Research on the development mode of general exclusive parts for spacecraft integration

Chen Zou¹, Lei Zhang¹, Jiandong Zheng¹, Shuang Zou¹
¹ Institute of Telecommunication Satellite, China Academy of Space Technology, Peking, 100094, China
Email: zouchen2019@sina.com

Abstract: As an important part of spacecraft, the research on general exclusive parts for spacecraft integration is still in its infancy. In this paper, based on the characteristic of spacecraft and exclusive parts, the development mode of general exclusive parts and the principles of configuration management for general exclusive parts are established. This paper explores the working mode of general exclusive parts adding, modification, abolition and deviation. Furthermore, this paper also suggests the thoughts on the construction of relevant databases.

1. Introduction
Exclusive parts for integration as one of the most important parts of spacecraft indicate connectors for satellite integration (including parts, assembly, and secondary structure). Recently because of the increasingly strict requirement on the cost of spacecraft development, a more efficient and economical working mode for the exclusive parts for integration is urgently necessary. Generalization is an efficient method to reduce management and manufactured cost and improve design efficiency. It is indicated that when general parts account for 13.7%, the manufactured cost can be reduced by 21.25%, while the management cost can be reduced by 20%.¹

General exclusive parts for integration indicate the exclusive parts that are interchangeably used between satellites. The research on the development mode of general exclusive parts for spacecraft integration is still in its infancy. This paper explores the development mode of general exclusive parts for spacecraft integration.

2. Development mode of general exclusive parts for integration
General parts are wildly used in industry, and the research on them is quite mature, most of which focus on mass production. It is involved that as the diversity of demand increases, using general parts is necessary to adapt to the demand change.² With the rapid growth of the number of spacecrafts, the demand for exclusive parts for integration presents a trend of increasing in both quantity and diversity. Therefore, in order to cope with demand growth, generalization is necessary. However, it is also indicated that facing the huge development cost, manufacturers need to consider generalization strategy cautiously.³ In conclusion, the premise of generalization is to reduce the development cost.

In order to reduce the cost of development, this paper introduces a development mode of "from the project to the project". "From the project" indicates that instead of re-development, the general exclusive parts for spacecraft integration are selected from the parts that have experienced several successful space flights. The specific team is founded to audit the generality of the exclusive parts,
separate the suitable ones from the management system for the specific project, and incorporate the suitable ones into an independent management system for general exclusive parts for spacecraft integration. "To the project" indicates the developers of general exclusive parts for spacecraft integration need to focus on serving the whole-spacecraft integration, and the configuration management for the general exclusive parts is based on the whole-spacecraft project management.

3. Configuration management
An independent management system with its own characteristic for the general exclusive parts for spacecraft integration is necessary, that is based on the general principles of spacecraft configuration management.

- It is suggested that the unified functional baseline, development baseline and production baseline are established, indicating stable configuration.
- The codes of ordinary exclusive parts for integration belong to the code system of a specific spacecraft, while the code system of the general exclusive parts is independent, which is significantly different from the ordinary one. Easy use and good expansibility are also necessary for the code system.
- The atlas of general parts for selecting is necessary and the records of characteristic information such as physical characteristics, functional characteristics, and history information are also essential.
- A specific team for configuration management is founded to manage configuration of general parts, whose responsibility is to audit new parts, update configuration documents, summarize the problems regularly arising during manufacturing process and whole-spacecraft integration, evaluate the existing products, and audit the necessity of the modification and abolition of general exclusive parts.
- It is efficient to use information tools recording configuration of general parts.
- It is necessary to record modification of configuration and catalogue.
- Based on the actual use of the general exclusive parts for integration, regular addition, modification and abolition are suggested.
- Configuration documents need to be approved formally as required.

3.1 The addition of the general exclusive parts for integration
According to the development mode of "from the project to the project", the specific team for configuration management audits the generality of the parts having multiple successful experiences of space flight, and the suitable ones are included in the catalogue of general parts. The process is shown in Figure 1.

M1 and M2 are the parts of the specific project development system and they are the prerequisites for the generalization.

M3: Qualification audit is the first step for generalization and the data submitted includes the property and performance, physical characteristics, drawings/models, resumes and other relevant characteristics of the exclusive parts.

M4: The configuration management team audits the exclusive parts according to the submissions, including the generality qualification and the completeness of the data. Due to the strict requirement of reliable and the characteristics of the exclusive parts, the general exclusive parts need to have the following characteristics:

- Normative requirements: General parts should have perfect product specifications, including detailed drawings/models, performance reports, resume reports, and the whole process specifications that indicates the process of design, manufacturing, acceptance and integration.
- Production assurance requirements: General parts should have been verified by batch production and multi-satellite (>=2) flight verification to ensure the consistency of production and quality stability.
- Product performance requirements: The physical properties of the products are well adapted
to the different project demands.

