# PROTECTION SPACELAB FROM METEOROID AND ORBITAL DEBRIS


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## ABSTRACT

As the first long-term on-orbit spacelab of China, TianGong-1 will stay aloft for 2 years. Its failure risk subjected to Meteoroid and Orbital Debris(M/OD) is hundreds of times higher than the risk of Shenzhou-5, Shenzhou-6 or Shenzhou-7, so the special M/OD protection designs have been applied. In order to reduce the penetration risk of radiator tube, the design of radiator has been modified by placing the tube at the side of radiator plate, and the new design does not affect the thermal control system without adding the mass. Secondly, Whipple structure is adopted in the two sides and front of spacecraft against M/OD impact.


## 1 PREFACE

Tiangong-1 is China's first spacelab launched on 29 September 2011,an experimental testbed to demonstrate orbital rendezvous and docking capabilities. During its two-year operational lifetime, the unmanned Shenzhou 8 successfully docked with the module in November 2011, while the manned Shenzhou 9 mission docked in June 2012. A third and final mission, Shenzhou 10 is scheduled to launch in 2013. Tiangong-1 is China's first spacecraft shielded from M/OD, Which ensure that it had been on orbit safety for one year and five months. In the paper, the shield designs are introduced.

## 2 RADIATOR

As important component of the thermal control system, the radiator is laid outside of spacecraft large-area, which enhances its risk of M/OD impact.

If the tube of radiator is penetrated by M/OD, maybe, the thermal control system is disabled functionally. So the shield design of radiator is fulfilled to improve its capability to resist M/OD.

### 2.1 PRIMITIVE RADIATOR

The sketch map of primitive radiator is presented in Fig. 1, the radiator is made of aluminum alloy with a liquid as working fluid.

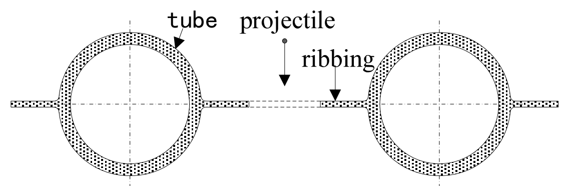



*Figure 1. scheme of primitive radiator*

By HyperVelocity Impact(HVI) numerical simulation and tests, the M/OD protection capability of radiator is evaluated. Made of 2A12 aluminum alloy, spherical projectile vertically impacts target, in the simulation and test.

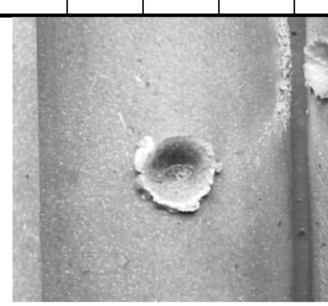
Simulation results is presented in Tab. 1. In the table, no penetration is represented by √, which penetration is represented by ×.

Test results is presented in Fig. 2, Comparison between test results and simulation results is presented in Fig. 3.

According to Fig. 3, the results indicate that prediction data by simulation agree with experimental data.

*Table 1. simulation results of primitive radiator*

| | 3 km/s | 4 km/s | 5 km/s | 6 km/s | 7 km/s | 8 km/s |
|---|---|---|---|---|---|---|
| 0.5 mm | √ | √ | √ | √ | √ | √ |
| 1.0 mm | √ | √ | × | × | × | × |
| 2.0 mm | × | × | × | × | × | × |



*D=1.2mm, V=4.21km/s, no penetration*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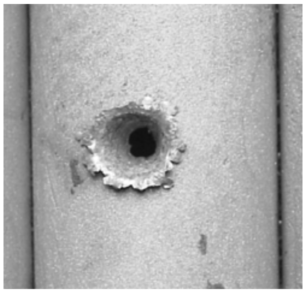


*D=1.2mm, V=4.12km/s, penetration*

*Figure 2. test results of primitive radiator*

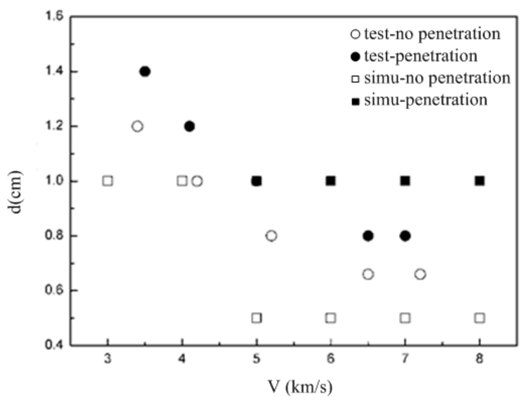



*Figure 3. comparison between test results and simulation results of primitive radiator*

## 2.2 IMPROVED RADIATOR

Because of being exposed to M/OD environment, the tube of primitive radiator is easily penetrated by M/OD. So scheme of improved radiator is proposed(Fig. 4), and the tube and the ribbing are fabricated as one whole body.

