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## Method of Comprehensive Risk Management for Satellite Transportation

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# Method of Comprehensive Risk Management for Satellite Transportation

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**Abstract:** Satellite transportation is the special link in the development of satellite. It's different to the constant and controllable environment in building. Due to the large geographical area, complex climatic conditions, limited protection of packing box of satellite, and many burst links in the process, these are many risk items in satellite transportation and the risk items are all highly hazardous. Transportation has critical influence for the development of satellite.

This paper analyzes the timing and methods of risk identification, risk assessment, risk decision-making and control in the transportation process for the purpose of comprehensive risk control of satellite transportation work, and puts forward the viewpoint of "Reducing risk list and quantifying risk control". The refined risk identification method proposes different control methods for different types of risks. The method designed in this paper is used in the factory transportation of satellites, and the application is in good condition, which effectively guarantees the safety of satellite transportation.

## 1. Introduction

Risk management is a key factor affecting the success of satellite transportation. In the process of satellite transportation, due to its large geographical area, diverse climatic conditions, multiple cooperative units, and complex participants, the probability of occurrence of risk events is much higher than other stages of satellite development. At the same time, satellite protection measures during transportation is limited, risk events can easily affect satellite safety and cause damage. At the beginning of 2016, the Japanese X-band military communications satellite DSN-1 was damaged on the way from Japan to the French Guiana launch site. The antenna was damaged and the satellite returned to Japan for repair.

The risk management and control method of satellite transportation has distinct characteristics compared with other stages of satellite development<sup>[1]</sup>. Satellite transportation is a multi-unit coordinated field operation, which is greatly affected by national policies, transportation planning, and climate conditions. The risk events faced by each satellite transportation are different. Only by mastering systematic risk control methods can we achieve comprehensive risk identification and effective risk management and control.

Based on engineering practice and risk control method, this paper refines the risk management and control methods in satellite transportation work, and puts forward the control ideas of "Simplified risk list and quantitative risk control", and summarizes the method of control, concrete, simple and comprehensive. In the practice, it has achieved good results and realized the "zero defect" of satellite transportation work, which is of great significance for improving the reliability of subsequent satellite transportation work and ensuring the success rate of satellite development in China.



## 2. Risk management principles for satellite transportation work

The risk concept adopted in this paper is defined as “Risk is the difference between the expected result and the actual result, the greater the difference, the greater the risk.”<sup>[2]</sup> The reason why this paper chooses this definition is that the risk includes not only “accidents” but also “unrecognized technical status”, which have the same impact on transportation work.

The risk management process includes five steps: “Risk identification”, “Risk assessment”, “Risk decision”, “Risk control” and “Result evaluation”<sup>[3]</sup>. Each step must be integrated in each stage of transportation work, the specific correspondence is shown in Figure 1.

Risk identification and assessment work is carried out during the design of the transportation plan and the detailed plan making phase. In the formulation of the plan, avoid the risk-high plan. In the detailed plan making phase, it is necessary to comprehensively identify the risk and conduct risk assessment, and develop risk control measures for events with high risk level.

In the transportation implementation phase, the risk events of high-risk levels are mainly monitored and corresponding controls are implemented. Identify the risk events in real time for temporary events during transportation.

In the transportation summary phase, for amending and improving the risk management method, risk assessments need to be carried out based on monitoring during the process.

