Technical Requirements of

International Space Science and Scientific Payload Competition

(ISSSP 2024)

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Content

1. Overview of Space Station Environment

1.1 Micro-gravity Environment

The China space station can provide a long-term micro-gravity environment, with a micro-gravity level (residual micro vibration acceleration) of 10^{-3}-10^{-4}g. Under the condition of the environment, phenomena, caused by the ground gravity effect, such as buoyancy convection, gravity settling, liquid pressure gradient in fluid (gas, liquid, melt) will basically disappear, and some secondary effect overshadowed by the ground gravity effect will be highlighted, resulting in significant change in fluid form and physical (chemical) process. These will directly affect or change the flow and combustion mechanism, and also affect the processing and preparation of related materials (including biological materials). In addition, micro-gravity will also have a direct effect on the experimental conditions of some fundamental physics, under which experiments can be carried out with higher indexes and accuracy to satisfy the verification of important fundamental physics theories. The survival and evolution of all living organisms (including human beings) have always been realized under the environment of gravity, and the influence of micro-gravity on organisms and their various aspects is very significant. Therefore, micro-gravity environment is a unique and valuable resource for related scientific research.

1.2 Orbital Position

The China space station runs in the near-circular low earth orbit with an inclination of 41-42 degrees and at an orbital altitude of 340-450 kilometers, circling the earth in about 90 minutes. The space station assembly is earth-oriented with three-axis stabilization The orbit of the space station is completely out of the earth's atmosphere and located in the F2 layer of the earth's ionosphere, which is suitable for sky-survey space astronomical observation and special space-physical research. For earth observation, the orbit of the space station covers the area within the south and north latitude 42 degrees, where 90% of the earth's population inhabit. Compared with the solar synchronous orbit adopted by general earth remote sensing satellites, the intersection local time of the space station orbit is constantly changing, enabling observation in the same area under variable light conditions. Due to the low orbital altitude, the spatial resolution of the same earth-observing instrument is higher.

1.3 Radiation Environment

Radiation comes from galactic cosmic rays and solar cosmic rays (including solar proton events). The main components of cosmic rays are protons (about 90%), helium nuclei (about 9%), and electrons, various heavy ions, gamma rays, etc. (about 1%). Cosmic rays have a wide energy range and a power-law descent in their energy spectrum (the higher the energy, the lower the flow). Due to the effect of the earth's magnetic field, space station running in low earth orbit within the range of latitude ±43° will deflect low-energy charged particles to the polar region. Only higher-energy charged particles (above about 1GeV/n) can arrive, reducing the total radiation dose. When the space station passes through the lower part of the south Atlantic anomaly of the earth's inner radiation belt, the charged particles trapped by the radiation belt have a significant effect on the space station, but the total radiation dose is not high. Solar proton events are random and can increase radiation dose significantly in a short time. Due to the protective effect of the cabin structure, the radiation measurement in the cabin is 1-2 orders of magnitude lower than that outside the cabin, but high-energy particles can still penetrate the bulkhead. Space radiation environment has certain harm to spacecrafts, astronauts and equipment, but the complex composition and energy spectrum form of cosmic rays cannot be simulated on the ground, which is a favorable condition for the research of radiation biology and a necessary condition for the research of high-energy astronomical observation and particle astrophysics.

1.4 Extreme Extravehicular Environment

Some experiments, including extreme heat and cold cycles, high vacuum, atomic oxygen erosion, solar ultraviolet radiation and cosmic high-energy radiation, etc. can be conducted in space station by using the extreme conditions outside the cabin. The performance of the materials, electronics, organisms and tissues outside the cabin will be significantly affected by the outer space environment. The particular environment (and its combination) is difficult to realize on the ground, which also illustrates the uniqueness of this experimental environment.

The space station's unique environment, over 10 years' continuous operation, sky-ground round-trip transportation support and astronauts' participation provide necessary conditions for systematically carrying out research on space life science and biotechnology, space basic physics, micro-gravity fluid physics and combustion science, space materials science, as well as important astronomical observation, earth observation, space physics research and new technology test, etc.

