algorithm was optimized, and the hardware-in-loop simulation test was carried out comprehensively, so as to creatively combine the Winter Olympics project with the quality management familiar to spaceflight personnel, so as to identify and avoid major mistakes in the design period, and improve the reliability and security of the whole system. Nearly one thousand ground tests have been carried out for the stage, compared with that for a normal rocket flight test is nearly 100. Through a variety of subsystems tests and comprehensive tests of whole system, all unreliable factors were eliminated, and "zero error" for live performance was achieved.

2.2. “Flying” Torch Light up the Snow and Ice Night

The burning system is the core part of the main torch. The research team made many innovations according to the requirements of the organizing committee. "Flying" is the name of the hand-held torch used in Beijing 2022. It is shown in figure 2 and it uses hydrogen as fuel and is the world's first high-pressure hydrogen storage torch, achieving zero carbon emission of the torch in the history of the Winter Olympic Games.



Figure 2: Torch of Beijing 2022

Hydrogen is green, but flammable, explosive and leaky, and there has been no successful use of hydrogen as torch fuel in previous Winter Olympics. In order to fit the design of the curved shell of the hand-held torch, the researchers made bold innovations and adopted targeted design and lightweight technology to "slim down" the entire combustion system, freeing up space to ensure sufficient fuel storage. At the same time, in order to ensure high reliability of the torch burning process, the researchers used aerospace design concepts.

2.3. Stage, Floor Screen and National Flag, Making Contribution to the Splendid Performance of the Opening Ceremony

During the opening ceremony, the huge stage in the center of the Bird's Nest and the huge floor screen were impressive, which are shown in figure 3. They are also constructed by aerospace units.

The construction area of the whole ground stage system is about 21,000 square meters, and the center of the stage is a huge lifting platform. During the whole opening ceremony, snowflake stage, torch and other creative performances were completed on this central lifting platform. It is composed of more than 40,000 screens, with an area of more than 10,100 square meters of floor display. With it, a magical world of ice and snow bloomed in the bird's nest. Actually, tens of thousands of signals zipped through complex circuits.

Relying on China's own industrial Internet platform, tens of thousands of screens were connected. Temperature, humidity, voltage, their working status were monitored in real time. Once abnormal, it will immediately alarm. There were a total of four signals and enough fault tolerance rate.



Figure 3: Floor Screen of Beijing 2022

On either side of the stage, flags fluttered from towering flagpoles. The design of these flagpoles was also done by aerospace units. Compared to the flagpole used in the 2008 Beijing Summer Olympics, the flag pole has a rotating function to better adapt to the changing wind at the Bird's Nest, so that the flag can be waved at any time.

2.4. Lifting Wires, Making the Ceremony More Romantic

In the opening ceremony of the Winter Olympic Games, the main torch and the Five Olympic Rings suspended, thanks to the cooperation of lifting wires. In December 2020, the lifting wire project team moved into the Bird's Nest and began to dismantle the lifting wire left over from 2008 Beijing Olympic Games in order to make preparation for the follow-up work. In June 2021, the overall creative plan of the opening ceremony was finalized, and the design, production and installation of lifting wire officially began. Finally the lifting wire devices were completed more than 50 meters above the ground at the Bird's Nest, and they can lift more than six tons of equipment, up from just a few hundred kilograms in 2008.

Like other systems, when the director had a sudden new idea in the rehearsal, the lifting wire team worked closely to adjust the lifting system of lifting wire in time. Until the opening ceremony, the lifting wire hoisting system was still in iteration.

2.5. Communication Systems Help Kick Things off

The number of people working for the opening ceremony of the Winter Olympics is still as high as 3,000, even though the number of people working for the opening ceremony has been greatly reduced due to the bad weather and the epidemic. In order to ensure the stable communication of the whole opening ceremony, the aerospace project team developed three subsystems according to

the actual demand, namely wired communication system, wireless communication system and wireless FM broadcasting system. The communication system terminal consists of 48 panels, 52 wired fanny packs, 36 wireless fanny packs, 700 wireless walkie-talkies and 7000 FM receivers. These three subsystems are completely interlinked. For example, the control panel can be directly connected to a wireless FM system or a wireless walkie-talkie, in emergency treatment can be effective.

2.6. Command and Monitor the Process in an Orderly Manner

The command and monitoring system of the Opening ceremony of the Beijing 2022 is developed based on the industrial Internet platform, which can provide instruction information to the field director, stage director and technical support personnel. In addition, the aerospace team installed more than 130 new cameras in the Bird's Nest to better control the status of various hardware equipment during the opening ceremony, staring at a number of visual blind spots such as the inside of the lifting stage. Surveillance video information can be automatically pushed to each post according to the monitoring requirements of different activities. If there is a problem, the system will inform all posts and the emergency plan will be activated immediately.

