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# Spacecraft Packaging Requirements and Transport Status

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**Abstract**. Since the place of spacecraft production is diffenrent from the launching site, long distance transportation is an indispensable link in the development of spacecrafts. This paper aims to introduce the requirements of spacecraft packing, the mode and characteristics of spacecraft transportation, and then provides reference for thepacking and transportation of spacecrafts.

## 1. Introduction

Protection is required in the transport of spacecraft development process. If the packing requirements are very high, the cost may be too high to afford. In contrast, if the requirements are too low, the protective effect will be discounted. Therefore, the correct packaging requirements should be put forward for spacecrafts. The transport of spacecraft is also an important part, and the proper mode of transportation should be considered at the beginning of the design. This paper introduces the packaging and transportation of spacecraft, especially the satellite and spacecraft, which can be used for reference in related fields.

## 2. The packaging requirements

### *2.1. Influence*

During the transportation and storage of the spacecraft, the natural environment has adverse influences on the spacecraft, which is shown in Figure 1. It is necessary to take measures to protect the spacecraft. The protection method can be seen from Table 1.

According to the protective measures, the transporting spacecraft can be protected by container. The environment conditions to maintain are as follows:

Pressure: It's always positive, maintaining at 0~2000Pa;

Humidity: Relative humidity≤60%, testing results show that, metal is not easy to rust when relative humidity is less than 35%, and non-metal is not easy to grow mildew when relative humidity is less than 60%;

Temperature: it can be adjusted;

Vibration reduction: The shock absorber shall be set up according to the inducement environment. The root value of the vibration acceleration [1] is not greater than 0.6g after the vibration reduction, and the impact acceleration is not greater than 1g.

Sealing: leakage rate≤200Pa/24h;

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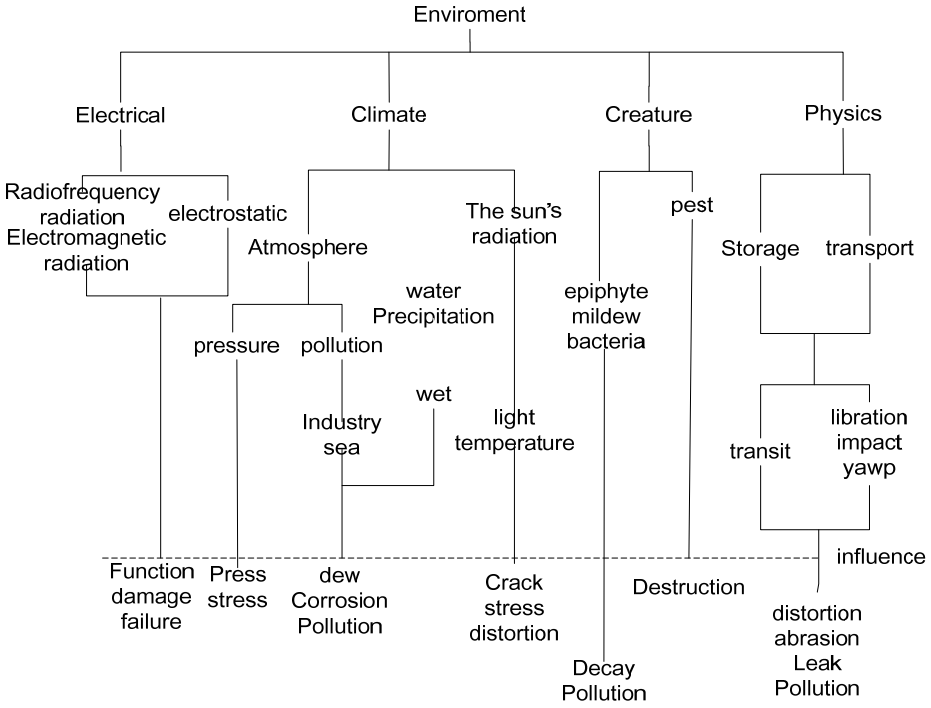



