The Application Exploration of Digital Twin in the Space Launch Site

Cai Hongwei[1(✉)], Zhou Bo[1], Yang Hui[2], and Li Xu[1]

[1] Xichang Satellite Launch Center, Group 5, box 16, Xichang 615000, Sichuan Province, China
11899944@qq.com

[2] China Astronaut Research and Training Center, Beijing 100094, China

Abstract. In view of the future development of space launch site, combined with the present situation and development of digital twin technology, the paper puts forward the idea of the construction of digital twin in the space launch site. The system analyzes the application prospect of digital twin technology in the space launch site, and designs the architecture of the digital twin of the space launch site, which is concluded that the digital twin body of the space launch site will completely change the operation management mode, the equipment guarantee mode, the task process, the organization command, and so on.

Keyword: Digital twin · Space launch site · Heterogeneous model · Three-dimensional vision · Virtual interaction · Visual control · Health management

1 Digital Twin

With the explosion of the new generation of technology represented by the Internet of things, large Numbers, cloud computing and artificial intelligence, the development of the intelligent industry has been opened, and the space launch site in China is also moving in a smart and intelligent direction. Digital twin, a frontier technology, are listed as the top six major technology in the future of defense and aerospace industry in 2017, being widespread attention by industry and academia [1]. In July and 2019, the world's most authoritative it research and consulting firm Gartner has listed digital twin as one of the top 10 strategic technology trends in recent three years [2], and has become an important cornerstone of the Internet of things and industry 4.0.

Digital twin is the object of the pointer to the physical world, and by digital means to build an entity that is identical to the digital world to realize the understanding, analysis, and optimization of the physical entity [3]. Digital twin is a virtual model of physical entities in a digital way, using data to simulate the behavior of physical entities in the real environment, and increase or expand new capabilities for physical entities by means of virtual interaction feedback, data fusion analysis, decision iteration optimization, etc.

Digital twin is a multi-dimensional, multi-scale, multi-probability simulation model for highly integrated multi-physical fields. It can use physical models, sensor data and

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historical data to reflect the function, real-time state and evolution trend of the corresponding entity of the model, and be applied in several areas such as aviation, aerospace, production, design, manufacturing, and intelligent city [4]. In the space field of NASA in 2010, NASA introduced the concept of digital twin in the release of the NASA space technology roadmap, which is intended to achieve a comprehensive diagnostic and predictive function of the flight system. The route map to achieve NASA's digital twin goals by 2027. NASA estimates that by 2035, the use of digital twin technologies will halve the cost of aircraft maintenance and extend the service lifespan to 10 times the current level. In recent years, the application of digital twin in aerospace has been widely watched by scholars both at home and abroad, and the digital twin technology has been widely used in the health maintenance of domestic and foreign aerospace vehicles. Li Shu and other people carry rocket launch site digital practice, demonstrate and develop the new rocket in the launch field full process and practice test, provide technical support for model development [5].

2 Artificial Intelligence

Artificial intelligence is a cross-subject that involves informatics, logic, cognitive learning, thinking, systems and biology, through a lot of research, using computers to simulate certain thinking processes and intelligent behavior, and to produce a new type of intelligent machine that can respond in a way that is similar to human intelligence [6]. It has been used in the field of knowledge processing, game theory, automatic programming, automatic programming, expert system, knowledge base, intelligent machine, etc., especially in the areas of unmanned driving, intelligent machine, image recognition and language recognition, which is changing the way people make life, which is driving the improvement of technological innovation, economic development and people's lives. In industries such as finance, healthcare, automobile and retail, artificial intelligence is relatively mature in these industries, such as companies such as finance, healthcare, automobile and retail, and the companies such as Google, Baidu, Tesla and Audi are joining in the case of self-driving cars [7–10].

3 Digital Twin Applications And Analysis In Space

Space always has a lot of risks. The space launch site is a prerequisite for space launch. The non-standard, maintenance, use and storage of environmental bad, short-term and reliable characteristics, and the continuous high density task of the development of the launch field for a long period of time, must seek more active and more scientific methods, to find out, to find out, to meet the problem of the resolution of the resolution and the reliability of the launch site, and to implement preventive maintenance and maintenance, to improve the overall reliability and safety of the launch site.

