中国空间技术研究院总体部
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同位素核源的气动特征分析

Aerodynamic characteristics analysis of radioisotope nuclear source

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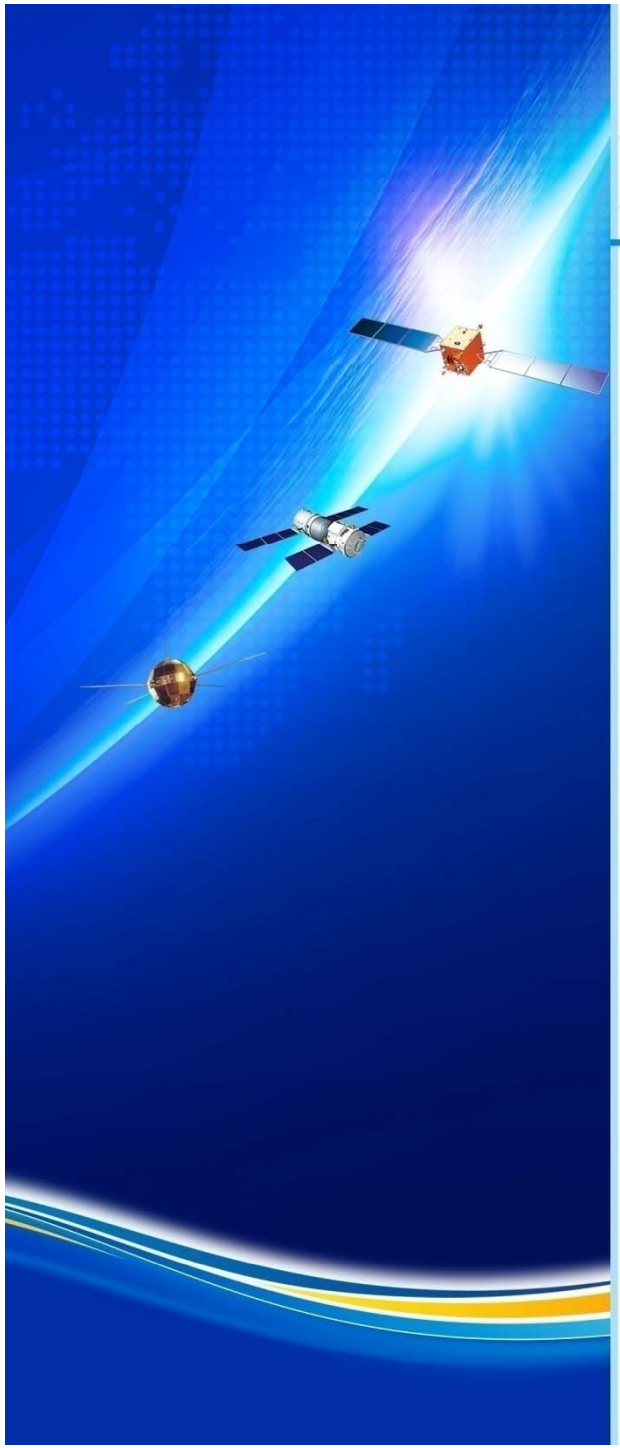

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1.引言 Introduction

中国探月工程三部曲，Chinese Lunar exploration Program

（1）绕，orbiting

CE-1，CE-2

（2）落，landing

CE-3，**CE-4**

- 14天月夜，同位素热源维持探测器温度
  RHU for maintaining temperature during the moon night
- 原位月夜温度采集提供电能
  supply electrical power for lunar night temperature acquisition