**Figure 1.** Affect the result

**Table 1.** Recommend ways to avoid impact

| Enviroment | Protective measure | Enviroment | Protective measure |
|---|---|---|---|
| precipitation | Resistant material; Protective coating Moistureproof coating; Sealed packing container | wind | Sealed packing container; Protective clothing; Fixing device |
| Salt fog | Same as in the above table | Pressure change | Positive internal pressure system |
| humidity | Container with a dehumidifying function The container uses dry nitrogen or desiccant; The others are the same as the above table | Sand and dust | Sealed packing container |
| temperature | Temperature control equipment; Special mode of transportation; Reflective coating | | |

### *2.2. Packing performance*

*2.2.1. Keep the pressure (humidity).* The pressure control is finished by filling the packing container with dry nitrogen. In the early stage, the control of the pressure in the container is accomplished by controlling the manual cut-off valve state of the inflatable pipe and the exhaust pipe. With the development of the production levels, the container control system can run automatically. The control system consists of inflatable pipe, exhaust pipe line and measurment and control line. The gas-filled path, the exhaust path installed solenoid valve, the pressure sensor and the solenoid valve are connected to the control system to control the pressure in the container remotely.

Because of the desiccant placed in the container before usage, the humidity can be keep. When filling the packing container with dry nitrogen, the pressure is raising, but the relative humidity in the box will also be low.

*2.2.2. Keep the temperature.* There are two measures to keep the temperature inside the container, active temperature control and passive temperature keeping. Filling the insulation material between two layers of covering, it can reduce the temperature exchange inside and outside the container. In the meantime, the container is also equipped with air-conditioning, which can be used to adjust the temperature of the container.

The air-conditioner signal is connected to the control system, and the air conditioning system can be controlled remotely.

*2.2.3. Vibration damping function.* A shock absorber is usually used to reduce the vibration of the spacecraft in both internal and external reduce vibration modes. The method of vibration reduction is internal vibration modes that the shock absorber is arranged between the spacecraft and the bottom of the container. During transportation, there is a relative displacement between the spacecraft and the bottom of the container. The other method of vibration reduction is external vibration modes that the shock absorber is arranged the outside of the packing container. The spacecraft and the bottom of the case has no relative displacement. The external damping vibration is insensitive to the mass change of vibration, and its applicability is broader. The cost of internal damping vibration is lower, the layout is simple and the outer envelope size can be reduced.

*2.2.4. Sealing.* Because most of the packing container are used as the spacecraft leak detection containers, the sealing performance of the packing cases is an important index. With the improvement of the production process, the performance of the domestic packing container can achieve very good index. Leakage rate is not greater than 150pa/24h. The sealing performance depends on the weld quality. At the same time, the packing container separates the cover from the sealing ring to ensure the sealing. The sealing structure show in Figure 2.

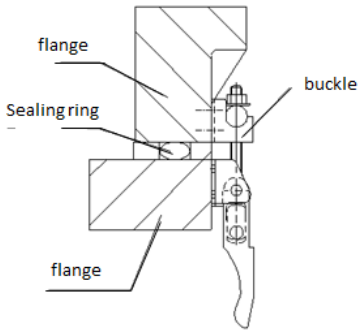



**Figure 2.** Sealing structure

## 3. Spacecraft transport

### *3.1. Highway*

No matter which mode of transportation is chosen, road transportation is a necessary means of transportation. As a basic transport, it plays an irreplaceable role. Restricted by bridge and culverts, long-distance transportation is not easy to achieve. The difficulty of road transportation is related to the route of transportation. With the development of superlarge spacecraft, it is also a challenge to highway transportation. According to China's highway transport standard [2] requirements, the length and width of the package should be less than 12160mm and 2500mm. The height of package after loading is not more than 4000mm. In excess of this limit, it shall be used as a special transport. The transport of large spacecraft generally exceeds this limit, especially the width. At present, width of the transport spacecraft between the two places is 5m, and the height after loading is 4.9m, which is only transported between Tianjin and Beijing. Due to the foreign spacecraft structural size and quality

parameters can't be transported by ordinary transport vehicles, it is usually carried out by large special transport vehicle with hydraulic plates [3]. According to the survey, ESA rocket Arian V type with 5.4m diameter. The rocket is firstly loaded into the container, and the road transportation is carried out by the trailer. Then the transport vehicle can enter the cabin and carry the sea transportation with the rocket body. ESA transport rocket show in Figure 3.