With the explosion of the new generation of technology represented by the Internet of things, large Numbers, cloud computing and artificial intelligence, the development of the intelligent industry has been opened, and the global space launch site is gradually transforming in the direction of intelligence and wisdom. Based on the technology of the Internet of things, artificial intelligence and BIM&CIM model, the space launch

site digital twin body is built to realize the high integration of the reality launch site and digital launch field, integrating personnel, process, data, technology and business system, realize the whole process of the launch site, the digital, network and intelligence of the whole elements, and promote the transformation and development of the space launch site.

All in all, it is possible to build the space launch site with high information fusion, which can provide strong support for the maintenance, equipment maintenance, equipment maintenance, failure prediction, health management, simulation training, task implementation, process optimization, evaluation, command decision, etc., and will enhance the comprehensive ability of the space launch site.

4 The Design of the Digital Twin System of the Space Launch Site

The space launch site digital twin system has large volumes and complex data. Through the combination of artificial intelligence algorithm and data, the consistency of the digital twin and physical ontology can be further improved. At the same time, artificial intelligence and large Numbers are analyzed and analyzed, which can predict the changing trends of the data of the ontology, including fault, life expectancy, etc.

The launch site digital twin system is a key function of the aided digital twin system by building a sound data storage structure, using cutting-edge data mining technology to search for key data in the full state of the twin body information.

The space launch site digital twin system consists mainly of four parts, including physical objects, virtual models, twin data and service systems. Physical objects are the basis of digital twin. Based on this, the virtual model of physical objects is constructed, and the virtual model is gradually consistent with the physical object through iterative optimization. Through the drive of the twin data, the virtual model and the service system are more coordinated by the continuous iteration optimization, making the service system more coordinated with the virtual model (Fig. 1).

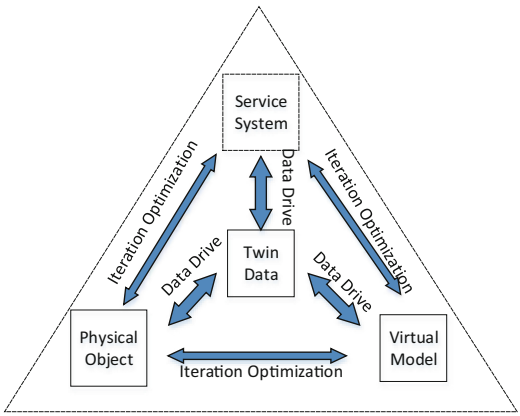

Fig. 1. Architecture of Space launch site digital twin

The key of the digital twin of the launch site is the information physics fusion, the multi-dimensional virtual model, the twin data, the dynamic real-time interaction connection, the service application and the whole element physical entity, etc.

Information physical integration is mainly refers to the realization of the intelligence perception and interconnection of physical elements, the construction of virtual model, the fusion of twin data, the realization of the connection interaction, the formation of the application service, and so on. The multi-dimensional virtual model is the core component of the overall design and planning, mission implementation, failure prediction, and health management of the launch site, and is the function engine of digital twin. The twin data is the core element of the digital twin of the launch site, which is derived from the launch field physical entity, virtual model, and service system, and is integrated into the each group of the digital twin system after fusion processing. Dynamic real-time interaction is the artery of the digital twin system of the launch site, and the dynamic real-time interaction connects the physical entity, virtual model, and service system to an organic whole.

The digital twin system of the space launch site involves many factors such as mathematical model, system integration, platform software and business. In order to realize the actual business requirements of the launch task, this paper reflects the dynamic energy of the unit of the launch field, the operation of the equipment status monitoring, the process control of the launch process, and the requirements of the multi-system expansion and access in the future, and the structure design of the platform, as shown in Fig. 2.

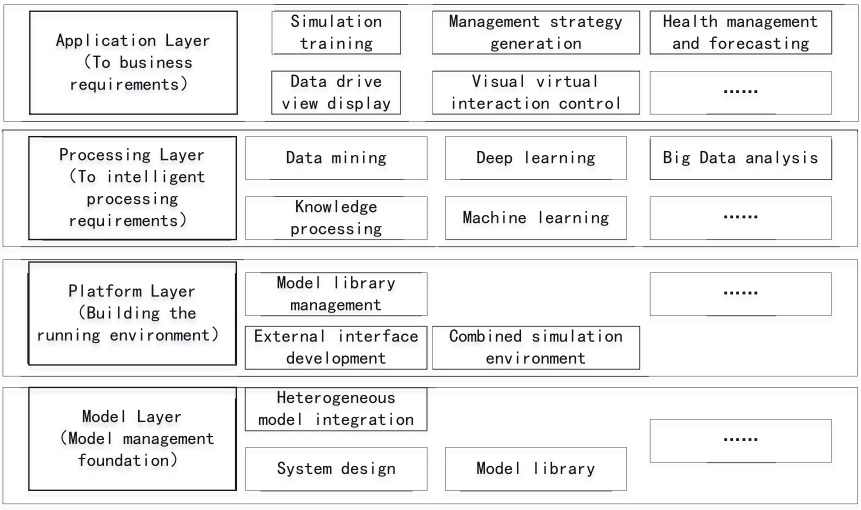

Fig. 2. Hierarchical structure of Space launch site digital twin.