2. Design Requirements for Intravehicular Test Payloads

2.1 Introduction to the Intravehicular Test Platform

The air pressure in the pressured cabin of the space station is 81.3kPa-104.3kPa, the temperature is 19-26℃, the relative humidity is about 30-70%, the gas composition is close to the ground atmosphere, and the noise level in the working area is no more than 65dB. In the space station, the special test platform (as shown in figure 1) provides the energy interface and information interface for the test payload, which realizes data exchange and power supply with the platform through B-type USB interface. With the support of the test platform, the test payload designers needn't to consider the technical details of measurement and control between the test payload in the space station and the ground equipment. The test payload can be measured and controlled by the ground equipment provided by the platform.

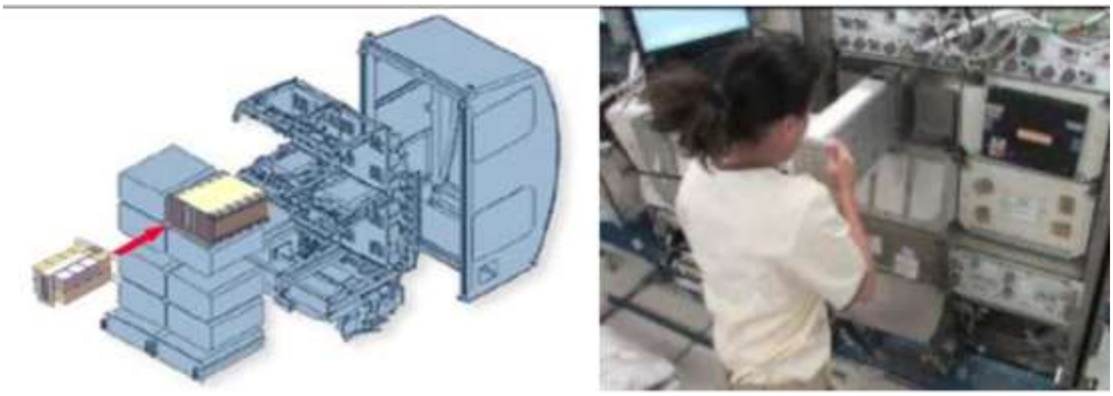

Figure 1. Intravehicular Test Platform

2.2 Volume Requirement for the Test Payload

The test payload module takes the cube (as shown in figure 2) as a unit (1U, with a volume of 10cm*10cm*10cm), which can be incrementally increased to 2U, 4U, 8U, 16U and 32U (maximum) according to the test requirements. The concept diagram of units of different sizes in the cabin environment is shown in figure 2. The design size of the test payload in the cabin is selected from the above geometric shapes. As the energy and information interface, the USB interface is shown in figure 3 and figure 4 at the side wall of the test unit, where A=33.55mm, B=95.37mm, C=66.45mm and D=16.43mm.

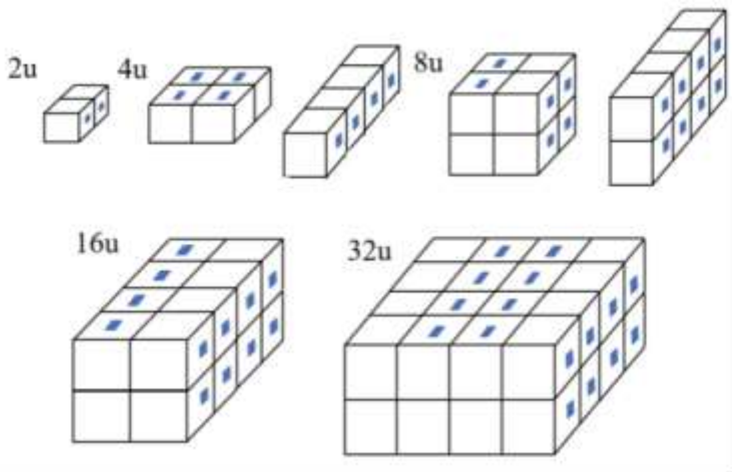

Figure 2. Concept Diagram of Units of Different Sizes in the intravehicular Environment