2.7. Wind Tunnel is a "Magic Tool" to Minimize Wind Resistance of Athletes with Perfect Posture for Training

In addition, many countries pay attention to the research and development and application of high-tech equipment, which can make athletes get twice the result with half the effort^[1]. Major power of the Winter Olympic Games have provided athletes with a variety of advanced training equipment in the process of preparing for the Winter Olympic Games, to help athletes improve their training effects and seek breakthroughs in potential advantages and backward events by means of science and technology^[2]. In this Winter Olympics, aerospace science and technology was used in the "wind tunnel".

Benefiting from the development of aerospace science and technology, the sport wind tunnel has been successfully applied. The diameter of the wind tunnel is 2.5 meters wide, 3 meters high, and the length of the test section is 8 meters. The wind speed is equivalent to a strong typhoon of level 14.

As we all know, the lower the wind resistance, the faster the speed, and the less energy the athlete uses. According to the related personnel, if air resistance can reduce by 10%, the athletes' performance can be increased by 1%. And in the millisecond world of the Olympics, 1% or 1‰ gap may decide the outcome of the game. In 2018, the steel frame of the winter Olympics Pyeongchang snowmobiles project, first man project with the sixth achievement gap is only 1.2%.

The magic of a sports wind tunnel is that it provides experimental support to reduce the wind resistance of an athlete, helping him to find the best motion posture and generate the least resistance to increase his speed. Then muscle memory is formed by targeting movements and postures with minimal wind resistance and by training them repeatedly over time. The precise control of the details in the sports wind tunnel will allow the athletes to win by the minute.

In the design of sports wind tunnel, designers investigate a large number of winter Olympic sports events, in a comprehensive consideration of the size of snowmobile, sled, snowboard and other winter Olympic sports equipment, as well as some Olympic sports equipment size, and then finally determine the length, width and height of the wind tunnel.

Considering the maximum speed in the fastest snowmobile project in the Winter Olympic Games is 151.2 kilometers per hour, so the maximum speed of 150 kilometres per hour. So it can fully meet all the current winter Olympic racing sports test training requirements.

Because the sports wind tunnel is mainly used by the athletes, so its accuracy, safety and comfort requirements will be higher than military wind tunnel.

The sports wind tunnel has been specially enhanced with safety measures. For example, it tries to avoid the use of screws and other easy to fall off fasteners in the wind tunnel, so as not to fly out of harm; Protective net is reasonably set up around the test platform. It does not only interfere with the test and can also prevent athletes from sliding; an emergency stop button should be set beside the coach accompanying the test, so that the coach can stop immediately in case of emergency. In addition, in order to facilitate the selection of motion posture, the sports wind tunnel also has the function of shooting and storage, including the data of force measurement, picture and the change of center of gravity after the change of posture of athletes at a time point, providing reference for the guidance of coaches. Athletes can also see their own movement test data on a screen on the floor in front of their eyes. The concept and principle of aerospace engineering design are embodied in every detail of design.

2.8. Aerospace Science and Technology Used in Live Broadcast

Aerospace science and technology also play an important role in the live broadcast of the games, communication satellite 8K broadcast winter Olympics events more visual impact.

Satellite communication plays an important role in the live broadcast of Beijing 2022. During the NPC and CPPCC sessions in 2020, the communication satellite helped the media realize the first "5G+8K+ satellite" live forwarding and the first "5G+8K+ satellite" live broadcasting of the NPC and CPPCC sessions. The live broadcast is an experimental verification of the 8K live broadcast of Beijing 2022. Compared with 4K live broadcast, 8K live broadcast has stronger visual impact, and can show more details, enhance the audience's realistic experience, and is very suitable for live sports matches. The Winter Olympic Games have complex venues, obvious advantages of satellite live broadcasting and wide coverage without geographical restrictions.

3. Characteristics and Analysis of Technology in Aerospace Engineering

Aerospace science and technology in Beijing 2022 is dazzling, because of the unique charm of aerospace technology. Throughout China's aerospace development, aerospace business is like a large and precise giant machine operation, operated under the aerospace engineering system. Vast resources such as people and things will be unified deployment. Then it produces strong efficiency, and pushes a seemingly impossible task into a reasonable in technology, reliable quality, and efficient operation of project entity.

Most aerospace projects meet national strategic needs, gather major interdisciplinary scientific research tasks, and are characterized by large implementation scale, complex tasks, technology-intensive, high risk, long development period and large investment^[2]. These characteristics require high safety and reliability of aerospace engineering technology. Given the challenges of the Winter Olympic Games, such as rapid changes in status, multiple specialties, difficult risk management and control, and tight development schedule, it is essential that high-quality and reliable space technologies should be applied to international large-scale events.

