학술용 소형시스템 우주환경시험설비 구축

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Academic level space environment testing facilities for small scale systems

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Introduction

Space environment testing is a crucial factor in successful mission accomplishment of a space system. Space environment testing includes both launch environment and in-space environment phase of the targeted system, which widely covers vibration/shock, thermal/vacuum/thermal vacuum, EMI/EMC, and radiation tests. However for small scale systems, it is not easy to perform all of the environment tests due to project budget issues either related to cost or time.

Recently the number of small scale systems has increased while the space environment testing levels stayed the same. Due to this, the development cost of small scale systems was not so much affordable when a unit level part was fully space qualified resulting to higher risk COTS (commercial off the shelf) part selection. However, recently there has been a study on such topic, aiming to set a standard for small scale system space environment testing. In this study, a realistic test is proposed in order to provide reliability while not over testing (“low-cost and fast-delivery“). Following this study, the objective was to set up a academic level space environment testing facility such that small system level tests can be performed in a single room, as in figure 1.

Considering various budgets (cost and space) and the system (or subsystem) of which can be developed as an academic level, the target of the testing facility was set to small scale systems, especially low orbit CubeSats. The approach in setting the testing facility was to set the tests and its levels to be performed. Once the tests and its levels are decided, then the test facility requirements are defined. In case of Seoul National University, the tests and its levels were decided referencing the QB50 requirements, NanoRacks requirements, and currently in-draft small satellite testing ISO. Each of the tests and levels are explained throughout the rest of the paper.

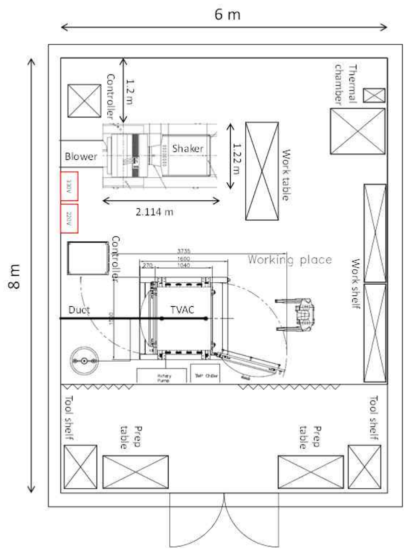

Fig. 1. Environment testing facility layout

Target system

The most important of all before starting to define the tests and the levels is to set the target system. As in individual university scale projects, it is not easy to jump into large systems or deep space explorers, the target was low orbiting small scale systems. System level-wise, low orbit was limited to 830 km considering the typical launcher specifications, and small scale was limited to 20 kg considering the boundaries between academia, research institutes, and industries. Unit level could expand to larger scale since unit testing specification will differ depending on its mechanical/electrical interfaces or functional requirements, thus the target was set to system level.

Vibration Tests

The main purpose of vibration tests is to test the mechanical integrity of a system or a unit. In a typical vibration test campaign, although a system is exposed to a launch condition of multiple vibration sources, the vibration test can be decomposed as though a launch phase has a dominant source (e.g. low frequency sine, random vibration, static acceleration, etc.). In order to perform such tests, a shaker is required, which is capable of controlling various vibration profiles. Thus, the key specification requirement is the ability to perform random, sine-burst, and sine tests.

The test levels were defined by taking the maximum levels from all of the references, which were 13 g for sine (maximum from quasi-static load) and 9.47 grms for random vibration. Detailed profiles can be found in the references.

After the tests and its levels have been defined, the output force of the shaker can be calculated from the test levels of a targeted system. The authors had assumed that up to 20 kg system can be developed. Including 40 kg jig fixture, 15 kg head expander, and 25 kg armature, the total mass requirement was set to 100 kg with a margin of 1.3, resulting 16.6 kN sine force (pk) and 12.1 kN random force (rms).

Combining the requirements, SAB15F-S452 shaker of Unholtz-Dickie Corporation was selected. Some of the key specifications of the shaker are shown in table 1.