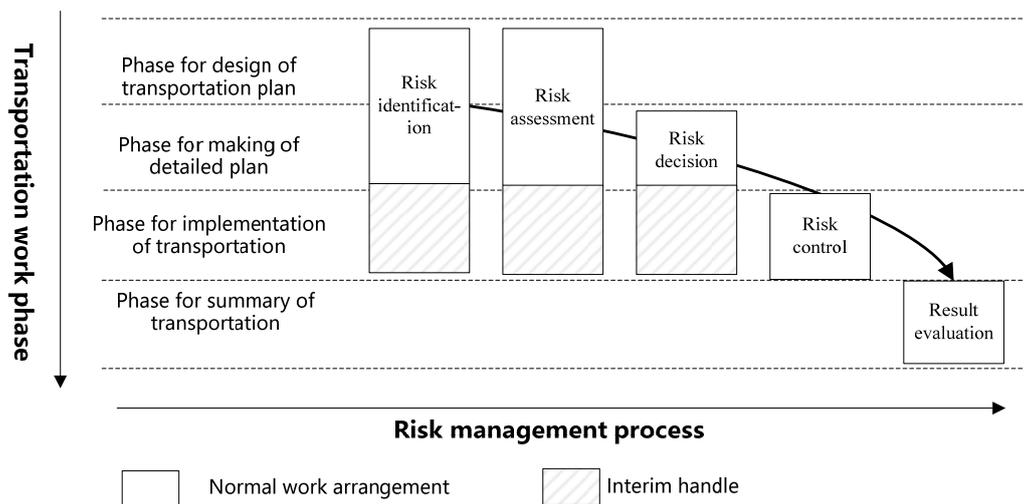


Figure 1. Correspondence between risk management process and transportation work phase

## 3. Comprehensive risk identification and risk assessment

### 3.1. Risk Identification

Comprehensive risk identification is a prerequisite for comprehensive risk management. In the satellite transportation work, the "Identification matrix method" is an effective means to ensure full identification.

The "Identification matrix method" evolved from the "Screen analysis method"<sup>[3]</sup> of risk identification. The entire transportation process meets the requirements as the overall goal, and the interference indicators meet the requirements, and are classified into “Environmental control risks”, “Accident risks”, “Human error risks”, and environmental control categories according to different environmental requirements can be further refined. Taking each stage of the transportation work as a horizontal dimension, the entire transportation process is divided into a matrix according to the risk type and the execution stage. For each matrix unit, the risks are identified one by one, so that the risk events are comprehensively combed.

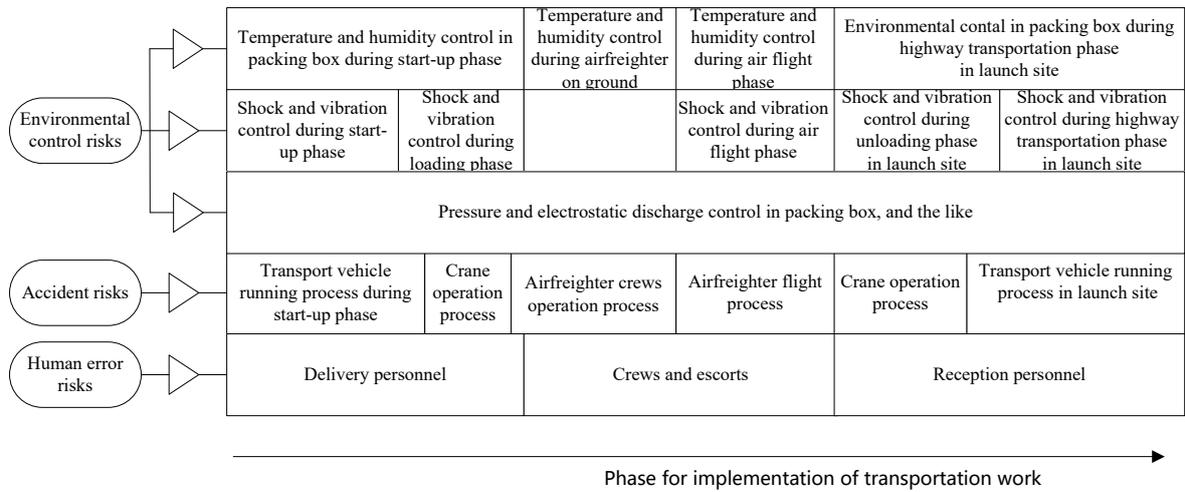


Figure 2. Risk identification matrix

3.2. Risk Assessment

After completing the list of risk events, the risk assessment matrix should be used to evaluate the risk level according to the “probability of occurrence” and “hazard”, and the events with higher risk levels are included in the risk control list, and risk control is designed item by item. Due to the compact pace of the tasks in the transportation work and the small number of personnel, the transportation risk control list is to be streamlined, and the risk control force is put into the necessary risk prevention.

