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Integrated Configuration management based on System Engineering

Xi Qiu, Jin Zhong, Wei Hui, Lixin Wang, Yi Yang and Jw Wang

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Qiu Xi, Zhong Jin, Hui Wei, Wang Lixin, Yang Yi, Wang Jw

Abstract The design and manufacturing process of an aircraft is a huge and complex SE-System Engineering, it involving a large group of specialized expertise. In the aviation design and manufacturing company(units), the production mode of small batch and multi modified production mode has become a trend. Following the System Engineering Approach and based on System Engineering Thought, it has become a consensus to establish an integrated configuration management model of multi-specialty collaboration. In this paper, configuration management is examined from the perspective of system engineering, the engineering domain involved in aircraft products is divided into many specialized fields, and according to the professional characteristics of the merger into the order-cluster, requirement-cluster, design-cluster, manufacture-cluster, repair-cluster, finance-cluster, manpower-cluster, supply-cluster, airworthiness-cluster etc, for these clusters of unified configuration management system called "Configuration management based on system engineering". Need is a macro perspective to control product requirements, product design, product manufacturing, supply chain, trial

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Qiu Xi
AVIC XI'AN AIRCRAFT INDUSTRY (GROUP) CO., LTD.
qx143@163.com

Zhong Jin
AVIC DIGITAL CAORPORATION Ltd..
zhongjin70@126.com

Hui Wei
AVIC DIGITAL CAORPORATION Ltd..
huiwei1314@139.com

Wang Lixin
AVIC XI'AN AIRCRAFT INDUSTRY (GROUP) CO., LTD.
wlx662@163.com

Yang Yi
AVIC DIGITAL CAORPORATION Ltd..
yangyi2424@126.com

Wang JW
Shanghai Aircraft Design and Research Institute
hswangjunwen@126.com

inspection, maintenance, human property supply and a series of processes. The management of multi professional coupling data based on system engineering can be realized by integrated configuration management, Improve data consistency to remove barriers between and within the enterprise. Build a new type of enterprise configuration control model for customer requirement integration, rapid development and manufacturing. For this paper attempts to propose a novel system engineering configuration matrix, which provides a new idea for the deepening application of system engineering.

1 Introduction

As the developing of engineering manufacturing systems, the specialized expertise from different manufacturing industries are all devoting to transition themselves into professionalization and elaborate expertise, the developing mode of an aircraft been completed from different part are becoming tendency in aircraft industry. Meanwhile, aircraft industry is a very complex traditional manufacturing industry, it refer to lots of professional domains, from aircraft products evolution, in its own related subjects, the general design can be divide into layout, arrangement, pneumatic, performance, operating stability, outline sub-domain, the strength design can be divide into static strength, dynamic strength, fatigue, loading sub-domain, the environment control can be divide into fuel, pipeline, cable, hydraulic, manufacturing technology can be divide into part, assembly, numerical control, additive metal, composite structure. And the following question is, the synergic complexity are increased during manufacturing one aircraft process, how to manage all these different domain's technical state into a uniformly specification are becoming a focus point in industry. For this reason, the configuration management are becoming very important.

2 The Development Process of China's Domestic Configuration Management

2.1 Domestic developing process of configuration management

As the using and developing of systems engineering approach in Chinese aircraft industry, to promote the development of aircraft industry, to promote the systems engineering method application in the field of industry from omni-directional and multi-level, our configuration management are constantly evolving. Until now, domestic configuration management are experienced following stages.

Stage one: manually statement management stage

In R&D of Y7(Xian Y-7), MA60(Modern Ark 60), we employing manually statement management model, to control part's validity with the record of forms, and its efficiency are very low and complexity. At this time, computer-based management was not widespread yet, the configuration management are not step into the informatization management stage.

Stage two: structured computer data management stage (Batch validity management)

As the developing and popularization of computer technology in society, we input the traditional statement into the computer during the researching and producing of one MA600's key model, managed by structured data BOM(Bill of Material), we recorded products, parts manufacturing process's validity, and fitter them in computer, in this way we avoided kinds of mistake from manually statement management. After many years operating, we found that in this process different department's communication and cooperation are based on parts' level interchange, too many engineering change caused more and more validity changing, and personnel from different departments are all burdened with frequent engineering change control. This model characteristic is that parts, AO(Assembly Order), FO(Fabrication Order)all have a effective interval marked with R(1~9999), more change order and AAO(Add Assembly Order)'s validity are extended based on this model, and informationized managing product data by PDM system. Because this configuration management model's managing model and operating model are very complexity, and all validity are manually control by person, it is very easy to make mistake, and it's also hard to reflect different sortie's technical conditions comprehensively and timely.

