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New Emergency Epidemic Prevention Space Products from the Perspective of Human Health

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Abstract: The outbreak of the novel coronavirus began at the end of 2019 and is still spreading around the world, with sporadic or localized outbreaks at home and abroad, and even mutation and escalation. Although the epidemic prevention and control has not slackened at all, the new corona-virus continues to mutate, spread rapidly and widely. However, since the outbreak of the epidemic, the detection and research of the virus by nucleic acid detection laboratories have been seriously inadequate. This paper introduces the general situation of emergency space products from the angle of human health, and introduces the background of the birth of new emergency anti-epidemic space products, the design scheme of the new type of emergency anti-epidemic space products is put forward, which are “Fire Eye” laboratory (air film version), “Fire Eye” air film negative pressure isolation ward and “Fire Eye” vehicle-mounted laboratory The function layout design of the emergency epidemic prevention space in the perspective of the combination of epidemic prevention and control can realize the full set of technical systems, such as rapid construction, positive and negative pressure conversion, intelligent integration, etc., as of April 2022, more than 370 fire laboratories have been set up in 37 countries and regions (283 domestic and 95 International), which have been welcomed and supported by the general public, and has had a very positive social impact.

Keywords: New Crown Epidemic, Global Spread, Epidemic Prevention Space Products, Nucleic Acid Detection, Epidemic Prevention Space

1. Introduction

The novel coronavirus started to break out at the end of 2019 and is still spreading around the world, with sporadic or local outbreaks at home and abroad and even mutating and escalating. Although the prevention and control of the epidemic has not been relaxed in the slightest, the new coronavirus continues to mutate, spread rapidly, and spread to a wide range, but since the outbreak of the epidemic, nucleic acid testing laboratories for virus detection and research have been severely insufficient. The major global epidemic has not yet subsided. The new coronavirus variant Omicron caused a rapid and multi-point outbreak of local epidemics [1]. The reality of the run on resources in the isolation ward in Hong Kong suggests that there is still a risk of outbreak in the future. This global public health problem has also exposed my country. Serious shortage of emergency protective reserves.

The new coronavirus has evolved into more than 1,000 different subtypes or branches. There are a total of 15 different mutant strains, of which 5 have attracted widespread attention. They are: Alpha, Beta, Gamma, Delta, and Omicron. The first three have been significantly weakened, and the latter two are now important. Delta (Delta) once led to an increase of 400,000 infections in India [2, 3]. Omicron led to a five-week sharp increase in the number of infections in the United States [4]. According to statistics, as of May 2022, Beijing time, the cumulative number of confirmed cases of new coronary

pneumonia in the United States reached 82.1 million, and the cumulative number of deaths was 990,000. From February 18 to May 9, 2022, the number of new confirmations in the United States is shown in Figure 1.

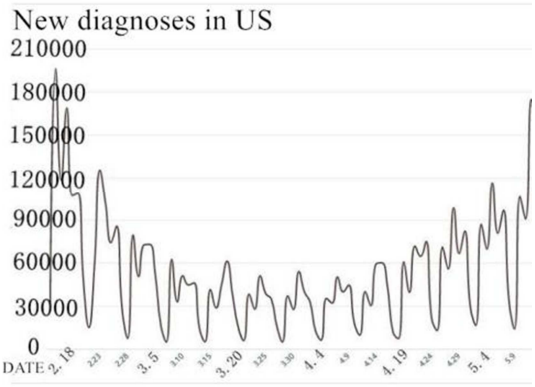

Figure 1. *The number of new confirmed cases in the United States.*

In this context, Chinese President Xi Jinping proposed the "Human Health Community" [5], which is an initiative for all countries in the world to jointly safeguard the safety of human life. In the context of the "dynamic clearing" of precise prevention and control of the entire chain in China and the cancellation of epidemic prevention restrictions overseas, designing highly mobile epidemic prevention space products and establishing an agile deployment system have become the key. The rapid construction of emergency space products not only puts forward high requirements for the products themselves, but also relies heavily on production, logistics, infrastructure and on-site management capabilities to form a space product system with fast production, full logistics, and easy storage, while coping with cross-regional reserve deployment in severe disasters The systematic strategy is to help build a community with a shared future for mankind as the focus of Chinese wisdom and Chinese solutions.