4. Control methods for different types of risks

4.1. Environmental control risk

During the entire transportation process, the satellite is required to ensure that the environmental characteristics of the satellite (including temperature, humidity, relative pressure, shock, vibration) are within the specified range. However, the harsh climate (such as high temperature, exposure, severe cold, etc.) will cause excessive temperature and humidity, and the bad road conditions and incorrect loading and unloading methods will lead to shock and vibration, and directly damage the satellite or cause potential damage; The changing external air pressure will cause the relative pressure inside and outside the *packing box* to be out of tolerance, destroying the *packing box* and indirectly causing damage to the satellite.

The environment in which the satellite is located can be described by the following model. The “external incentives” affect the “environmental indicators” of the satellite through the “transformation relationship”. If there is no accurate understanding of “external incentives” or “transformation relationships”, satellite “environmental indicators” are at risk.

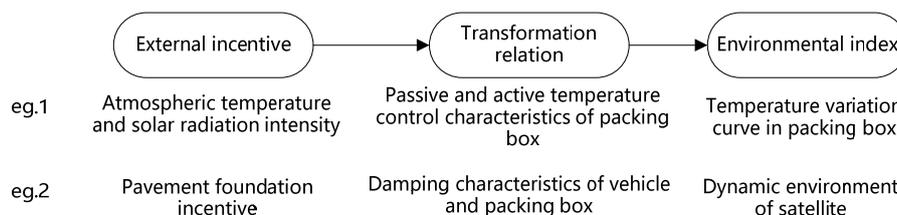


Figure 3. Environmental Control Model

Therefore, the control of environmental control risks should start with the first two items of the environmental control model. For "external incentives", the methods shown in Table 1 can be used to accurately understand.

Table 1. External incentive identification

Relevant environmental indicators	External incentive	Recognition methods
Temperature, humidity	External temperature curve	Weather forecast
	Sun exposure	Weather forecast
	severe cold	Weather forecast
Relative pressure	Transportation route elevation	Map
	Airfreighter climb speed	Technical agreement with airlines
Shock, vibration	Pavement foundation incentive	Transportation route survey
	Hoisting operation	Crane technical parameters

The cognition of the “transformation relationship” requires advance technical research work to form technical accumulation.

Table 2. Transformation relationship

Relevant environmental indicators	Transformation relationship	Key parameter	Instructions
Temperature, humidity	Passive temperature control ability of packing box	Heat capacity (c), thermal resistance ( $\lambda$ ), irradiation absorption ratio ( $\alpha$ ) of packing box	The external excitation data is brought into the temperature of packing box change calculation equation <sup>[4]</sup> , and the temperature variation curve in the packing box under a certain temperature control strategy is calculated.
	Active temperature control capability of packing box	air conditioning power (Wac) of packing box	
Relative pressure	Relationship between altitude and relative pressure	Altitude pressure coefficient (k)	Calculate the packing box charging/unloading pressure strategy based on altitude changes.
Shock, vibration	Shock absorption characteristics of shock state	Vehicle/ packing box shock absorption characteristics	Confirm vehicle speed in different states based on external excitation and vehicle/ packing box shock absorption characteristics <sup>[5]</sup> .
	Damping characteristics of periodic vibration	Satellite/ packing box combination base frequency $f$ ,	

A thorough understanding of the details of transportation is the basis for the use of technical means for risk prevention and control. For example, in the case of a satellite packaged airfreighter on a clear summer day, the temperature inside the packing box is likely to exceed the standard due to the high outside temperature, but the harsher environment is that the satellite packing box and other cargo (contained containers) have just been loaded into the airfreighter. In the state, due to the exposure of the sun, the temperature of the accompanying container is high, and the environment inside the enclosed airfreighter cabin will rise above 40°C. Therefore, the focus of preventing the risk of “excessive temperature in the packing box” is not only the temperature control strategy of the satellite packing box itself, but also the temperature control strategy of the accompanying container.