1) Model layer: provides multi-source heterogeneous model integration and system design function, compatible with existing models and supports the subsequent model

extension, and supports the framework of system design based on the model integration base for the overall perspective of the launch site. The virtual object building of the launch site is realized by means of mixed particle degree and multi-level model.

2) Platform layer: provide the operating environment for virtual objects, form the experimental environment based on the model simulation of the model, and consider the external extension interface, support the external object of the external group 3d view, control device, and control signal, and realize the dynamic coupling of multi-type elements.
3) Processing layer: the data processing of a number of twin systems is supported by the intelligent processing of the twin data, which meets the requirements of the different business log processing application, which mainly implements the real data, the data mining, the machine learning, the knowledge processing, the large number analysis and so on, and the ability to improve the data application through the intelligent processing algorithm.
4) Application layer: provides auxiliary function of docking with launch field business, supports the management of space data, data driven visual view, algorithm based device health management, model based equipment control, launch field digital model library management, simulation task management and execution, etc.

The space launch site digital twin system is based on platform software, and it is a functional module such as model integration, system design, simulation test environment and external element extension. The model integration module solves the standardization description of different professional model elements, and provides prerequisites for multi-professional models and platform applications. The system design module solves the problem of the digital launch field, which can be designed by the model of the graphical system based on the model, and builds the simulation object of the application scene quickly by using the model library form management model and the data interface. The simulation test environment solves the problem of digital engineering management and model operation, and supports the performance of typical launch field workflow and task execution. The external element extension module solves the problem of the digital launch site and the external data interaction, and supports the dynamic display of three dimensional viewing based on real-time data.

With the development of artificial intelligence technology, artificial intelligence technology will gradually spread into all walks of life, and it will change the work and lifestyle of people. With the maturity of the digital twin system of the space launch site, artificial intelligence technology will be gradually introduced, and the dual-wheel drive of digital twin and artificial intelligence will be achieved, and the launch site will be continuously driven and improved (Fig. 3).

Through the full integration of artificial intelligence and digital twin, based on the three-dimensional visual human–computer interaction and artificial intelligent data processing platform, the space launch site digital twin body, the carrier digital twin, the spacecraft digital twin, and the full simulation of the space launch mission, the prediction of the emergency in the mission. For the space launch site important facilities, the digital twin is constructed, which can predict the structure of the important facilities of the space launch site, the fatigue damage of the material, the failure of the system caused by the prevention structure and material problems. By building the digital twin

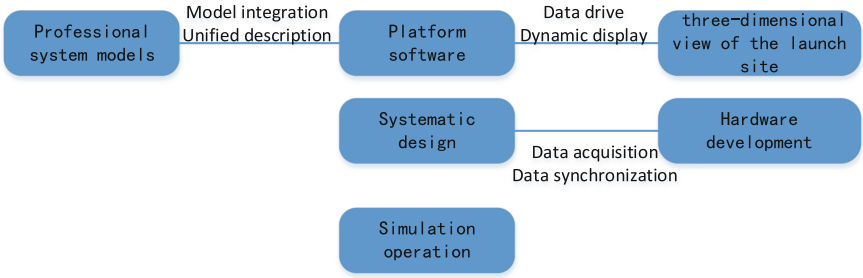

Fig. 3. Multi-level system design framework schematic diagram

of the launch site, the real-time data drive can be used to observe the real-time operation state of the space launch site more fully, and detect the situation in real time. Using the space launch site digital power, it can carry out fault prediction, fault localization and promotion, and through artificial intelligence processing, it can provide optimal control strategy and method for the real-time operation management of the space launch site, realize the effective and the system's launch field health management, and effectively avoid the risk of the space launch site.

Typical application of the digital twin body of the space launch site.

1) Application in visual human–computer interaction.

The launch field digital twin is preset to the external interface at the model level, which can receive external data or pass the model operation to the outside. This method can be used to make a link to the group broadcast data of the cloud platform using the cloud platform, and realize the control of the external equipment of the digital launch site and the state feedback of the external equipment, which is the system of the launch field of the fusion (Fig. 4).