3.1. High Reliability

Reliability is one of the core aerospace technologies and also the comprehensive embodiment of the aerospace technology level^[3]. In the development process the design, analysis and verification of reliability and safety are continuously strengthened. And comprehensive planning, design, analysis, development and process control are carried out to ensure the reliability and safety of the satellite

and to meet the mission requirements. Redundancy design, key function redundancy, key interface redundancy, key hardware redundancy, especially card level, device level, system level backup, are carried out to eliminate single point of failure and to improve system reliability. And power supply, thermal control and other security control are achieved to improve system reliability^[4].

3.2. Emphasize the Systematic and Holistic Design Concept

The aerospace engineering components are interrelated, interdependent, interactive, coordinated and restricted by each other, and organically linked as a whole. It follows the level principle of modern systems engineering, and carries out operation according to strict hierarchical structure, with obvious orderly hierarchical characteristics.

Due to the complexity of aerospace engineering technology and the variability of various factors in the implementation process, it is difficult for the specialized design of a single technical department to satisfy the consideration of multiple systems, multiple professional fields, theory and engineering practice. Therefore, it is extremely important to strengthen the systematic and holistic design to ensure the interconnection of various technologies and plans.

4. Analysis of Aerospace Engineering Management Methods

The efficient operation of the aerospace management organization is the guarantee of the complete process. The special aerospace Winter Olympics project has 10 teams from 7 branches of the National Olympic Organizing Committee upstream, and more than 70,000 construction workers from 10 external teams downstream. Therefore, the management team carries out weekly meetings and daily reports. Finally, the number of participants, project progress and plan are strongly correlated, and the whole life cycle and all factors are controlled.

The scientific method of the aerospace management organization is the foundation of the smooth operation. The opening ceremony of the Winter Olympics was fraught with difficulties. The LED stage area of the opening ceremony of the Beijing Winter Olympic Games is the largest in the world. In addition, it is waterproof, snow-proof and frost-proof, which increases the difficulty exponentially. Any screen display problems will affect the artistic effect of the entire opening ceremony. So the research team strictly followed the aerospace standards and methods until the more than 10,000 square meters of the stage achieve safe use.

During the Winter Olympics, the aerospace team actively learned from the management experience of major aerospace projects, earnestly explored the operation mode and mechanism of special projects for the Winter Olympics, to ensure the quality and quantity of the special projects with the ideas of aerospace systems engineering and management philosophy. Aerospace system engineering management is the whole process of model system from scheme feasibility demonstration, scheme design, engineering design, engineering development to design finalization and production equipment. In the aspects of technology, plan, organization, progress, quality and others, six basic elements of human, financial, material, technology, information and knowledge management are analysed and managed. The basic approaches are explained as follows.

4.1. Strengthen the Top-level Control of the General Unit.

Aerospace engineering management firstly strengthens the overall technical operation, coordination and management mechanism in the whole process of model development, overall planning and comprehensive integration of the whole system.

The general unit uses the method of system analysis to demonstrate and design the overall scheme, decompose the function, performance index and structure of subsystem according to the

requirements of the project.

And then the general unit conducts comprehensive integration again on the basis of subsystem demonstration and test verification. After several iterations, the overall performance of the project is optimized. According to the approaches of technical development, the decomposition and integration of funds, progress and guarantee conditions are carried out. After several iterations, optimization of development process and implementation plan is realized under certain constraints. The technical coordination and dynamic management of development plan between the whole system and sub-system are implemented in the process of project development.

In the fall of 2021, the construction of the LED stage in the National Stadium needs to be accelerated due to the adjustment of the plan, but the on-site construction personnel are far from meeting the schedule. After identifying this risk point, the winter Olympics special team coordinated across provinces, recruited more than 100 skilled workers, completed nucleic acid testing in the first time and rushed to Beijing to help.

4.2. Form the Administrative Command and Technical Command Organizational System

A system engineering management method with Chinese characteristics has been formed in aerospace engineering since the 1960s. It took management mode of big science engineering under the state-led project organization, and set up the most authoritative and unified leadership organization and coordination. That is, from the "15-member special Committee" at a higher level during the period of "Two bombs and one satellite" to the "Special Committee on Manned Space Flight" and "China Manned Space Engineering Office" chaired by the Premier of The State Council during the period of manned space flight. It forms the "One system two lines" engineering organization management system. That is administrative command line and technical command line, to break the department, region and the limitation of the system and so on. It also achieves the goal of the aerospace engineering, organization and coordination, command decision-making system such as the effective implementation of the management activities^[6].

For this Winter Olympic Games, the aerospace team focused on the aerospace systems engineering management, and set up a "leading group, two general systems and a special office" in reference to major aerospace projects. Among them, the leading group focused on the overall analysis, identified difficulties and key points; the "two general" organization ensure the bottleneck of the short board, and advance scheduling; Special offices adhere to the requirements of daily and weekly reports and reverse scheduling.