Figure 3. Factual Picture of USB Interface

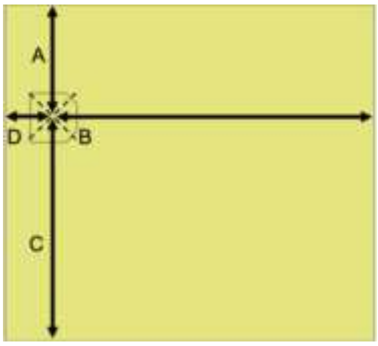

Figure 4. Position of USB Interface

2.3 Mass Requirement

For the test payloads of 1U, 2U, 4U, 8U, 16U, 32U, the maximum mass is 1kg, 2kg, 4kg, 8kg, 16kg, 32kg respectively.

2.4 Power Supply

Test payload of 1U is provided with power supply of 2W, 5VDC through the USB interface located in the aluminum housing. Therefore, for the payload of 2U, 4U, 8U, 16U and 32U, there are 2, 4, 8, 16 and 32 USB interfaces respectively, corresponding with the maximum power of 2*2W, 4*2W, 8*2W, 16*2W and 32*2W. Figure 5 shows the geometric distribution of the USB interfaces provided by the platform for the test payload.

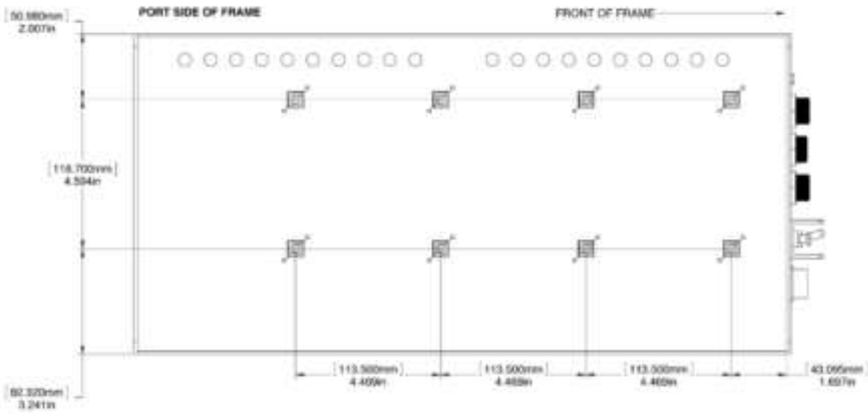

Figure 5. Geometric Distribution of the USB Interfaces

Besides, the intravehicular test platform can provide 28VDC and 30W power supply for each payload. If the above 5VDC, 2W power supply cannot meet the power demand of the test payload, this 28VDC power supply can be used.

2.5 Sensor Support

The sensor types provided by the platform include temperature, humidity, O_2 concentration, CO_2 concentration, NH_3 concentration sensors and camera, etc.

2.6 Data Processing

The loading platform provides transmission channels for data upload and download. The test platform requires that the data storage device for the test payload be recognized as a USB2.0 storage device by the platform's embedded computer. The data download speed provided by the platform for the test equipment is 3Mbps, the upload speed is 50 bytes per second, and the upload file size is limited to 60K bytes. The test platform provides control instruction set, and the test personnel can send control instructions to the test platform through ground equipment.

3. Design Requirement for Extravehicular Test Payloads

3.1 Introduction to the Extravehicular Test Platform

Outside the pressured cabin of the space station, there are exposure experiment platforms, large payload hangpoints and extensive experiment platform hangpoints to support research in space astronomy, space physics and environment, earth science and applications, new aerospace technologies, and new space application technologies, etc. Outside the space station, **the special extravehicular test platform** (as shown in figure 6) provides mechanical interfaces, energy interfaces and information interfaces for the test payload. Test payload implements data exchange and power support with the platform by Type-B USB interface. With the support of the test platform, designers of the test payload needn't to consider the technical details of measurement and control between the test payload in the space station and the ground equipment. The test payload can be measured and controlled by the ground equipment provided by the platform.