As requires changing and configuration theory developing, domestic type as ARJ21, MA600 appears two kinds of engines during research and development process, and this two different state are stated with A/B, the state of A/B don't have same validity in same sortie. So we Incorporate the concept of partial configuration management on sortie validity management, but because of the PDM system's management logic are incompletely, it can't reflect two different state of technical parameter comprehensively, and still causing sudden problem till now.

Stage three: computer data modular management stage(Optional Configuration management)

The aircraft products data becomes more complex as their requirement are more diversification, more simplified and delayering modularized management idea are emerged as the request, that is allocation configuration management. Example of C919(COMAC C919) and some other helicopter types, they are modularizing product, and record their validity in module, and parts in module don't have validity. Concretely the product are dividing into VCI(Variable Configuration Item) unit from design side, and write validity section in VCI, and all their parts will not written any validity, and when validity need to be changed, only change order number or upgrading version. The VCI partition are not considering manufacturing separation surface.

As the development of management mode, configuration management's new explore way turning into wipe off effectiveness and use the overall modular configuration as the core of the design, production, logistics , financial control etc. modular control, new configuration management theory which is based on select-able configuration to control whole design process starting occurrence. We can take MA700 type as an example, during development process we renounce all Interval validity, select-able allocating product design with CI(Configuration Item)\ (Configuration Solution)\ DM(Design Module), select-able allocating manufacturing side's technological design with CA(Configuration Assembly)\ PCI(Process Configuration Item)\ AOL(AO List). This new configuration management model have a big step forward in technology.
From macroscopic view, the evolution of configuration management make clerk's management granularity promoting from part level to product level, from simplex design agreement to request, manufacturing agreement, and with a flatter structure, more simplify way to do reach and manufacturing synergy.

2.2 Definition of configuration management

In the above we described domestic configuration management's development history, in early stage of configuration management, it's more concentrating on product and its derived data configuration, so now let's takeoff the shackles of conventional thinking, extending the configuration to all professional domains in engineering, reconsidering the essence of configuration management and giving a new definition of it. Configuration management means that in one certainly moment or in some given conditions, the set which is constituting by requirement, design state, manufacturing state, supply state, financial control state, resource state, manpower state, etc. described by relevant documents and data, that is, a set of technical states of all engineering activities which is related to the project.
Enterprise from the initial requirement decomposition began to implement configuration management, configuration management to drive all the design, producing, delivery, financial control, logistics, changes, maintaining, scrapping etc. controlling operation, we can be seen that customer selection is the process of pulling out a series of subsequent processes, so we call this mode as integrated configuration management.

3 Configuration management method based on System Engineering

Combined with the development of aviation industry configuration, depending on the advantages of previous configuration management and the characteristics of aircraft products with many specialties and complex life cycle, the perspective of

system engineering is adopted to conduct configuration management, and a model based on the system engineering configuration matrix to manage the technical status of data is constructed.

3.1 System engineering matrix

In the field of system engineering, the system engineering cube is shown in Fig. 1.