4.2. Emergency prevention and control measures

Another common type of risk is the risk of sudden accidents. These risks are affected by the occurrence of risk events. These risks include “vehicle scraping during transportation”, “vehicle failure can't drive”, “transportation machine can't arrive on time”, “the wind can't lift”, etc., such accidents can't be predicted, but can be controlled by a certain risk analysis method. This article uses “Bow-tie analysis method<sup>[6]</sup>” as a risk analysis method for sudden accidents. This method combines a safety barrier map and a fault tree analysis method for prevention purposes, and is highly visual and easy to operate. Figure 4 shows the risk of using “the crane can't arrive on time” as a precaution, and explains how to use Bow-tie.

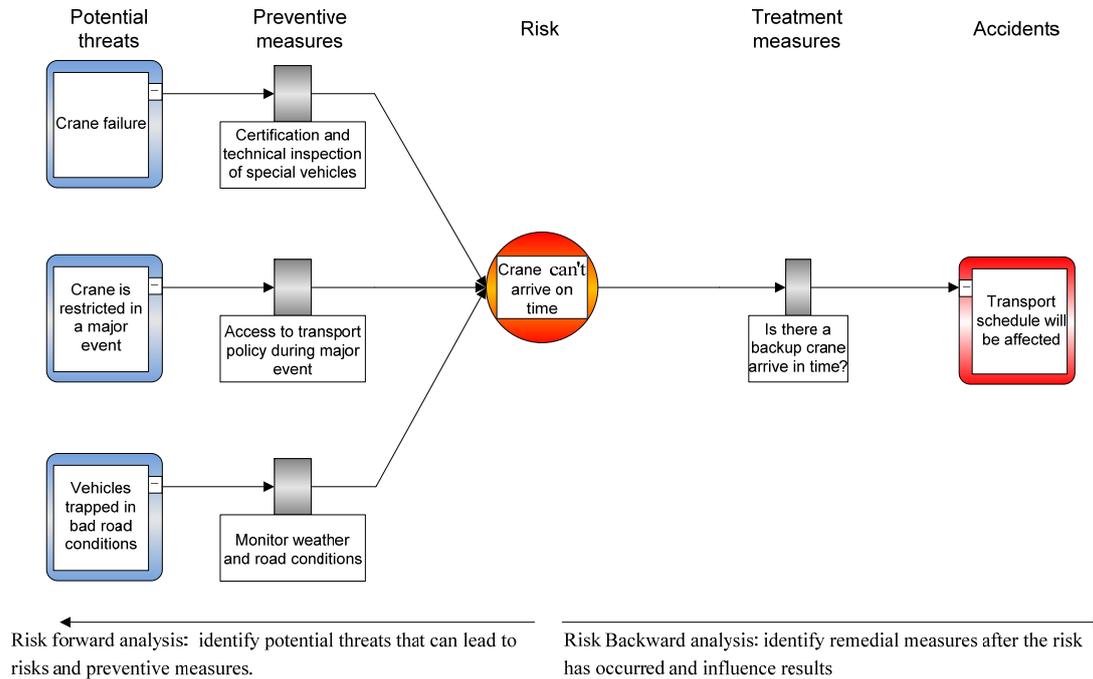


Figure 4. Bow-tie analysis chart

The Bow-tie analysis method analyzes the risk events forward and backward respectively. Forward analysis aims to identify potential threats and preventive measures that can lead to risks. The purpose of the backward analysis is to identify remedial measures after the risk has occurred. Combine forward analysis and backward analysis to jointly develop risk plans.

For example, a spacecraft will be unloaded from the airfreighter using a crane in the airport of launch area. The transport owner had performed a technical safety check on the crane three days ago before use. At that time, the crane was working on another site in the city. Part of the road is a mountain road from here to the airport. One day before the airfreighter arrived at the launch site airport, the launching area torrential rain, the transportation manager and the aerospace logistics company recognized the impact of heavy rain on the mountain road, and asked the crane company to immediately send people to check whether the crane could return normally. The crane company found through the road condition that some of the mountain roads were muddy and slippery, and the crane could not pass. The person in charge of transportation and the aerospace logistics company urgently re-find the qualified cranes and organized technical safety inspections to ensure smooth transportation.