3.2 Extravehicular Test Module

The test payload module takes the aluminum cube as 1U, which can be incrementally increased to 2U, 4U, 8U, 16U and 32U (with the maximum of 40cm*40cm*20cm). The extravehicular test payload can be produced without using aluminum cube walls. At this point, the height of the test payload in the vertical direction to the test platform shall not exceed 20cm, and the maximum area occupied by the test payload in the test platform shall not exceed 40cm*40cm, that is, the total volume still does not exceed 32U. The concept diagram of units of different sizes in the extravehicular environment is shown in figure 7. The design size of the test payload outside the cabin is selected from the above geometric shapes.

Figure 6. Extravehicular Test Platform

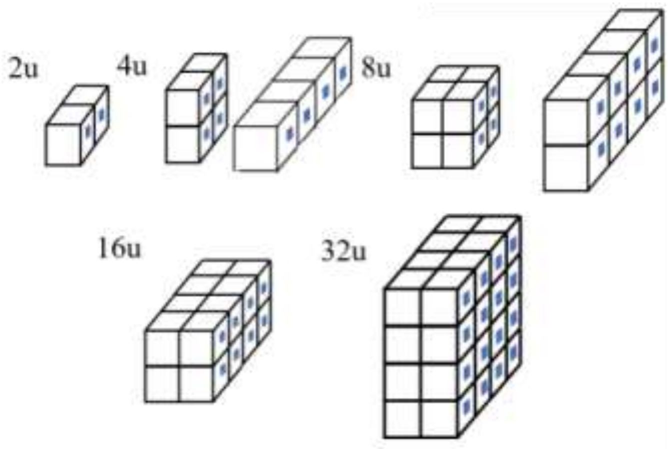

Figure 7. Concept Diagram of Units of Different Sizes in the Extravehicular Environment

3.3 Mass Requirement

For the test payloads of 1U, 2U, 4U, 8U, 16U, 32U, the maximum mass is 1kg, 2kg, 4kg, 8kg, 16kg, 32kg respectively.

3.4 Power Supply

The extravehicular test platform provides each extravehicular test payload with power supply of 28VDC, 30W and power supply of 5VDC, 2W through the USB interface located in the aluminum housing. According to the USB2 high power standard, 5VDC USB power supply allows a maximum current of 500 mA. The power supply is permanently applied to the platform; for the load of 2U, 4U, 8U, 16U and 32U, there are 2, 4, 8, 16 and 32 USB interfaces respectively, with the maximum power of 2*2.5W, 4*2.5W, 8*2.5W, 16*2.5W and 32*2.5W correspondingly.

3.5 Sensor Support

The sensor types provided by the platform include temperature sensors and camera.

3.6 Data Processing

The loading platform provides transmission channels for data upload and download. The test platform requires that the data storage device for the test payload be recognized as a USB2.0 storage device by the platform's embedded computer. The data download speed provided by the platform for the test equipment is 3Mbps, the upload speed is 50 bytes per second, and the upload file size is limited to 60K bytes. The test platform provides control instruction set, and the test personnel can send control instructions to the test platform through ground equipment.

4. Design Requirement for CubeSat

The launching mode adopted by the CubeSat designed in this contest differs from that of launching rockets; instead, the CubeSat is transported to the space station as payload of cargo spacecraft, and then catapulted into space via the **CubeSat deployer**.

Requirements in this chapter shall be complied with to ensure the efficient integration of the CubeSat and the **deployer** (as shown in figure 8), as well as launching and loading in the cargo spacecraft. These requirements are listed in the following categories: structural and mechanical system, electrical system, environment, and safety.