- Product interface requirements: The product interface is well generalized, that is suitable for the shelf products.
- Product demand requirements: In the foreseeable future, there will be multiple demands.
- Product storage requirements: The physical performance of the parts is stable during ground storage, which has long-term storage conditions.

For the general exclusive parts with incomplete information, the applicant needs to resubmit the application after completing the information.

M5: The team for configuration management issues generic codes for the new general exclusive parts.
M6: The team for configuration management approvals the new general exclusive part drawings/models formally.
M7a1: The team for configuration management updates the atlas according to the drawings/models approved.
M7a2: The team for configuration management updates the configuration documents of general exclusive parts according to the information submitted.
M8: After all the process above, the team for configuration management publishes upgraded notice of the general exclusive parts.

![Flow chart for the addition of the general exclusive parts](image)

Figure 1. Flow chart for the addition of the general exclusive parts

3.2 The modification of the general exclusive parts for integration

The modification in this section refers to the non-temporary one. Because the configuration of general products usually involves multiple projects, for the general products, subversive modification of critical dimensions (such as interface dimensions) are not acceptable generally, and the modification that induces significant property degradation is prohibited.

When it is necessary to modify general exclusive parts for integration, the configuration management team comprehensively analyzes the impact on the functions, performance and interfaces of relevant projects. After the unified demonstration, collaborative verification and approval accepted by all partners concerned, to reduce the risks induced by the configuration change and realize the unified control of the configuration of general products, the designers implement the modification. The process of the modification of general parts is shown in Figure 2.
Figure 2. Flow chart for the modification of the general exclusive parts

M1: The designers in charge of general exclusive parts for integration submit a modification application to the configuration management team.

M2: The configuration management team reaches an agreement on the necessity of the submitted modification with the partners who are involved with the modified item.

M3: The designers in charge of general exclusive parts for integration modify the drawings/models according to the items approved, record the modified items completely and execute permitting procedure.

M4a1: The team for configuration management updates the atlas according to the content approved.

M4b1: The team for configuration management records the modified items and updates the version number of the drawings/models in the relative configuration documents.

M5: The team for configuration management publishes upgraded notice of the general exclusive parts.

3.3 The abolition of the general exclusive parts for integration
The general exclusive parts in space flight are not suggested to be scrapped. The team for configuration management evaluates the impact of the abolition. If the team for configuration management identifies the general parts to be scrapped, the designers must make obvious mark on the drawings/models and delete them from the atlas.

3.4 Deviation of general products
Due to the particularity of spacecraft design, the cost of using general exclusive parts in the original configuration may be larger than the benefit induced by general exclusive parts in certain condition. It is necessary to allow deviating the configuration of general exclusive parts temporarily. When the designer considers it is necessary to make a temporary deviation, he need apply for a deviation permission. However, unlike the ordinary exclusive parts facing specific projects, the using objects of the general parts are not specific. The using objects must be strictly controlled within the scope of the ones approved, that is the principle of “who deviates, who uses” to prevent unexpected use.

The deviation is not the basis for the modification of configuration documents, but the configuration management team needs to pay attention to multiple deviations of the same product on the same issue, analyze and evaluate whether to modify the current configuration documents of general exclusive parts to form a continuous working mode for improvement.

4. The database for the general exclusive parts for integration
In order to effectively utilize data resources to guide design, it is necessary to construct a database for the general products systemically. It is suggested to establish the database for the general exclusive parts for integration, including all kinds of characteristic, model/drawings and description information necessary. The database has a high utilization rate and does not fail at the end of a specific project. The general product database is defined as two parts: the database for design and the database of drawings/model. The two parts cover the complete information for design.

The database for design includes the information as follows:

● The mechanical properties and electrical properties of general exclusive parts;
● Information of physical properties such as surface characteristics, material, heat treatment status, weight, etc.;
● History such as the source of general parts, project usage, historical change, etc.;
● Requirements for acceptance management;
● Product list;
● The commissioning requirements;
● Other information necessary.

The model database includes both 2D-drawings and 3D-models. The database of 3D-models has appropriate interface with the model base for the whole-craft integration to lay the foundation for the digital integration based on the models.

The database fitted for the actual condition needs to be updated regularly. It is necessary to emphasize the consistency between 2D-drawings and 3D-models and update the data regularly.

5. Conclusion
Because of the small batch production pattern for spacecraft, it is imperative to reduce the development cost. It suggests the development mode of "from project to project" for the general exclusive parts for spacecraft integration to reduce the cost, which indicates the general exclusive parts are selected from the ones verified during a specific space project and separated from the specific project management system. They are constantly expanded and improved to meet project requirements. Furthermore, this paper suggests a database with integrated information improved synchronously to support the whole-spacecraft development.

References
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