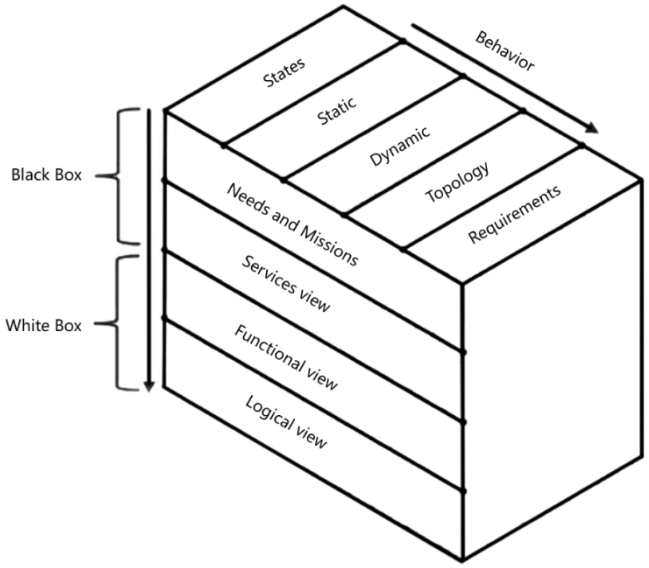

Fig. 1 System engineering

Abstract behavior into various professional work behaviors in daily manufacture(One of the characteristics of system engineering is that all professional behaviors are carried out in parallel. For example, when a product designer is designing the shape, he will consider whether the structure can be processed and assembled, and whether the materials with the structural strength can be supplied. Therefore, all majors are conducted simultaneously on the macro level, but in fact they will not start at the same time due to anthropic factor. In this paper, theoretical models are discussed first), as shown in Fig. 2.

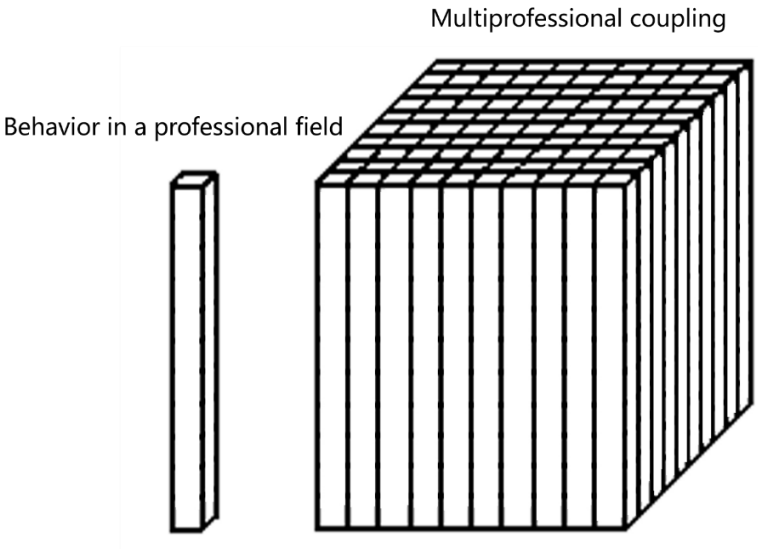

Fig. 2 Multi-professional coupling

Further, we divide the whole process of system engineering RFLP (Black box for R and white box for F and L) into two stages. RFL represents the scheme stage of doing something while P represents the implementation stage. We subdivide the data growth particles of each professional behavior. In this way, we divide it from the perspective of data growth in time, as shown in Fig. 3.

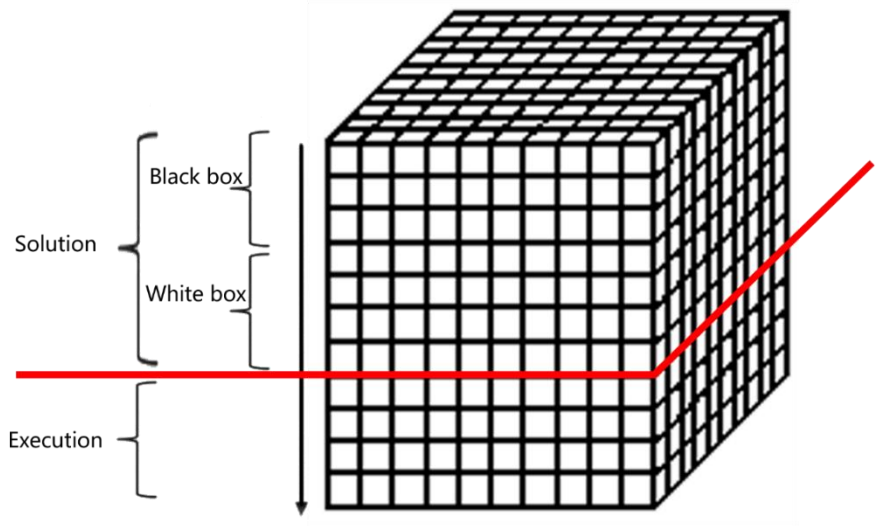

Fig. 3 Program and implementation

At a certain engineering time or under a certain condition, slice the model in Fig. 3, and get the result as shown in Fig. 4