2) Application in visual simulation training.

The digital twin model is based on the control instruction of external equipment or control input device, and the corresponding mathematical model component of the launch field digital twin is simulated by the simulation control instruction, and the work data of each group in the system is passed to the two-dimensional display interface or three-dimensional view, and the performance of the digital launch site is shown in the digital launch field. The staff can simulate the workflow path of the real space launch mission in this virtual scenario to provide the role of the simulation training environment for the staff without the mission (Fig. 5).

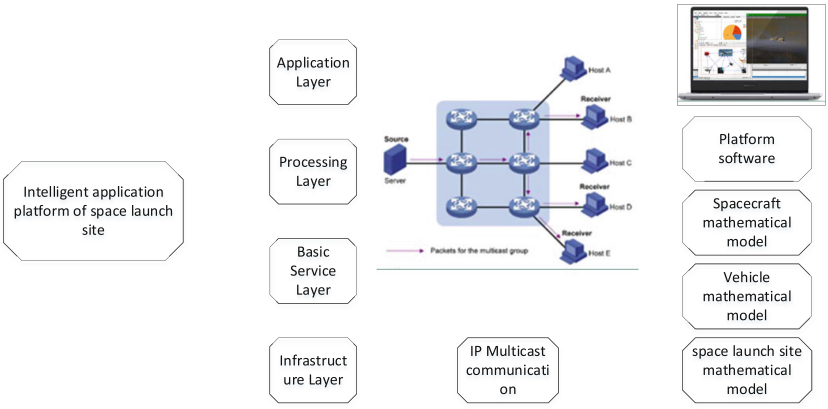

Fig. 4. Equipment data visual interaction diagram

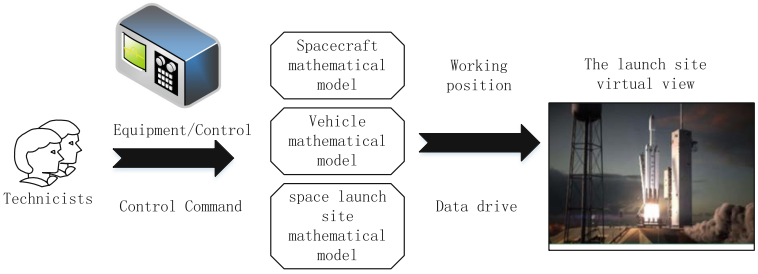

Fig. 5. Simulation training application schematic diagram

5 Conclusion

The digital twin technology has been applied in the space and aviation industry at home and abroad, and has played an important role in design, manufacturing and application. The application of the space launch site must be the result of the deep fusion of digital dual technology and artificial intelligence technology, which will bring revolutionary changes in the operation management mode, equipment guarantee mode, task process and organization command, which will provide strong support for the daily operation, equipment maintenance, failure prediction, health management, simulation training, task implementation, process optimization, evaluation, command decision, etc., and the application prospect is very broad.

References

1. Tao, F., et al.: Digital twin and its potential application exploration. Comput. Integr. Manuf. Syst. **24**(1), 1–18 (2018)
2. Meng, S.H., et al.: Digital twin and its aerospace applications. Acta Aeronautica et Astronautica Sinica **41** (2020). (in Chinese). https://doi.org/10.7527/S1000-6893.2020.23615

3. Shi, P.: The concept, development form and meaning of digital twin. Software Integrated Circuits **9**, 28–33 (2018)
4. Su, R.: The development and application of artificial intelligence are reviewed. Electronic world 84–86 (2018)
5. Shafto, M., et al.: Modeling, simulation, information technology & processing roadmap. National Aeronautics and Space Administration 5–7 (2010)
6. Li, S., et al.: Research of launch vehicle digital launch process. Missiles Space Vehicles **2**, 22–26 (2019)
7. Su, X.: Artificial intelligence review. Dig. Commun. World **1**, 105–112 (2018)
8. Tao, F., Zhang, M.: Digital twin shop-floor: a new shop-floor paradigm towards smart manufacturing. IEEE Access **5**, 20418–20427 (2017)
9. Li, H.: Thoughts on the development route of smart rocket. Astronaut. Systems Eng. Technol. **1**(1), 1–7 (2017)
10. Zhuang, C., Liu, J., Xiong, H., Ding, X.: The connotation, architecture and development trend of product digital twin. Comput. Integr. Manuf. Syst. **23**(4), 753–768 (2017)