4.3. Implement the Product Development Route with "Three Steps" as the Core

The so-called "three steps", namely pre-research generation, research generation, production generation. Technical conditions for new products can be created through advance research. Then the technical level will be improved through research and development, the performance of existing models of products will be constantly improved, and the life cycle will be prolonged. Through continuous improvement of production process technology, the significant improvement of product technical performance will be promoted, product serialization and standardization production capacity will be improved, with the development cost reduced^[5].

4.4. Develop Project Management of Four Technical Stages

In terms of technical stage management, there are four stages: scheme, preliminary sample, sample and preparation. Each stage of project development has a clear definition, task and standard of the completion, and stepping into next stage must also have a strict evaluation and review. As we know

that with continuous advance, the cost of correcting design flaws will grow. So in the process of development, the state of the system is described after a stage is completed, and then a baseline is formed. When a stage is completed, it is necessary to assess whether the desired objectives have been met, and necessary to examine design maturity and analyse technical risks^[6]. It provides decision basis for the next stage of development. The latter stage of development will not begin until the previous baseline has been established, stabilized, and controlled. Taking technical review as node of each stage, the critical technical reviews include system design review (SDR), preliminary design review (PDR) and Critical design review (CDR).

4.5. Establish the Concept of "System Quality"

In the process of development and production of aerospace projects, the concept of "system quality" is provided. Through continuous research and practice on quality problems, the "double five" standard for system quality problems was established. It refers to each five requirements of technical and management zeroing in quality problem zeroing. Firstly, technology zeroing refers to accurate positioning, clear mechanism, recurrence of problems, effective measures, drawing inferences from one another. Secondly, management zeroing refers to clear process, clear responsibility, and implementation of measures, serious handling, perfect rules and regulations. The "double five" standard is a quality management method with Chinese characteristics that has been constantly summarized, improved and made innovation in practice by aerospace personnel. And the "double five" standard has promoted the continuous improvement of the quality of aerospace products and the promotion of systematic management capabilities.

The "double five" standard refers to finding and analyzing the causes of the management of quality problems in design, production, assembly and test, and taking preventive and improvement measures to prevent the recurrence of problems, so as to improve the risk prevention and control ability of the organization^[7].

5. Thoughts on the Industrialization of Aerospace Science and Technology

Aerospace and other advanced technologies play a leading role in developing productive forces, promoting social civilization and enhancing national defense capabilities. The industrialization of these technologies will drive the national economy. Practice has proved that a breakthrough in the high-tech field can drive the development of a number of industries^[8]. For example, the development of aerospace industry will mobilize the development of electronics, information, materials and even basic industries. However, to promote the industrialization of aerospace and other advanced technologies, we need to focus on human resources and property rights systems, institutions and mechanisms^[9].

It is necessary to train a group of experts who dare to innovate, and a plenty of entrepreneurs who understand technology and are good at management, which is one of the keys to accelerate industrialization. To develop aerospace technology, first of all, we need a number of innovative and inventive experts, so as to cultivate a number of high-tech achievements with independent intellectual property rights. Without these, one cannot make bricks without straw. Of course, at present, many units also have a lot of high-tech achievements in aerospace, but the rate of high-tech industrialization is still low, lack of technologically savvy and well-managed entrepreneurs to facilitate the transformation of these achievements. Therefore, it is necessary to strengthen the construction of research and research teams and technological entrepreneurs^[10].

Building a property right system, Institutions and mechanism in line with market economy is the second key to accelerate high-tech industrialization. The first is property rights. Is knowledge worth nothing? How to define the ownership of intellectual property rights? How to safeguard

owner's equity? Many more need to be determined by legislation and policies, otherwise it will affect the transformation and transfer of high-tech achievements. The second is institutional. Due to the imperfect market economic system and the existence of multiple legal person system of enterprises, the situation of "seeking development together and concentrating strength to do great things" has seriously affected the process of high-tech industrialization. The last but not least, it is the mechanism. At present, a perfect cooperative competition, incentive restraint and evaluation mechanism in line with the law of market economy development has not been well established. Without cooperation, large-scale high-tech projects like the aerospace industry cannot develop. Without competition, it cannot develop. Without incentives, constraints and evaluations, it cannot stimulate the enthusiasm and creativity of scientific and technological personnel, it cannot select the best and eliminate the bad, and it cannot achieve sustainable and sound development.

6. Conclusion

This paper introduces the application of aerospace science and technology used in the winter Olympic Games in Beijing 2022, and analyses aerospace science and technology in engineering projects and the characteristics of aerospace engineering management method. The industrialization of aerospace science and technology is explored to how better serve the people at home and abroad, the industrial projects, civil and commercial enterprises, and to provide ideas for the related people.

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