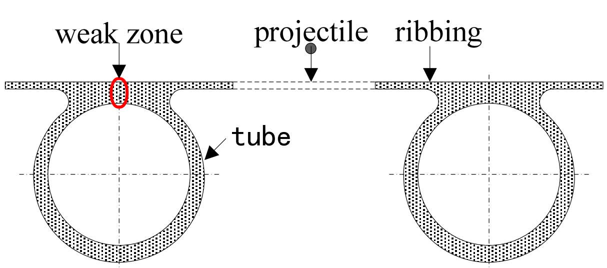



*Figure 4. scheme of improved radiator*

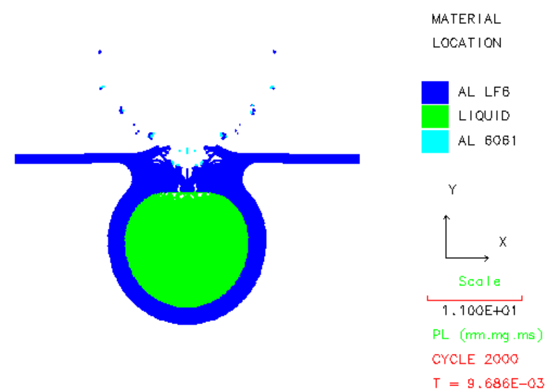
The M/OD protection capability of the obvious frail part(Fig. 4) is evaluated by simulation.

Simulation results of improved radiator is presented in Tab. 2 and Fig. 5. In the table, no penetration is represented by √, which penetration is represented by ×.

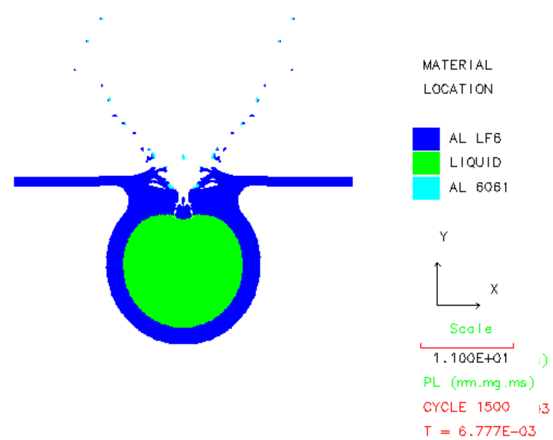
Finally in short, A 1mm diameter projectile can penetrate the tube of primitive radiator at 5km\s, but a 1mm diameter projectile can penetrate the tube of new radiator at 7km\s, and a 1.5mm diameter projectile can penetrate the tube of new radiator at 5km\s. It becomes obvious that the capability to resist M/OD of new scheme is reinforced.

*Table 2. simulation results of improved radiator*

| | 2 km/s | 2.5 km/s | 3 km/s | 4 km/s | 5 km/s | 6 km/s | 7 km/s | 8 km/s |
|---|---|---|---|---|---|---|---|---|
| 0.5 mm | √ | √ | √ | √ | √ | √ | √ | √ |
| 1.0 mm | √ | √ | √ | √ | √ | √ | × | × |
| 1.5 mm | √ | √ | √ | √ | × | × | × | × |
| 2.0 mm | √ | × | × | × | × | × | × | × |




*D=1.0mm, V=6.0km/s, no penetration*




*D=1.0mm, V=7.0km/s, penetration*

*Figure 5. simulation results of improved radiator*

## 3 PRESSURE CABIN

The risk assessment of Tiangong-1 indicate that the side faces and forward face of the pressure cabin has higher impact probability(Fig. 6), hence, shield design of the zones is more important.