（3）回，returning

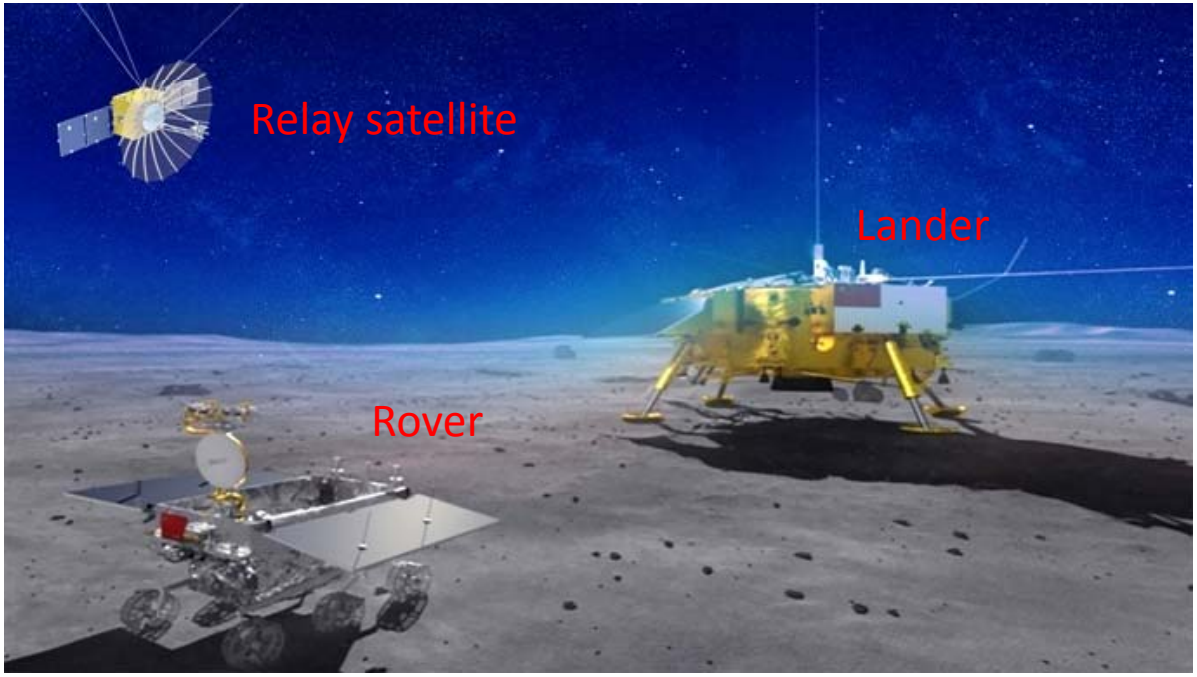
CE-5t， CE-5， CE-6

1.引言 Introduction

嫦娥四号使用核源情况，nuclear source used in CE-4

A. 着陆器，Lander

B. 巡视器，Rover



2.嫦娥四号核源特点

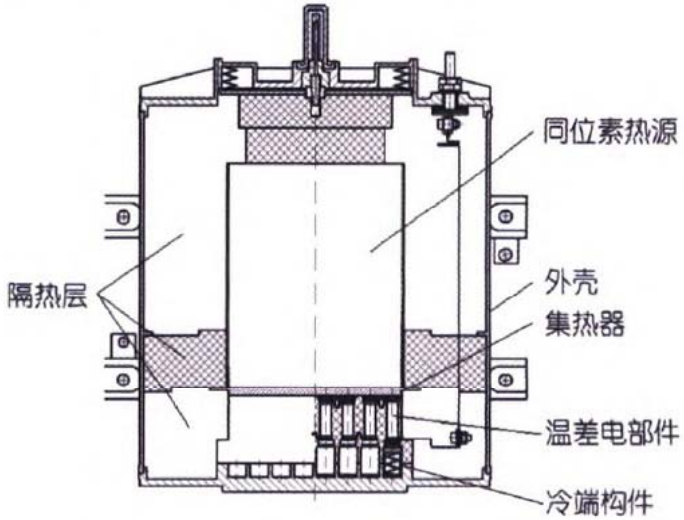
The features of nuclear source in CE-4

同位素热源由铱、铂铑等合金包裹，金属包壳外是低密度碳材料构成的隔热层，最外是碳烧蚀层。

Radioisotope heat source consists of iridium, platinum-rhodium alloy, and wrapped in a low density C insulation layer, and C ablation layer at the top.

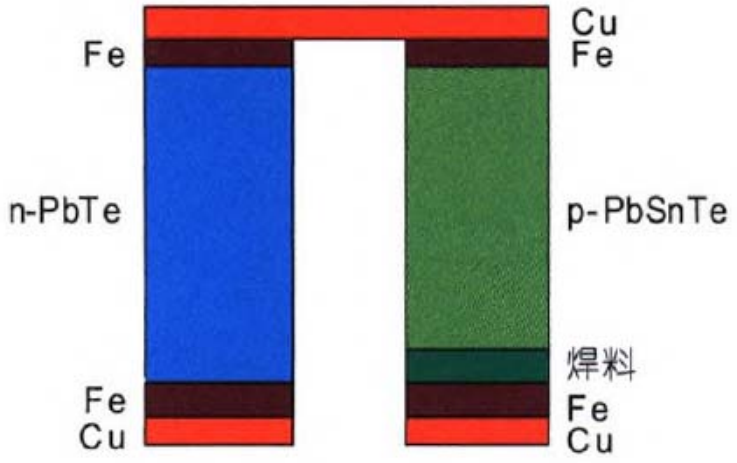
采用温差电单体实现热电转换，外壳为密封的圆柱形金属壳体。

The thermoelectric monomer is used to realize thermoelectric conversion, the shell is a sealed cylindrical metal