Table 1. SAB15F-S452 key specifications

Specification	Value
Three axis configuration with slip table	
Sine Force (pk)	20 kN
Random Force (grms)	20 kN
Frequency range	DC to 3,000 Hz
Displacement (pk-pk)	51 mm
Armature weight	22.7 kg (f_0=2,300 Hz)
Head expander weight	13.2 kg (f_0=1,900 Hz)

Fig. 2. SAB15F-S452 being installed

With the given specifications, up to 45 kg system can be tested with the same margin.

Shock Test

Shock test is required to test the launcher stage or fairing, and satellite separation events. Shock test level is set as the following.

Table 2. Shock test SRS profile

Frequency [Hz]	Spectrum [g]
30	5
100	100
700	1500
1000	2400
1500	4000
5000	4000
10000	2000 (4000)

A hammer type shock test facility, SNUSHOCK-2 was designed and built in-house, as shown in figure 2. The SRS can be set by changing the height of the hammer, damping material, and the position of the DUT (device under test) away from the impact point, as shown in figure 3.

Fig. 3. SNUShock-2 under test

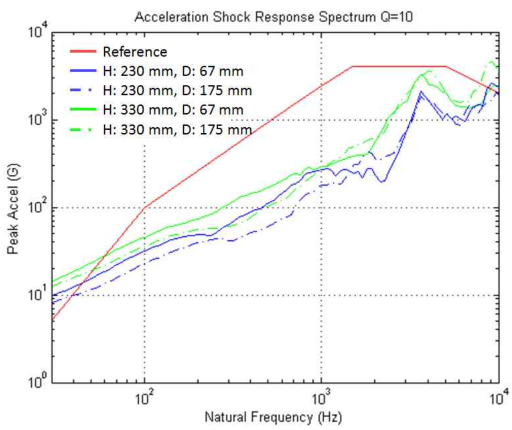

Fig. 4. Shock test SRS profile plot

Currently, SNUSHOCK-2 is only capable of two axis shock tests and the low frequency response does not reach up to the targeted SRS. Therfore, SNUSHOCK-2 must be upgraded to enable higher shock levels and three axis shock tests.

Thermal tests

Once the satellite is in orbit, the satellite can be exposed to bare sun, deep space, and Earth while in vacuum. Due to this, the satellite thermal condition may change, and thus the satellite must be tested whether the system is operational in such conditions. In order to be capable of performing such tests, a thermal vacuum chamber is widely used. The worst test condition was taken from the reference, and the dimensions were set such that the size of the shroud is three times larger than the target system size, which is 200 mm × 200 mm × 300 mm. The thermal vacuum chamber requirements are shown in table 3.

Table 3. Thermal vacuum chamber requirements

Parameter	Value
Temperature range	-70˚C ~ +100˚C
Ramp rate	1˚C/min
Tolerance limit	±2˚C
Vacuum level	10^{-3} Pa (10^{-5} mBar)
Shroud dimension	Φ850 × 900

The thermal vacuum chamber was developed according to the requirements by Yoonseul, as shown in figure 5.

Fig. 5. SNU thermal vacuum chamber

The chamber has been tested with the vacuum level and is currently at test for thermal control.

Besides the thermal vacuum chamber, SNU also installed a thermal chamber. The main purpose of the chamber is to perform unit level tests or cold start and hot start tests. The thermal chamber requirements are shown in table 4.

Table 4. Thermal chamber requirements

Parameter	Value
Temperature range	-35˚C ~ +70˚C
Tolerance limit	±2˚C
Internal dimension	< 400×200×600 mm^3

Fig. 6. LI-CTC605P thermal chamber

At the moment, a small size vacuum chamber is being designed to enable unit level thermal vacuum tests at 10 Pa level.

Cleanroom

As environment tests must be performed at acceptance test levels also, it is important to be able to maintain the cleanliness to a certain level. The cleanliness required by the QB50 requirement is ISO Class 8, which is equivalent to class 100,000. Currently, there is an assembly room in SNU, which is also class 100,000 as shown in figure 7.

Fig. 7. SNU class 100,000 cleanroom

In order to maximize the allocated space, a 7 m × 5.5 m × 2.5 m class 100,000 cleanroom will be covering the whole testing facility once all the facilities are set.

Conclusion

Academic level systems may be small and the target may differ from industrial or institute levels, however still require an adequate level of testing to increase the success.

Targeting low orbiting small systems up to 20 kg, the tests and its levels were based on available reference test requirements.

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