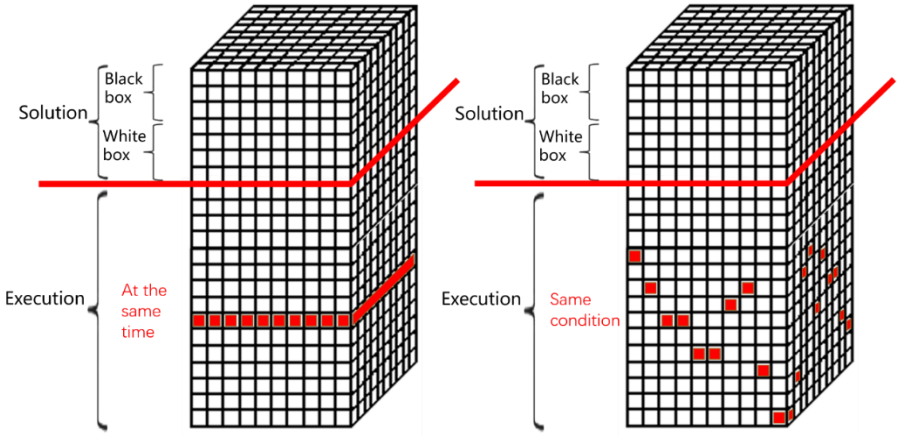

Fig. 4 Configuration conditions

It can be seen that through the filtering of time and specified conditions, we can get data sets of different technical states, which is called a configuration in the system engineering matrix.

3.2 Configuration simplification - Specialty cluster

There are so many majors involved in the manufacture of an aircraft. The current management granularity and the subdivision of major can not allow all majors to participate in the manufacture in parallel. Therefore, in order to simplify the configuration control, it is necessary to merge the majors. The majors with similar functions need to be merged into one cluster(Similar majors depend on each other but they are also independent. Emergent elements generated by multi-professional coupling are separated into new majors and independently controlled), and finally configuration management is carried out for these clusters. As shown in Fig. 5, the following cluster combination is a consolidation mode based on the current business work division (Such as order cluster, requirement cluster, design cluster, manufacturing cluster, maintenance cluster, financial cluster, human resource cluster, supply cluster, airworthiness cluster, etc.), and the status, static, dynamic, topology and requirement in Fig. 1 are also a cluster division form). Here is an example but not an inevitable consolidation method.

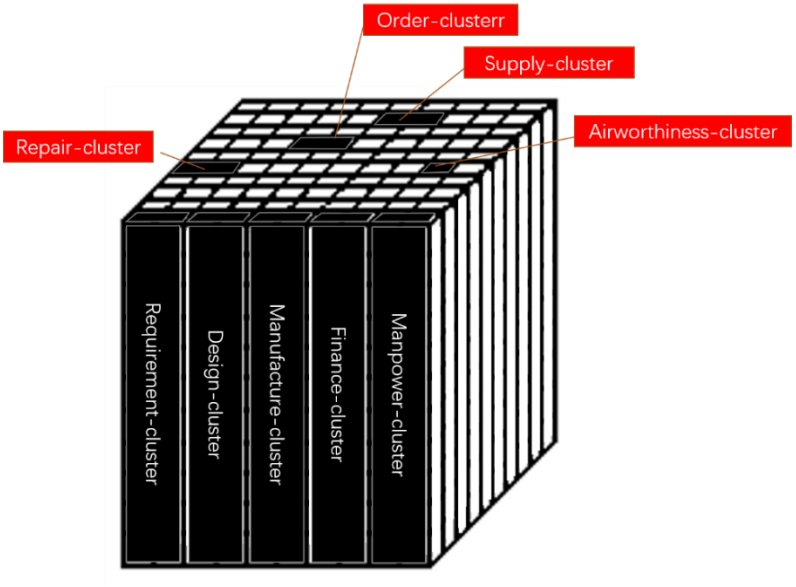

Fig. 5 Professional nest

Through the above means, we will classify all majors involved in our work and develop clusters and sub-specialties that need to be controlled, then conduct configuration control management on clusters. With the subdivision of more specialties, this system engineering matrix has the ability to expand clusters and disciplines infinitely.

3.3 System engineering configuration matrix

In the above content, we have finished the induction of the system engineering configuration matrix section. The induction of the longitudinal state axis is shown in Fig. 6.