2. Overview of Emergency Space Products from the Perspective of Human Health

According to the report "Human Losses Caused by Disasters 2000-2019" released by the United Nations, from 2000 to 2019, a total of 7,348 major disasters were recorded worldwide, resulting in 1.23 million deaths, a total of 4.2 billion people affected, and economic losses as high as 29,700. One hundred million U.S. dollars. Taking the outbreak of the new crown epidemic at the end of 2019 as an example, the epidemic that lasted for nearly three years is still raging [6, 7]. According to the WHO report, as of July 1, 2022, the cumulative number of confirmed cases in the world is about 545 million, and the cumulative number of deaths About 6.335 million, the world's public health security is facing great challenges. Various disasters show that we must strengthen the development and application of high and new technologies represented by information technology and space technology in disaster detection, forecasting, emergency response and post-disaster reconstruction. It also prompts the design of high-mobility emergency space products and the establishment of agile deployment. importance of the system.

At present, the research on emergency disaster prevention and mitigation space products [8] at home and abroad mainly focuses on conventional construction methods, and optimizes project management and construction technology. However, when it comes to the rapid construction of conventional emergency hospital projects and its role in disaster prevention and control of public health events, Qi Chao pointed out that the maximum construction period compression that can be achieved by these methods is far from the limit construction period compression requirement. After the outbreak of the new crown epidemic, the construction of traditional emergency isolation wards has many bottlenecks, such as high cost, long construction period and high installation difficulty. For example, the Huoshenshan Hospital built in 10 days and the Leishenshan Hospital in 12 days cost a lot of manpower and financial resources, and it was still difficult to meet the special requirements of responding to the rapid spread of the epidemic at that time. At present, we urgently need to explore the systematic, agile and long-term effectiveness of the global reserve and supply chain construction of emergency space products under the new stage of disaster prevention and mitigation [9, 10] of the large-scale rapid construction system. Through the intelligently integrated functional modules and the equipment design principle of air-film tent space combination, the emergency ward construction plan of "hour-level delivery of medical housing, daily-level construction of emergency medical bases, and monthly-level construction of long-term medical bases" is realized.

In order to solve the problems of high cost, long construction period and high installation difficulty in the construction of traditional emergency wards, this paper focuses on "easy to build and transport" and boldly and innovatively imagines the easy-to-form air film structure with intelligent integration. The medical function modules are highly integrated, and it is a space product system design for disaster prevention and mitigation that adapts to the deployment of global emergency reserves for severe disasters. In response to different uses such as public health events and post-disaster rescue, it can also adapt to different conditions and requirements, and can meet the design requirements of the whole-process system that combines peace and war and rapid response. At present, foreign air-membrane structure buildings are mainly used in industrial plants, exhibition halls, museums, logistics warehousing, sports venues, agriculture, etc., and are not used in emergency epidemic prevention and disaster relief. In response to the urgent needs of various countries to deal with epidemic infectious diseases such as the new coronavirus, BGI and Tongji University proposed a modular fire-eye membrane negative pressure isolation ward construction system. The system has the advantages of

modularity, low energy consumption, easy to build, more intelligent, storable, air transportable, and recyclable. Through the closed gas environment management, the directional flow of internal air is realized, and the innovative design of the HVAC and HEPA systems ensures the negative pressure environment in the ward area and the cleanliness of the exhaust gas, which meets the requirements of the combination of epidemic prevention and control.

