Research on Modeling and Collaborative Preparation Technology of Space Engineering Project Plan Management

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Abstract. Space engineering project plan management is a kind of plan management work which takes space products as the basic object. The traditional planning management is transformed into scope management and time management respectively in project management, but it is also closely related to cost management, quality management, human resource management, supply management, risk management and communication management [1]. Project management is not a specific management technology or tool, but a management idea and concept, which emphasizes the use of scientific theories and methods to comprehensively manage the project under the constraints of many factors such as time and resources [2]. The purpose of this paper is based on the basis of building the space engineering project plan management model, to study the multi-level collaborative planning method of space engineering project, realize the information sharing and coordination, optimize the allocation of resources. In this paper, the general principles of multi- level collaborative planning are proposed. This paper focuses on multi-level collaborative planning and monitoring technology, and proposes a cross-domain collaborative planning technology based on unified WBS (work Breakdown structure) code to realize aerospace multi-level planning, and adopts mission model function integration technology and project deliverables association technology to realize project process tracking and control.

Keywords: Aerospace engineering, WBS, project management, multi-level planning model， coordination

1 CONSTRUCTION OF PROJECT MULTI-LEVEL PLAN MANAGEMENT MODEL

With the continuous increase in the number and quality requirements of aerospace missions, project management is also facing new challenges. The communication of project process information is slow, untimely, and inefficient, resulting in poor timeliness and frequent distortion of planning and scheduling, which affects the decision-making and judgment results of the leadership [3]. Chinese aerospace enterprises implement a multi-

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level organization management system. Corresponding to the multi-level organization structure, the multi-level planning of the project should be able to adapt to the distributed planning business model in the process of project management, in which the summary plan is made first, and the distributed plan is distributed step by step and refined step by step.

A global network planning model covering multiple projects is constructed to describe the tree structure of WBS and the logical relationship between tasks. The network planning model constructed in this way does not need to reduce the degree of coupling between tasks, and can completely describe the hierarchical and logical relationship between tasks. The work breakdown structure further defines the "work that must be carried out". It divides the work into smaller and more manageable tasks, and each descending level means a more detailed description of the project work [4].

According to the need of project management granularity, the project plan is graded, the top level is the overall project, the lower level is composed of a number of sub-projects and activities, and the sub-project level can be further stratified according to the needs, so as to form a multi-level network planning model.

The Control Flow C and Document Flow D of Multi-Level Network Plan. The control flow C and document flow D in each level of a network plan can be represented as a collection of tuples:

$C=\{c_0...c_i...c_m\}$ where $c_i=\{from_i, to_i\}$, $D=\{d_0...d_i...d_m\}$ where $di=\{from_i, to_i, document_i\}$

$from_i$ And to_i are the sub-networks or activities in the network plan, while c_i indicates that $from_i$ can only start after to_i ends, d_i represents transmitting documents from $from_i$ to to_i .

Activities T. The lowest level element that makes up a project, an activity T can be represented as a quadruple: $T=\{ManID, Resource, DesignDurTime, Trigger\}$

Among them, *ManID* represents the person responsible for the activity, *Resource* represents the resources occupied by the activity, *DesignDurTime* represents the design duration of the activity, and *Trigger* represents the trigger after the activity ends.

Multilevel Network Planning Model. The project network plan P can be decomposed into a 0-level network plan composed of n network plans P_{0i} and m activities T_{oj}, as well as the control flow C_0, document flow D_0 , start node S_0 and end nodes E_0 between them, namely: $P=\{P_{01},..,P_{0i}...P_{0n}, T_{01},..,T_{oj}...T_{0m}, C_0, D_0, S_0, E_0\}$, $i=1...n$, $j=1...m$

Among them, each P_{0i} can be further decomposed into a Level 1 network plan consisting of n_i network plans P_{1ij} and m_i activity T_{1ik}, as well as the control flow C_{1i}, document flow D_{1i}, and start node S_{1i} and end node E_{1i} between them, namely:

$P_{0i}=\{P_{1i1}, ..., P_{1ij}...P_{1in}, T_{1i1}, ..., T_{1ik}, ..., T_{1im}, C_{1i}, D_{1i}, S_{1i}, E_{1i}\}$, $j=1...n_i$, $k=1...m_i$,Where: P is the level 0 project, namely the total project, P_{0i} is the level 1 project, P_{1ij} is the level 2 project.