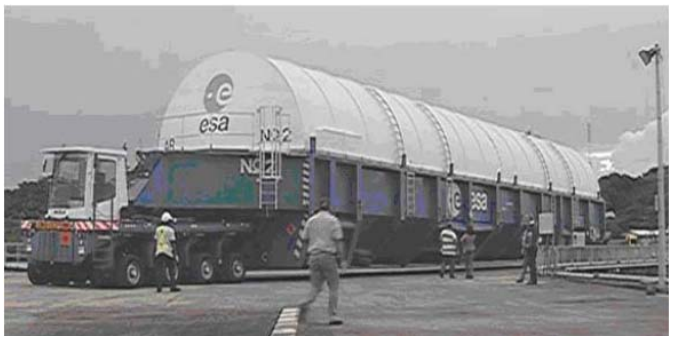



**Figure 3.** ESA transport rocket

*3.2. Railway*

Compared with road transportation, railway transportation time is determined and transportation environment is simple. But it is restricted by rail, bridge and culvert, which can hardly be applied to the transportation of large spacecraft. In railway transportation, the relationship between the packing outline and the transport boundary is mainly considered, and the weight can meet the requirements. In accordance with the standards [4], the general dimensions of the packing parts length shall be less than 13020mm, and the transportation of the package after loading and the width of the vehicle exceeding the limits of the locomotive vehicle shall be special transportation. In the use of railway transport, the over-limit conditions are determined by the actual contour of the railway. The overlimit pass should not only meet the transport boundary, but also be approved by the main transport railway bureau. At present, China's railway transport maximum spacecraft is TG-1, which is super limit, its width is about 4200mm, and its height is about 3880mm. The width is larger than the packing container of the railway plane, and the transport bearing slot is used in practice. Transport bearing slot shown in Figure 4.



**Figure 4.** Railway transport fixture

*3.3. Air freight*

Air transport is the most efficient way of transportation. At present, the small packing cases of domestic spacecraft are mainly transported by YE-76, and large spacecrafts are required to lease large aircraft. Large transport aircraft mainly have the U.S. C-5, C-17, Ukraine's AN -225, AN -124, AN -70, and A300-600ST of European airbus. The cargo compartments of An-225 and C-5 are the same size as that of An-124. The air transport of large spacecraft will be the main factor limiting the

development cycle. Foreign spacecraft are transported by air in the form of airlift, the large spacecraft is transported by aircraft or in the cabin, and the Columbus cabin was airlifted to the United States by A300-600ST. Choosing air transportation as a mode of transportation is important to note that as the plane transport, open packing pressure balance channel, packing container environment is decided by the cabin environment, spacecraft have special transportation requirements for special treatment.

### *3.4. Shipping by sea*

Larger spacecraft, which exceed roads, rail and air carries need to be transported by sea. Compared with other methods, longer transportation time is required, and the transportation boundary is the widest. Marine transportation is mainly determined by the launch site of its destination, so long as the transportation boundary can be met, the shipping can be satisfied. In view of the limitation of our coutry's no super large aircraft, it will be a large spacecraft transportation task for a period of time. The two characteristics of Marin transportation.Firstly, the humid climate conditions and the environment of high salt fog are the most difficult to transport the spacecraft at sea, so the strict protection measures are taken. Secondly, the Marine environment has the characteristics of low frequency and large amplitude. Therefore, it is necessary to carry out research on the vibration reduction technology suitable for the Marine transportation of spacecraft. China has successfully carried out the naritime transport of the spacecraft, which has been transportted by sea to the launch site in Hainan.

## 4. Conclusion

At present, the domestic spacecraft packaging technology has been approaching maturity, which is equal to the international level. However, it is important to develop the transport conditions of large spacecraft to ensure the development of spacecraft: Firstly, large transport vehicle should be developed to meet the transport requirements of large spacecraft, Secondly, the development of large transport aircraft can accelerate the efficiency of spacecraft transportation, reduce the development cycle of spacecraft, and weaken the dependence of spacecraft airlift on foreign transport aircraft.

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