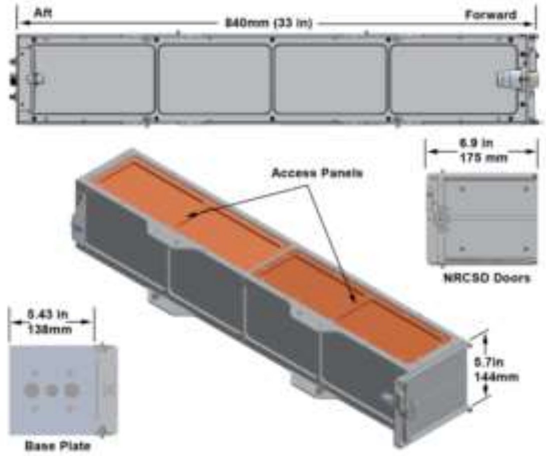

Figure 8. Shape and Size of the Deployer

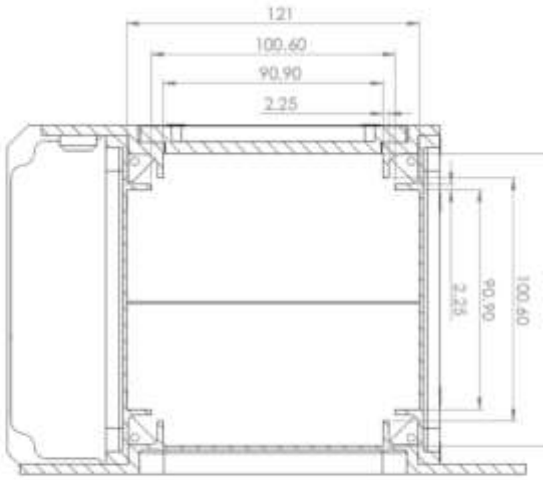

Figure 9. Schematic Diagram of the Deployer’s Transversal Surface

Refer to Appendix A for interface information between CubeSat and deployer and other design requirements.

Appendix A

Interfaces between the CubeSat and the Deployer and Other Design Requirements

1. Structure and Mechanism Interface

The deployer is designed as a CubeSat which is able to contain 1U, 2U, 3U, 4U, 5U, 6U (maximum), and its coordinate system definition is shown in figure 10.

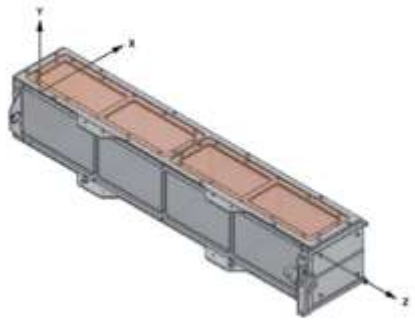

Figure 10. Coordinate System Definition

The mass of CubeSat depends on its volume. The full mass of CubeSat of 1U, 2U, 3U, 4U, 5U, 6U is 2.4kg, 3.6kg, 4.8kg, 6.0kg, 7.2kg, 8.4kg respectively.

The mass center of a CubeSat coincides with its geometric center as much as possible. The deviation of X-axis and Y-axis from the mass center shall not exceed 2cm. The deviation of Z-axis from the mass center is related to the volume: for CubeSat of 1U, 2U, 3U, 4U, 5U, 6U, its deviation of Z-axis is no more than 2cm, 4cm, 6cm, 8cm, 10cm, 12cm respectively.

1) CubeSat has four orbits on the z-axis, each of which is located at an angle of the CubeSat envelope, allowing the effective payload to slide along the deployer's orbital interface.

2) CubeSat's orbits and shell shall not exceed the transversal surface size specification as shown in figure 11.

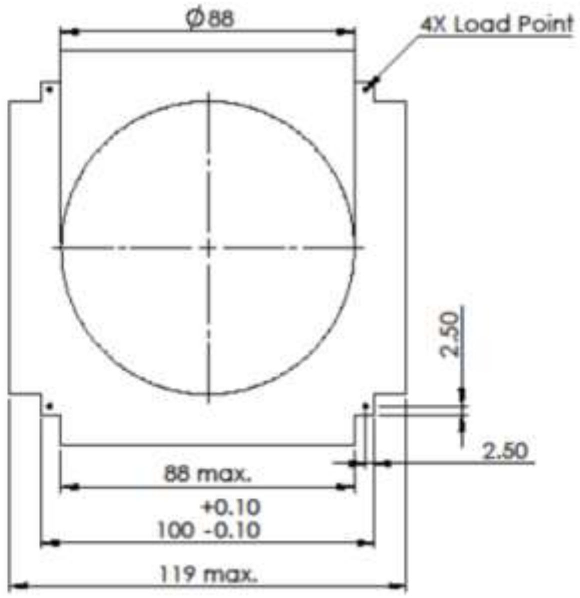

Figure 11. Transversal Surface Size Range

Note: The "min" following any size shall be considered the minimum size requirement for the feature, and any size "max" shall be considered the maximum size requirement for the feature.