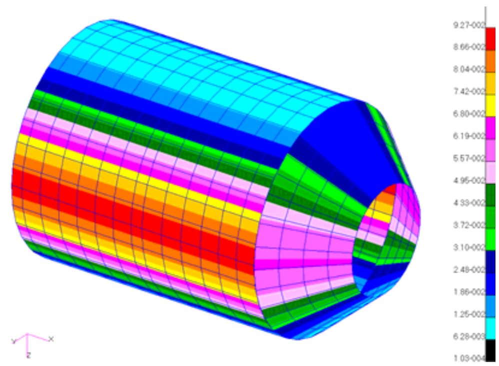


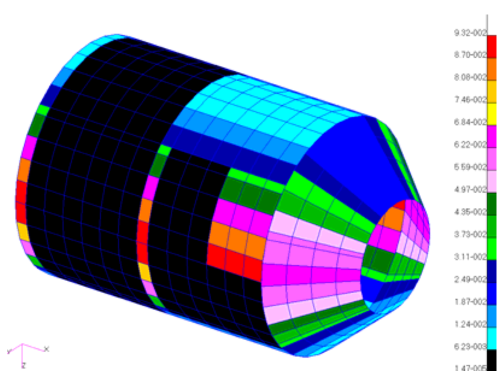
*Figure 6. Distribution for number of impacts per area with d>1cm*

### 3.1 SHIELD DESIGN

Above all, the radiator should be taken as bumper and the structural wall as rear wall, that is in other words, the radiator and the structural wall should be taken as Whipple with standoff 51mm. In this case, PNP of the pressure cabin is promoted from 0.1336 before shield to 0.3366 after shield(Fig. 7).

Secondly, the cone face and side face of the cabin are protected by adopting Whipple structure, PNP of the cabin is promoted to 0.6995(Fig. 8).

Protection parameters of TianGong-1 is presented in Tab. 3



*(radiator laid in black zone )*

*Figure 7. Distribution for number of penetrations by only radiator protection*

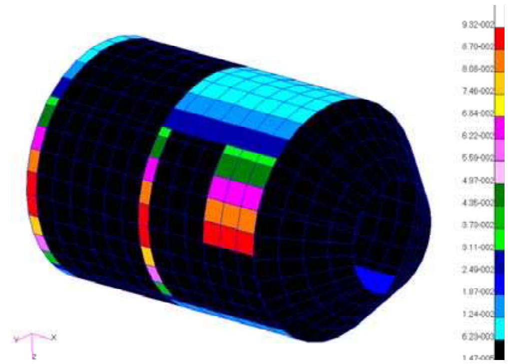


*Figure 8. Distribution for number of penetrations by special protection*

*Table 3. protection parameters of TianGong-1*

| | Whipple (radiator) | Whipple (cylinder) | Whipple (cone) |
|---|---|---|---|
| Bumper Mat | 5A06 | 6061 | 6061 |
| Bumper thickness (mm) | 1.0 | 1.0 | 1.0 |
| Standoff(mm) | 51 | 51 | 70 |
| Rear wall thickness (mm) | 2.5 | 2.5 | 3.0 |

### 3.2 VERIFICATION

Hundreds of HVI tests have been finished to verified the protection capability of the Whipple. The specimen and projectile are presented in Fig. 9 and Fig. 10, the test results of Whipple are presented in Fig. 11 and Fig. 12, the ballistic limit curve of Whipple are presented in Fig. 13 and Fig. 14.

According to the test results, Whipple with standoff 51mm can resist a 5mm diameter projectile made of AL at 6km\s, and Whipple with standoff 70mm can resist a 6-mm diameter projectile made of AL at 7km\s.

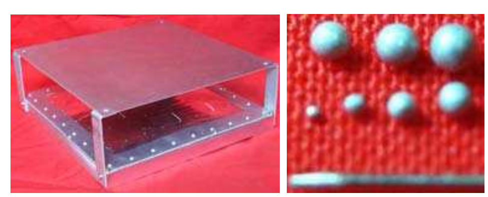
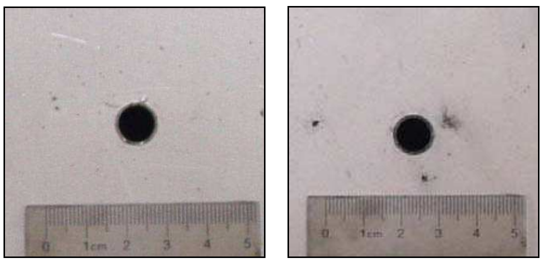
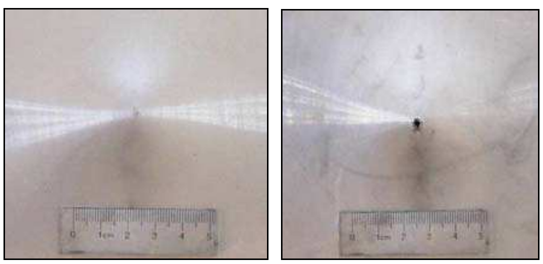