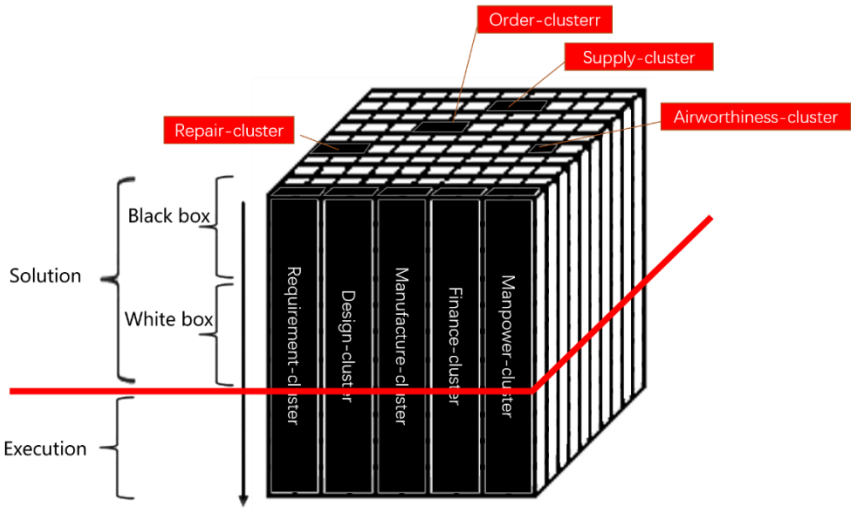

Fig. 6 State axis

Here are four typical professional clusters for vertical division:

DS (Design Solution)	MS (Manufacturing Solution)	SS (Service Solution)	CS (Cost Solution)	.....
DP (Design Physics)	MP (Manufacturing Physics)	SP (Service Physics)	CP (Cost Physics)	.....

Fig. 7 Segmentation stage

Continue to subdivide the scheme stage to compare the manufacturing scheme MS and manufacturing realization MP with the actual business.

	content		content	
DS	Design requirements	MS	Manufacturing requirements	.....
	Design function		Manufacturing function	
	Design logic		Manufacturing logic	
DP	Design modeling	MP	Manufacturing execution	.....

Fig. 8 RFLP in the matrix

Take manufacturing cluster and actual business for example: (Each professional cluster has its own RFLP)

Manufacturing requirement analysis: it is to decompose the requirements of manufacturing links in the initial requirements, such as processing requirements, assembly requirements, CNC requirements, etc.
Manufacturing function design: that is to define the idealized process of product assembly process.
Manufacturing logic design: manufacturing unit design (Manufacturing task) is carried out for manufacturing process, such as dividing virtual manufacturing station, formulating its processing and assembly process, and allocating manufacturing requirement to manufacturing unit, finally defining ideal processing and assembly flowchart (The key point of this link is to define all delivery processes and consumption time of products, i.e. process route and process planning flowchart).
Manufacturing Execution: on the basis of the processing and assembly process, the specific manufacturing units are divided into the designated internal and external production units (The key point of this link is to assign the manufacturing units to the specific physical station/supplier, to create the actual production flow chart, to carry out virtual production and to confirm the specific operation process under each physical station, i.e. engineering order), and then carry out physical production execution.
So far, we have completed the definition of the longitudinal state axis based on system engineering. The section is the collection of professional clusters, and the growth state of data is along the longitudinal direction. The data is separated and defined by RFLP in each cluster, and the data is recorded, controlled and called.

3.4 Applications of matrices - Modularization

In the whole process of aircraft development and batch production, product designers, manufacturing personnel, maintenance personnel, etc. need to reorganize the products according to their own business needs, so as to form a unit body convenient for business personnel to organize production and maintenance activities or independent accounting in their own business field. For example, the manufacturing (assembly) unit can be reorganized according to the manufacturing conditions in the manufacturing process for convenience Production organization and supply division; in the maintenance phase, the maintenance unit is reorganized according to the maintenance conditions so that it can be maintained quickly; in the cost control phase, the maintenance unit is reorganized according to the operation principle of the lowest cost for the convenience of cost control. The whole modularization is completed in two steps:
Division of engineering unit: through multi-professional joint review of products, it is divided into the smallest engineering unit (The physical object is a component or a part) which is coordinated and used by multiple majors and does not need to be subdivided.