3) The minimum width (X- and Y-side) of each CubeSat orbit shall be 6mm.

4) The edge of CubeSat orbit shall have a circular chamfer with a radius of 0.5mm±0.1mm (min).

5) The end of +Z orbit of the CubeSat shall be completely exposed with a minimum surface area of 6mm x 6mm.

6) The end of the CubeSat orbit (+/-z) shall be coplanar with other orbit ends, with an error within ±0.1mm.

7) The length of CubeSat orbit (Z-axis) shall be (+/-0.1mm):

1U orbit length: 113.50mm

2U orbit length: 227.00mm

3U orbit length: 340.50mm

4U orbit length: 454.00mm

5U orbit length: 567.5mm

6U orbit length: 681 - 740.00mm

8) CubeSat orbits shall be continuous and shall have no gaps, holes and/or fasteners.

9) From the direction of +/-Z-axis, the minimum distance between the CubeSat orbit and the CubeSat +/-Z-axis surface shall be 2 mm. That is, the orbit shall be at least 2mm away from the appendices (e.g., solar panels, antennas, etc.) on the CubeSat.

10) The CubeSat orbit shall be the only mechanical interface between each axis (X-, Y-, Z-axis) and the deployer.

Note: This means that if the satellite moves in any direction within the deployer, the only contact point of the effective payload shall be in the orbit or at the end of the orbit. No attachment or part of the satellite shall touch the side wall of the deployer.

11) The hardness of the CubeSat surface in contact with the guide rail of the deployer shall be equal to or greater than the hard anodized alumina (Rockwell hardness 65-70).

Note: Hard anodized alumina surface is recommended.

12) The surface roughness of the CubeSat orbit and all loading points shall be less than or equal to 1.6 μm.

2. Power Switch

1) The CubeSat shall have at least three power switches for switching on the main power supply after the CubeSat is ejected.

2) The expansion switches for pusher/plunger type shall be located on the steel rail end plane of the CubeSat -Z plane.

3) The expansion switches for roller/lever type shall be embedded in CubeSat orbits (+/-X/Y plane).

4) The roller/slide switches shall remain in contact with the deployer track along 75% of the full length of the steel rail.

5）The deployment switch of the CubeSat shall be stationary.

6）The force applied by the expansion switch shall not exceed 3N.

7）The total force of all deployment switches of the CubeSat shall not exceed 9N.

3. Deployable Systems and Integration Constraints

1) CubeSat deployable systems (such as solar arrays, antennas, effective load derricks, etc.) shall have independent constraint mechanism independent of the deployer.

2) CubeSat shall be able to be integrated in the deployer without distinction.

4. Electrical System Design

1) All power storage devices shall be located inside the CubeSat.

2) While the CubeSat is in the deployer, any system of the CubeSat itself shall not be run in order to avoid any possible danger.

3) The CubeSat's electrical system shall include at least three switches. In the deployer, all switches must be disconnected. After the CubeSat is ejected from the deployer, all switches are closed and the CubeSat power supply is connected as shown in Figure 12. The satellite suppression scheme shall include a ground branch switch that disconnects the battery from the negative terminal to the ground along the power line.

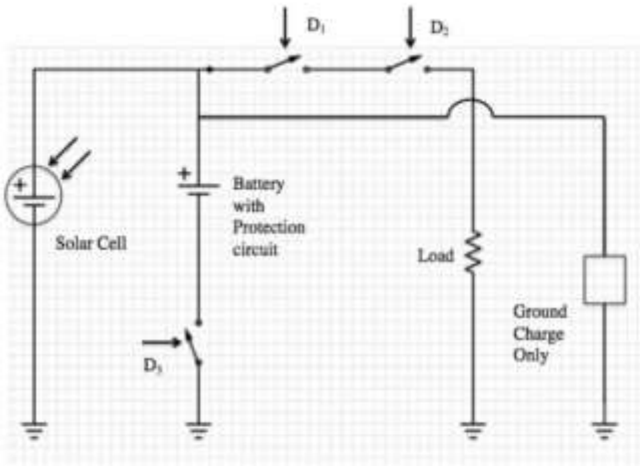

Figure12: Schematic Diagram for the 3 Physically-driven Independent Suppression Switches

5. Electrical System Interface

There are no electrical interfaces or data interfaces between the CubeSat and the deployer, and the CubeSat is completely out of power in the deployer.