*Figure 9. specimen and projectile*

*Figure 10.  specimen after HVI test*



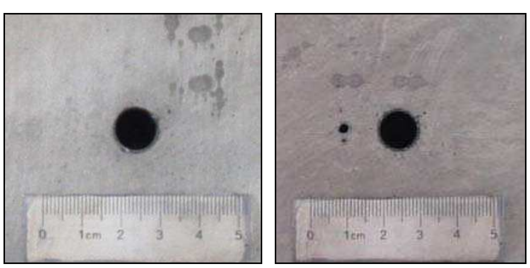
*bumper*



*rear wall*

*V=6.09km/s, d=5.00mm  V=5.88km/s, d=5.24mm*

*Figure 11.  test results of Whipple(standoff 51mm), normal impact*



*bumper*

*rear wall*

*V=7.00km/s, d=6.02mm  V=6.71km/s, d=6.00mm*

*Figure 12.  test results of Whipple(standoff 70mm), normal impact*

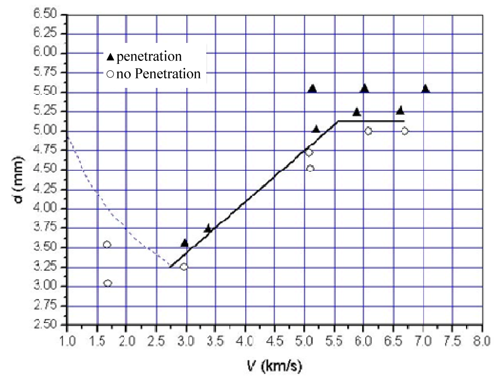



*Figure 13. ballistic limit curve of Whipple(standoff 51mm), normal impact*

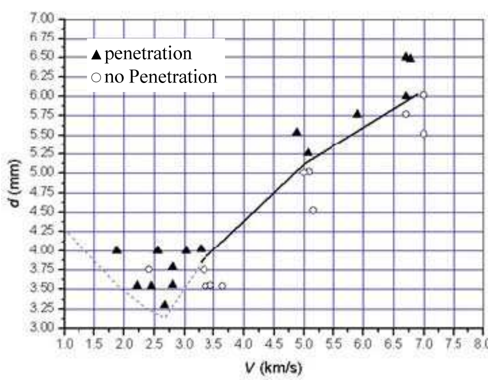



*Figure 14.  ballistic limit curve of Whipple(standoff 70mm), normal impact*

## 4 CONCLUSION

Tiangong-1 is China's first spacecraft protected from M/OD. On condition that limited mass, PNP of the pressure cabin is promoted from 0.1336 before shield to 0.6885 after shield. And that, the M/OD protection capability of the tube has been significantly raised by modifying design of radiator.

Whipple is adopted to protect spacelab, but the capability of Whipple is lower, So advanced protection structures and materials having been developed for China's space station and low earth orbit satellite.

## 5 REFERENCES


[1]. IADC WG3 members. (2003). Protection manual. *Inter Agency Debris Committee.*

[2]. J C Liou. (2002). The new NASA orbital debris engineering model ORDEM2000. *NASA/TP-2002-210780.*

[3]. (1991). Space Station Program Natural Environment Definition for Design, Revision A. *NASA SSP-30425.*

[4]. Eric L. Christiansen. (2003). Meteoroid/Debris Shielding. *NASA TP 2003-210788.*

*[5].* S.G. Zheng, Z.Y. Han, J. Yan, J.Y. Fan, G.J. Qu. (2005). Calibration and Application of M/OD Failure Probability Assessment Code. *Proceedings of the 4th European Conference on Space Debris.*

*[6].* J.G. Yuan, Z.Y. Han, S.G. Zheng, G.J. Qu. (2009). MODAOST’s Application in M/OD Shield Optimization of Japan’s Pressurized module. *Proceedings of the 5th European Conference on Space Debris.*