3. The Birth of a New Type of Emergency Epidemic Prevention Space Product

At present, the research on emergency space products at home and abroad mainly focuses on conventional construction methods, and optimizes project management and construction technology. However, the maximum construction period compression that can be achieved by these methods is far from reaching the limit construction period compression requirements. At the same time, in the new stage of epidemic prevention and disaster prevention that urgently needs to explore a large-scale rapid construction system, the global reserve of emergency space products and the construction of the supply chain are urgently needed. Systematic research is not yet complete. The comparative analysis of the existing emergency space product construction methods is shown in Table 1. With the spread of the epidemic around the world, starting from 2020, the "Fire Eye" emergency epidemic prevention space product series developed by BGI and Tongji University's School of Design and Innovation has become the "Chinese business card" of anti-epidemic actions, from China to the world, on a global scale Help the prevention and control of the new crown epidemic, and protect the world and people's well-being.

Table 1. *Comparative analysis of existing emergency space product construction methods.*

model	3D printing	packing box	Expandable container	tent/membrane structure	Vehicle form
On-site installation (take 2000 square meters as an example)	10-15 days with heavy equipment and need to 3d print house shells on site	7 days, equipped with heavy equipment and professional construction team	6 hours, light equipment and ordinary workers	24 hours, light equipment and ordinary workers	2 hours, can be operated without professional engineering team
Device integration	Low degree of integration, the house needs to be printed on site	Fresh air system, air conditioning, water treatment and other equipment need to be installed on site	Most of the equipment has been integrated, and only electric work needs to be done on site	Fresh air system, air conditioning, water treatment and other equipment need to be installed on site	Highest level of integration with little on-site work
Convenient for storage and secondary location selection	not possible	not possible	possible	possible	possible
base conditions	foundation, levelling	foundation, levelling	foundation, levelling	as long as the ground is level	No strict foundation requirements
easy transport	Land/Sea/Air	Land/Sea	Land/Sea	Land/Sea/Air	sea freight
Capacity	High productivity	Mature supply chain with high production capacity	Fewer professional suppliers and low production capacity	Can integrate civilian suppliers, high production capacity	High technical requirements and low production capacity
total life cycle cost	high	high	higher	Low	high
Average weight per square meter built	200-400kg/square meter	200-300kg/square meter	200-300kg/square meter	40-60kg/m^2	300-500kg/square meter

"Fire Eye" emergency epidemic prevention space products include "Fire Eye" laboratory (air film version), "Fire Eye" air film negative pressure isolation ward, "Fire Eye" vehicle laboratory, etc. The original idea of "Fire Eye" laboratory came from Wang Jian, chairman of BGI. The "Fire Eye" laboratory built by BGI in the early stage of the epidemic is a laboratory for nucleic acid detection of the new coronavirus. "Fire Eye" is taken from Monkey King's "Fire Eye" in "Journey to the West", one of the four famous Chinese novels. Sun Wukong's "Fire Eye" can identify ghosts and ghosts, and the "Fire Eye" laboratory can accurately detect viruses. The inspiration of the "Fire Eye" air film laboratory comes from the isomorphic relationship between "gene-cell-human" and "human-architecture-urban living organism", which is like a "life-like building". In the future, the laboratory can be turned into a concrete shell structure by spraying composite materials and become a permanent building. "Life-like architecture" draws on the bionic structure of double-layered cell membrane, using arch structure and double-layered air-film structure, which can directly inflate the interlayer air column of the double-layered air-film, and the air column is supported by positive pressure, while the interior of the space uses The fresh air system achieves negative pressure and meets the requirements of the biosafety laboratory. This process is like the process of an egg embryo in a mother's body. During the birth process, the surface gradually hardens and becomes an egg. Therefore, the "Fire Eye" gas-film laboratory is also known as a "life-like" building.