CubeSat shall be able to withstand random environment with appropriate safety margin.

Test inspection records are required to verify that all external components are installed correctly and do not pose a risk of loosening. According to the danger classification of CubeSat, additional post-test inspection records may be required. When the CubeSat is inside the deployer, the end of Z-axis direction can withstand a force of 1200N. CubeSat shall be able to withstand the relative humidity of all pre-deployment mission phases, i.e., relative humidity (RH) during ascent and in-orbit flight shall be between 25% and 75%.

6. Airlock Pressure Relief

CubeSat shall be able to withstand the pressure limit and decompression/supercharging rate of the airlock cabin as defined below,

Airlock pressure: 0-104.8kpa,

Decompression/re-supercharging rate of the airlock: 1.0kpa/s.

7. Safety Requirement

CubeSat shall be designed to eliminate or control all existing hazards in accordance with the requirements and guidelines given in this section. The following items contain general specific safety requirements adopted in standard CubeSat designs. However, in many cases, the specific design requirements depend on the CubeSat's hazard classification (especially CubeSats with non-standard design features).

Generally, hazards are classified in accordance with the following definitions:

1) Definition of catastrophic hazard - any situation that may result in

• disabling or fatal bodily injury

• losing the space station

• damaging manned space vehicle

• damaging major ground facilities

2) Definition of key hazard - any situation that may result in

• non-disabling bodily injury or illness

• losing major components of the space station

• losing redundancy of on-orbit life (i.e., only one hazard control is left)

3) Definition of marginal hazard - any situation that may result in

• space station components in non-key path

• bodily injury that causes minor discomfort (not requiring medical attention) to the crew

• in need of intervention from a second crew member and/or consultation with the flight surgeon

Examples of CubeSat features/faults for evaluating potential hazards are shown below

- structural failure
- failure in save application loading
- fracture
- stress corrosion
- mechanism
- fastener integrity and secondary sealing feature
- failure or blast in pressure system
- breakage
- leakage of or exposure to dangerous or toxic substances
- danger in propulsion system
- improper operation
- deployment of attachments
- hazards caused by operating radio frequency system on the space station hardware and crew
- battery failure
- use of flammable or toxic substances
- use of fragile materials
- electrical system failure that causes shock or burn, including wiring, fusing, and grounding
- electromagnetic interference (EMI)
- magnetic field
- collision with the space station or a visiting aircraft after deployment in orbit

Hazard control shall be adapted to hazard type and occurrence. Many CubeSat hazards are under the control of the deploying staff, because the CubeSat are located in the deployer before the space station is deployed.

4) The CubeSat shall be designed to prevent the release or generation of any foreign object debris (FOD) during all phases in the mission.

Note: The main problem is the fragile material exposed to the outside of the satellite (solar cell cover glass, optical lenses, etc.).

5) Ventilation

The maximum effective ventilation ratio (MEVR) of a CubeSat structure and any enclosed container inside the cup-shaped object shall not exceed 5080cm. The calculation is as follow

$$MEVR = \left(\frac{Internal\ Volume\ (cm)^3}{Effective\ Vent\ Area\ (cm)^2} \right) \leq 5080\ cm$$

The effective ventilation area shall be considered as the sum of the open surface areas of any vent location or transversal areas where air may escape the CubeSat or its subsystems.

Note: After the final integration, the space station crew will not provide battery charging, support services and/or support.

6) Pyrotechnics

The CubeSat must not contain any pyrotechnics unless the design method is approved by the organizer of the contest.

Note: To control potential hazards, the use of circuit fusing systems is allowed.