#### 4.3. Human factor risk prevention and control

There are many transportation cooperation units, and the units that directly operate the products such as transportation fleets, airfreighter, and cranes are all cooperative units. The personnel of the collaboration unit are highly uncertain and do not understand the demand for product transportation. It is easy to affect the transportation work due to the misoperation or wrong behavior of the personnel.

During the development of satellite transportation, it will face multiple collaborative units and multiple key positions, as shown in Figure 5. The key of human factor risk prevention and control is to identify new units, new positions and new personnel to ensure that they understand the needs of the position. The conventional technical requirements convey the path for the person in charge of transportation to convey the information to the person in charge of the collaboration unit, and the person in charge of the cooperation unit will then implement it to the frontline personnel. When the key first-line position is undertaken by the new personnel or the person in charge of the cooperation unit is undertaken by the new personnel, at the transportation site, the transportation person in charge shall conduct direct risk communication with the key front-line personnel to ensure the requirements and risks understanding of the key positions.

Taking the satellite installation process as an example, in the operation of pulling the satellite packing box into the cabin along the airfreighter slide rail, the transporter loader (foreign personnel and for the first cooperation) shall fix the traction cable to the guide rod of the satellite packaging box. At the point, the fixed point of the guide bar is not the bearing part on the packing box. Pulling here will cause the packing box to be damaged and a serious technical safety accident will occur. The person in charge of transportation found that the intention of the loader was stopped and stopped, persuaded the foreign carrier to replace the traction tool, and carried out the traction operation according to the designated position of our company to successfully complete the transportation task.

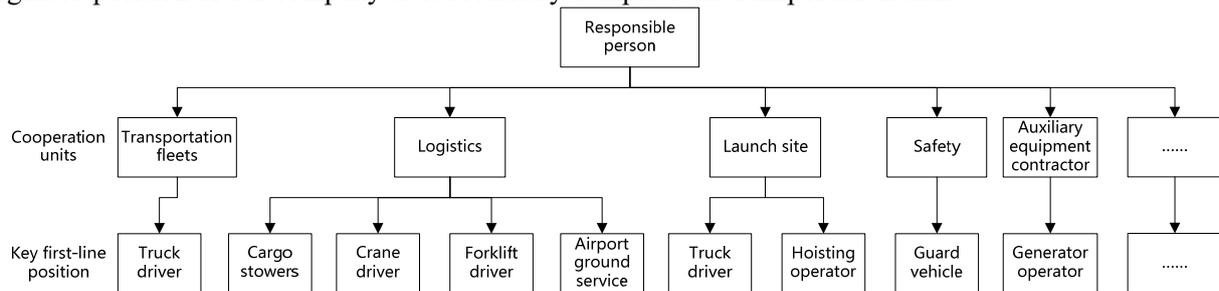


Figure 5. Transportation work collaboration unit / personnel

## 5. Risk control coupling

The purpose of risk control is to reduce the occurrence of risks and thus prevent accidents. The risk is unavoidable, but the purpose is “zero accident”. Therefore, the control of risk should not be blind and complete, and the control of any kind of risk requires a certain price, and this cost may lead to an increase in another risk.

For example, in order to reduce the risk of excessive shock vibration during road transport, it is possible to control by reducing the speed of the vehicles; however, too slow a speed may cause the vehicles to travel on the road for an increase in time, increasing traffic accidents, traffic jams, and the like. The probability of occurrence of a class of risks; in order to prevent the risk of excessive temperature and humidity in the ground stop phase of the airfreighter, it can be sent to the airfreighter for overnight duty, but this will cause fatigue, resulting in an increase in the risk of errors for the next day. Therefore, only a comprehensive understanding of the risk, quantitative control, can achieve the goal of the lowest overall risk.

## 6. Conclusion

This paper analyzes the timing and methods of risk identification, risk assessment, risk decision-making and control in the transportation process for the purpose of comprehensive risk control of satellite transportation work, and puts forward the viewpoint of “Reducing risk list and quantifying risk control”. The refined risk identification method proposes different control methods for different types of risks. The method designed in this paper is used in the factory transportation of satellites, and the application is in good condition, which effectively guarantees the safety of satellite transportation.

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