In the above way, the project plan is subdivided level by level until the project is completely decomposed into the final level network plan which contains only activities and does not contain any sub-network plan. The multi-level network planning model is shown in Fig.1.

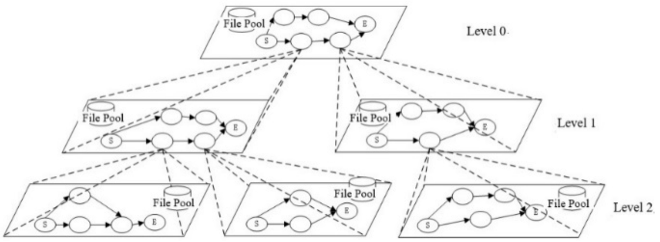

Fig. 1. Multilevel network planning model

A network plan for a single project can be described by an ordered set of items and activities, where the connection between items v_i and v_j is the task (v_i, v_j), the connection point between activities is the item, v_i is the before item, v_j is the after item, and the items V and activity E can form a unique directed acyclic graph with a starting and ending point, represented by a tuple G=(V, E) composed of the set of item V and activity E. Where, the set of items: $V=\{v_0, v_1, \cdots, v_i, \cdots\}, i=0...(2n-1)$, ($n$ is the total number of actual tasks in the project). Activity set：

$$E=\{(v_0, v_1), \cdots, (v_i, v_j), \cdots\}, i=0...(2n-1), j=0...(2n-1)$$

Since each task has a corresponding outline level in the WBS hierarchy, there is a time constraint relationship between the summary task and its subtasks, that is, the start time of the summary task must not be later than the start time of any of its subtasks, and the completion time must not be earlier than the completion time of any of its subtasks. In order to describe this constraint relationship by network planning model, virtual activities need to be added, which have zero duration and consume no resources. As shown in Fig.2, the summary task (v_1, v_4) and its subtasks (v_2, v_3) can be described in the same network planning model by adding two virtual activities (v_1, v_2), (v_3, v_4) (represented by virtual arrows), so that the hierarchical structure of tasks in WBS can be represented by the network planning model.

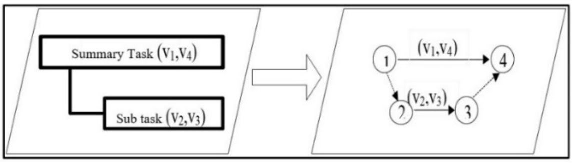

Fig. 2. The transformation of WBS hierarchy

Through the above steps, a directed acyclic graph G is obtained, if the actual number of tasks in the project is n, then the number of vertices of the graph G is $m=2n$, the number of edges is $v=3n-2+p$, (where p is the total number of logical relationships between tasks in the project).

In this way, the network plan of a single project is obtained, a global network plan covering multiple projects below any level in EPS can be constructed. This "network planning technology" is widely used in aerospace, nuclear industry, electronics, construction and other industries [5].

2 RESEARCH ON MULTI-LEVEL PLANNING TECHNOLOGY

The refinement of plans is an important basis for plan assessment and a prerequisite for further implementing "strict and detailed" management in aerospace model projects [6]. For enterprise multi-project management, multi-level planning is based on "EPS (enterprise project structure)–WBS (work breakdown structure)–Activity–Step" in the project management system, and the top to bottom planning is carried out by senior management. Then from the bottom of the project team to the top of the bottom-up planning, and the establishment of milestones in line with the needs of different management levels.

If all levels of project progress data are derived from the basic database at the bottom operation level, the problem of disconnection between high-level plan and low- level implementation plan can be solved, and the consistency and effectiveness of communication between various management levels and between the project team and external project stakeholders can be ensured. So that the plan can really play a guiding and controlling role in the project implementation process.

2.1 Multi-Level Plan Coordination Mode

According to the management mode of aerospace model development, follow the scientific planning method, based on WBS, through WBS refinement, establishment of operation logic, cycle estimation, resource allocation, signing and confirmation steps to plan, with the progress of the project gradually improved; Finally, on the basis of full communication, the project management system was used to carry out the fine distribution, tracking feedback and status monitoring of the model plan, which assisted the manager to find the short line of the project in time and take measures.

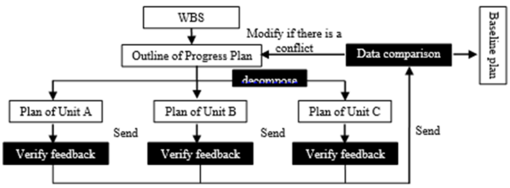

Fig. 3. The collaborative project planning process

The multi-level planning of the plan can well adapt to the business model of distributed planning in the model application, in which the summary plan is made first, distributed step by step, and refined step by step. The collaborative project planning process is shown in Fig.3.