Since the outbreak of the new crown epidemic in 2019, BGI has been committed to nucleic acid detection for epidemic prevention and control. In addition to the traditional "Fire Eye" laboratory, BGI has successively launched square cabin type, hard air film type, soft air film type, and vehicle-mounted integration. various laboratories. In April

2020, in order to solve the problem of no new coronavirus testing laboratories in some countries and regions and meet the needs of rapid and large-scale detection of new coronavirus nucleic acid, the team of BGI and Tongji University designed and developed nucleic acid for new coronavirus and other pathogenic microorganisms. The inflatable membrane structure virus detection laboratory for detection - "Fire Eye Laboratory (gas membrane version)". As of June 2020, 20 gas-film version Fire Eye laboratories have been launched in China, which have played an important role in the "epidemic" of the civil war and continued to ensure the domestic nucleic acid testing needs to fight the epidemic. BGI has sent more than 35 million new coronavirus detection kits to the world, covering more than 180 countries and regions. There are 58 "Fire Eye" laboratories operating overseas, distributed in 17 countries (regions) around the world, and the maximum daily testing throughput of "Fire Eye" laboratories has exceeded 200,000. The "Fire Eye" laboratory has become the "Chinese business card" of the anti-epidemic action, from China to the world, and has become the "outpost" of the international community to jointly respond to the new crown epidemic. Figure 2 shows the area covered by FireEye Labs globally.

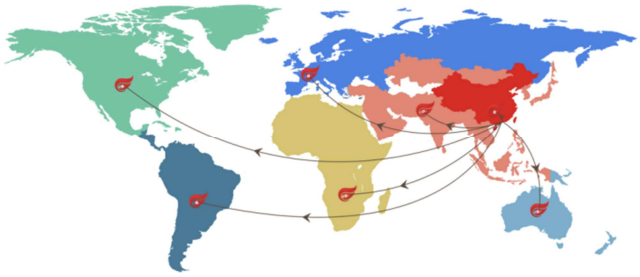

Figure 2. *Fire Eye Lab went overseas.*

"Fire Eye" emergency epidemic prevention space products follow "Moore's Law" [11, 12]. "Moore's Law" means that chips are getting smaller and smaller, and the amount of information they contain is increasing. In the future, buildings will no longer be constructed of reinforced concrete, but a modular building system with a movable inflatable membrane structure. The energy consumption of construction will be less and less, and the wisdom will be higher and higher. The characteristics of using "Moore's Law" to create the ultimate air film building products include:

(1) Intelligent [13, 14]: equipped with cutting-edge professional automated experimental equipment; optical interactive contactless access control and transfer window system, no need to swipe card, face, fingerprint recognition, and can also be controlled while wearing protective clothing; intelligent cabin pressure control system, automatic adjustment Air pressure in each area to achieve negative pressure; all systems are managed through mobile phone integration.

(2) Intensification: It can be accurately delivered to the world through air transportation, adopts a distributed system design to simplify the installation process, and uses the BIM system [15] to unify and remotely manage the supply chain, transportation, construction and operation.

(3) To beautify: The white air film is matched with the light strip, which is simple and clean. With indoor intelligent equipment, it is full of futuristic, space and ritual sense.

(4) Serialization: The small-step fast-running design idea of iterating while practicing, gradually improving and standardizing products, and then developing an integrated vehicle-mounted testing laboratory and air film sampling booth for use together, and can be transformed into homestays and disaster relief buildings in the future., Forum buildings, etc.

4. Design Scheme of New Emergency Epidemic Prevention Space Products

4.1. "Fire Eye" Laboratory (Air Film Version)

The core key to responding to the global outbreak is saturated detection: early detection of infected persons; saturated admission: extremely low case fatality rate. Early detection, early isolation, and early treatment can control the spread of the epidemic. Faced with the urgent new demand for new crown detection, it must be fast, flexible, and low-cost. The "Guidelines for the Implementation of New Crown Nucleic Acid Testing for All Staff" issued by the Comprehensive Team of the Joint Prevention and Control Mechanism of the State Council requires that cities with a population of more than 5 million should complete the task of nucleic acid testing for all staff within 3 days, while traditional laboratories have long construction periods and construction costs. High two limitations, become the main limiting factor in the actual emergency detection application. The "Fire Eye" nucleic acid testing laboratory (gas-film version) makes up for many deficiencies of new laboratories in reality. It not only has low cost and high efficiency, but also has the characteristics of national production, high integration, intelligence, storage, and easy transportation. It has a high volume compression ratio, can be folded and transported, and can be transported by air to the place of demand. It can be quickly deployed, constructed, and put into use. It provides a negative pressure environment. It is built by inflating and can be put into use after the equipment is installed. The daily detection throughput scale can reach several thousand to 200,000 per day, which is suitable for large-scale testing and national testing, which greatly relieves the pressure of local nucleic acid testing in the outbreak.