Reorganize cluster unit: business personnel recombine to form their own domain compatible module units in their respective professional cluster areas based on the minimum engineering unit. For example, according to the business needs, the engineering unit is allocated to the corresponding design unit, manufacturing unit, maintenance unit and cost unit for the design cluster, manufacturing cluster, maintenance cluster, cost cluster, etc. (Four typical clusters are illustrated here, each cluster is essentially a collection of engineering units of products in the cluster, and the connection definition is separately set with another engineering unit). The cluster unit here is similar to a task tray (Only the engineering unit is the product itself), and the process is shown in Fig. 9.

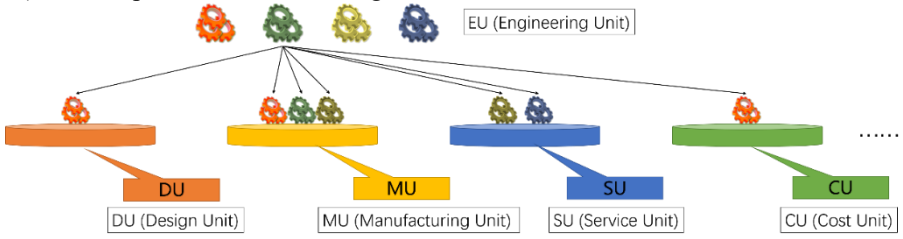

Fig. 9 Module unit

This data is presented on our professional cluster as shown in Figure 10.

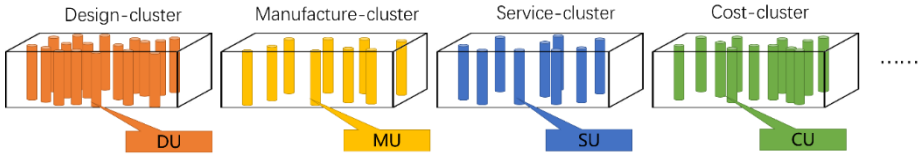

Fig. 10 Professional cluster and cluster unit

The essence of engineering unit (EU) is the minimum structure of product segmentation after multi-professional coordination (The most detailed can be to parts), the essence of cluster is a set of strongly related specialties, and the essence of cluster unit is a set of strongly related engineering unit EU. In the vertical matrix, these data are divided into scheme stage and implementation stage according to system engineering (RFL is the vertical subdivision of scheme lattice, which is not included in the scope of configuration management due to the granularity and complexity of management).

Configuration control elements: (Define engineering unit EU jointly)

1. Cross section: in the professional cluster, the unit of the cluster is defined as a configuration control element, such as design unit DU and manufacturing unit MU.
2. Longitudinal direction: according to the scheme level XS (X represents any professional cluster) and execution stage XP divided by system engineering, as the other two configuration control elements.

By controlling the configuration control elements, the whole system engineering configuration matrix is recorded, controlled, changed and derived.
According to the configuration matrix based on system engineering, a spatial matrix of business process is developed, which can also be regarded as a preliminary enterprise operation model. In the early stage of various engineering work, if the situation is not considered properly, the configuration of disciplines, clusters, engineering units need to be adjusted and supplemented.

4 Conclusion

Through the development and integration of system engineering and configuration concept, it will significantly reduce the coordination difficulty among various majors. The integrated configuration management based on system engineering no longer focuses on the product itself, but focuses on a series of development engineering behaviors from requirement to delivery of the product. While conducting configuration control, it also unifies various data sources, integrates various professional knowledge into a set of system for management, ensures the unity and consistency of data, and facilitates data management and data backtracking. At present, the development mode of MA700 aircraft is developing to the direction of comprehensive and multi-professional configuration.
The difficulty of integrated configuration management based on system engineering lies in the division and combination of disciplines. At this stage, we are still unable to realize the full professional coupling simulation of aircraft design and manufacturing industry. What we can reach is the coupling simulation of most disciplines and the non coupling simulation of some disciplines. Under such a background, how to reasonably subdivide and merge professional behaviors into clusters is particularly important, and more are needed Industry experts work together to research and develop.
If system engineering theory is the guidance of enterprise development, integrated configuration management is the skeleton of multi-disciplinary collaboration of system engineering. In terms of its development, configuration management may break many existing professional block management modes in the future, such as BOM management, change management, data management, human management, financial management, maintenance management, supply management, etc., and become a more mature and comprehensive mode Face new mode.

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