2.2 Cross-Domain Collaboration Based on Unified WBS Code Mapping

According to the multi-level organization management system, it is unrealistic to implement a set of plan management system centrally. Therefore, it is proposed that each organization should establish its own plan management system, and realize the multi-level space plan management through cross-domain cooperation. This kind of planning coordination in different planning management systems among different organizations is called cross-domain coordination. The summary plan is made by the master unit in the system of his own unit, and each sub-plan is completed in the system of each participating unit. The cross-domain bidirectional transmission of data is realized by relying on "data synchronization". The sub-nodes of each plan are still executed in the plan management system of each participating unit, forming a system group structure with the general unit as the superior and the participating unit as the subordinate. At ordinary times, the plan management work at all levels can be carried out independently in their own systems. The two layers of the system rely on data synchronization technology to achieve two-way transmission of data, complete the project information synchronization between the upper and lower systems, so that the operation of the cross system is isolated and closed to the user. Other plan management systems or cooperative units that do not use any computer system can exchange data through the agreed data exchange template.

Cross-Domain Data Transfer. Cross-domain collaboration follows the following rules:

Different domains are identified according to the domain level of the task, and different projects are identified according to the project representation of the task.

Each domain exported only the tasks generated by its own domain.

The project represents the same task with the WBS code identification uniqueness.

The task WBS code of different projects can be the same. For the task with the same WBS code, update operation should be done according to the last update time.

For tasks where WBS code does not exist, insert operation is done.

When inserting a task, update the rules of parent node, outline number and outline level: according to the tree structure, the parent node is processed first and then the child node is processed; If the parent node is identified as "-1", it will be added as the first-level child node of the root node and placed at the end. The rest will be added as the last child of the parent node.

The strategy of changing the outline number when updating the task: all nodes join as the last child of the new parent node and update the outline number, outline level accordingly.

Conflict Resolution Techniques for Synchronized Plan Compilation. In the actual process of establishing multi-level project plans, because different sub-plans or different parts of the same plan are prepared by different organizations or people, and there are logical constraints between the sub-plans and the limit of the upper planning time node, it is necessary to establish a collaborative mechanism to make the process of making project plans at all levels be completed in the environment of mutual consultation. To reduce the number of rounds, improve work efficiency, strengthen the interaction of the planning process, and ensure the accuracy of the plan.

Based on the exclusive-lock mechanism, a conflict resolution technology for synchronous planning is proposed by establishing a planning control room and a planning collaboration room. Finally, the multi-organization collaborative planning model is formed, as shown in Fig.4.

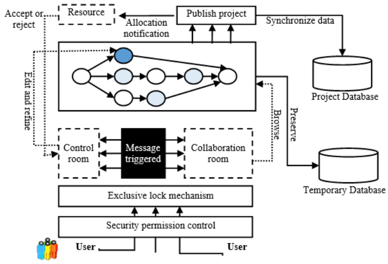

Fig. 4. Collaborative planning model

Users with the role of plan editor in the organization have the right to edit the work breakdown unit. The process is controlled by the security authority control unit of the system.

Due to the existence of time and logical constraints between the work units in the upper plan, the planning personnel entering the control room must interact with other organizations in the process of plan decomposition and refinement, so as to ensure the rationality and accuracy of the whole project plan. In the actual operation process, all the personnel involved in the plan cannot be guaranteed to participate in the planning work at the same time, so the system must support synchronous interaction and asynchronous interaction.

Synchronous interaction refers to the working mode in which the staff of the control room and the staff of the collaboration room browse the preparation of the project plan at the same time, and can communicate in time through communication tools such as instant message and public whiteboard. The asynchronous interaction is more complex, requiring the system to store the operation history data affecting the responsible work unit of the organization, and send the change notice to the planner of the organization through the message trigger, so as to negotiate with other planners in time and change the schedule of the plan.

3 CONCLUSION

Based on the theory of project management and the thought of system engineering, this paper analyzes the multi-level plan management mode, constructs a multi-level network plan model to adapt to the multi-level organization management mode, and expounds the process of realizing the multi-level plan management of aerospace engineering project through WBS preparation, multi-level plan collaborative preparation, multi-level plan control and other methods. It is of practical significance to improve the level of project management in the development of large and complex products.

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