The "Fire Eye" laboratory (air film version) adopts the flame-retardant, wear-resistant and high-stability PVC material as the main material of the building, and forms an air arch structure through a double-layer air film for modular layout, and four functional areas are set up. ——The sample receiving area, reagent preparation area, sample preparation area and amplification area are equipped with new crown nucleic acid detection kits, automated sample preparation, nucleic acid extraction equipment, Class II biological safety cabinets, QPCR instruments and other experimental

equipment, which can be expanded in the future for antibody detection Equipment, gene sequencers, high-performance servers and other advanced equipment.

On April 3, 2020, the complete nucleic acid detection process. The nucleic acid detection process is covered, and the single-layer gas film air-filled column structure is used to play a supporting role. The room is under positive pressure. cover. The "Fire Eye" laboratory (air film version) (version 1.0) is shown in Figure 3.

Figure 3. *"Fire Eye" laboratory (air film version) (version 1.0).*

4.2. "Fire Eye" Air Film Negative Pressure Isolation Ward

When responding to major public health emergencies, the mode of supply and allocation of medical resources in isolation wards plays a decisive role. In view of the highly infectious characteristics of the new crown pneumonia virus, the hospitalization of new crown patients requires a large number of negative pressure isolation wards. However, a large increase in the supply of isolation wards in the absence of a major outbreak will result in a waste of medical resources; because of the outbreak of the epidemic It is difficult to accurately predict the time and location, so the "combination of epidemic situation" should be used to adjust the supply of medical resources in isolation wards. The "Fire Eye" air-film negative pressure isolation ward provides a feasible solution to this dilemma. The system has the advantages of modularity, low energy consumption, easy construction, smarter, storable, air transportable, and recyclable. Through closed gas environment management, the directional flow of internal air is realized, and the innovative design of HVAC and HEPA systems ensures the negative pressure environment in the ward area and the cleanliness of exhaust gas, which meets the requirements of "combination of epidemic prevention and control".

The inflatable membrane structure can realize the rapid construction and rapid transfer of the isolation ward, and the construction can be completed in less than 1 day; and there are few construction restrictions. The formation of medical corridors and room units in the isolation ward is conducive to improving the safety of use and can meet the standard of negative pressure space; good mobility and application flexibility, and modular design, which can determine the medical module that meets the input according to the task requirements. When a large number of wards are not needed at ordinary times, it is only necessary to deflate, compress and fold the air film ward for storage, which greatly reduces the storage space. The physical schematic diagram of the "Fire Eye" air film isolation ward is shown in Figure 4.

Figure 4. *Schematic diagram of the "Fire Eye" air-film isolation ward.*

4.3. "Fire Eye" Vehicle Laboratory

With the strengthening of epidemic prevention and control, higher requirements have also been placed on the timeliness of laboratory construction. To this end, BGI and the School of Design and Innovation of Tongji University combined the laboratory with a large truck to develop the "Fire Eye" vehicle-mounted laboratory, which not only fully considers global biosafety requirements and industry norms, but also has the ability to respond quickly, move quickly, and put into use quickly. The characteristics of the laboratory make the laboratory more scientific and technological. The "Fire Eye" vehicle-mounted nucleic acid detection laboratory system has the advantages of being movable, expandable, integrated, and intelligent. The foldable and expandable design can be compressed like a computer compressed file, or the wing cabin can be expanded to form a more compact state. big space. The "Fire Eye" vehicle-mounted nucleic acid detection laboratory is suitable for localized outbreaks and regional screening. It combines the nucleic acid detection laboratory with large trucks in the form of vehicle-mounted or vehicle-mounted, which further breaks through the limitations of the site. The characteristics of quick response, ready to call, able to fight, and expandable space are more in line with the needs of "combination of peace and war". There are four versions of the "Fire Eye" vehicle laboratory:

(1) Huajing - Vehicle-mounted containerized fire eye laboratory (version 1.0) is shown in Figure 5. It adopts a single container design, and the testing equipment is fixedly installed in the carriage. The vehicle arrives at the scene of the outbreak, and the debugging time is 30 minutes later. It can be put into use and can complete 2000+ single-tube tests every day.

Figure 5. *Huajing - Vehicle Containerized Fire Eye Laboratory (Version 1.0).*

(2) Huaxiang - Vehicle-mounted Fire Eye Laboratory (Version 2.0) is shown in Figure 6. Compared with the Vehicle Fire Eye Laboratory of Version 1.0, the Foldable Fire Eye Laboratory of Version 2.0 has a larger area and higher throughput. Provides a comfortable experimental environment for the experimenter. It is a semi-automatic deployment laboratory. It can be put into use within 40 minutes of debugging by four workers, and can complete 4000+ single-tube tests every day.

Figure 6. *Huaxiang - Vehicle Folding "Fire Eye" Laboratory (Version 2.0).*

(3) Huarui - Vehicle-mounted fire-eye laboratory (version 3.0) is shown in Figure 7. Version 3.0 of the vehicle-mounted fire-eye laboratory can be expanded in area and has a larger throughput, which is a fully automatic deployment laboratory. Only one worker is needed, and the cabin can be automatically deployed in one minute to complete the construction of the main laboratory, and can complete 6000+ single-tube tests every day.

Figure 7. *Huarui - Vehicle Pull-Out "Fire Eye" Laboratory (Version 3.0).*

(4) Fire Eye Laboratory (Wing Film Version) (Version 4.0) As shown in Figure 8, the cabin is more compact and can be transported to the required place by air, and then transported by the truck body after landing. After the cabin is unfolded, the air film prefabricated in the cabin is inflated to form an experimental space. In cold or hot different regions, single-layer or double-layer air membrane solutions can be used according to requirements.

Figure 8. *"Fire Eye" Laboratory (Wing Film Version) (Version 4.0).*

5. Conclusion

The novel coronavirus started to break out at the end of 2019 and is still spreading around the world, with sporadic or local outbreaks at home and abroad and even mutating and escalating. The new coronavirus is constantly mutating, and the mutated virus is more contagious. We have to attach great importance to the mutation of the new corona-virus. We need to do physical protection and actively vaccinate in daily life. When a new crown outbreak occurs in a certain place, Timely detection of infected people and effective isolation, so that the epidemic can be quickly prevented and controlled, and efficiently achieve "everything that should be checked and all that is willing to be checked". The main conclusions of this study are as follows:

(1) This paper introduces the overview of emergency space products from the perspective of human health; introduces the background of the birth of new emergency epidemic prevention space products;

(2) The design scheme of new emergency epidemic prevention space products is proposed: "Fire Eye" laboratory (air film version); "Fire Eye" air film negative pressure isolation ward; "Fire Eye" vehicle laboratory.

(3) The“Fire Eye” anti-epidemic space products all adopt modular design, with good maneuverability and flexibility, and can decide the input medical module according to the mission demand. The“Fire Eye” product series is highly coordinated to form a set of epidemic prevention mobile hospitals, screening infected cases as early as possible, timely admission and treatment of infected patients, to prevent the further spread of the epidemic, is helping the global anti-epidemic.

(4) After the epidemic situation stabilizes, the“Fire Eye” product series can continue to play an important role in the

large-scale crowd detection in the aspects of reproductive health, infectious diseases, tumors and so on, and become the improvement of people's livelihood and health, promote life science research and develop an important“New public health infrastructure” for the life health industry.

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