同位素温差电池

radioisotope thermoelectric battery



温差电池单体

thermoelectric monomer

3.核源气动特征分析

The Aerodynamic characteristics analysis of the nuclear source

探测器发射过程中三种故障模式，火箭二级工作段和三级一次工作段故障，将导致探测器再入地球。

There are three failure modes in the launching process, the failure of the second working stage and the third primary working stage will lead to the reentry

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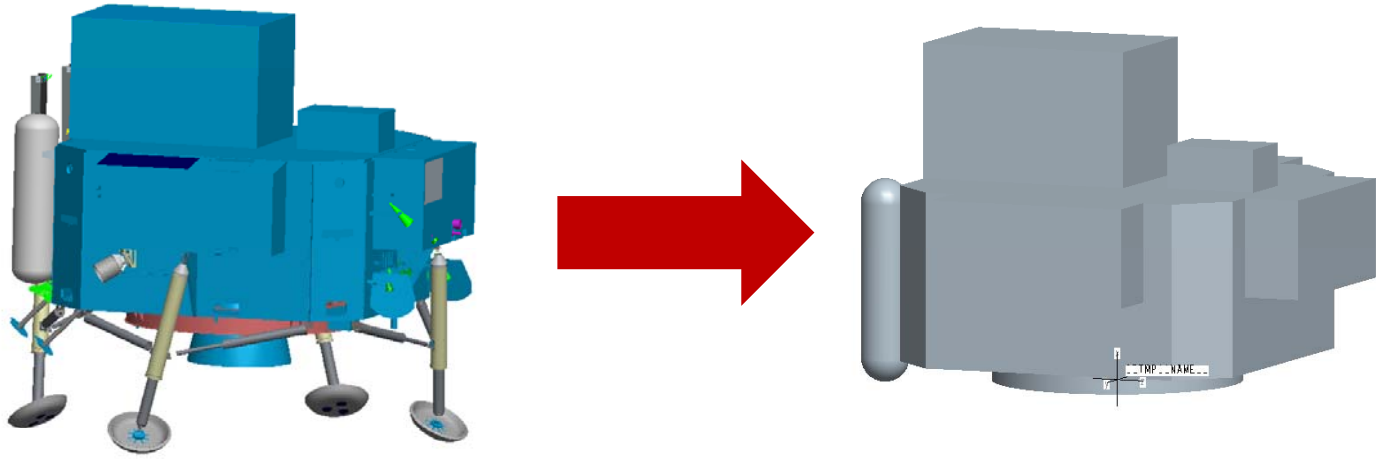
The Aerodynamic characteristics analysis of the nuclear source

探测器简化处理

simplification



3.核源气动特征分析

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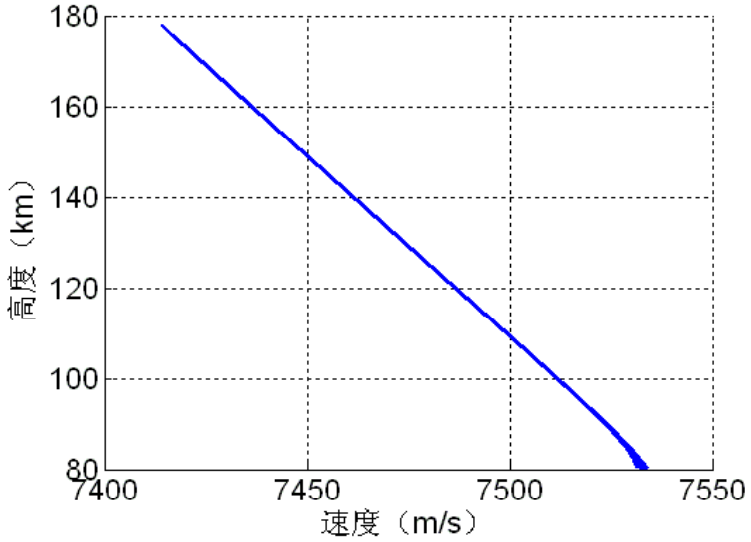
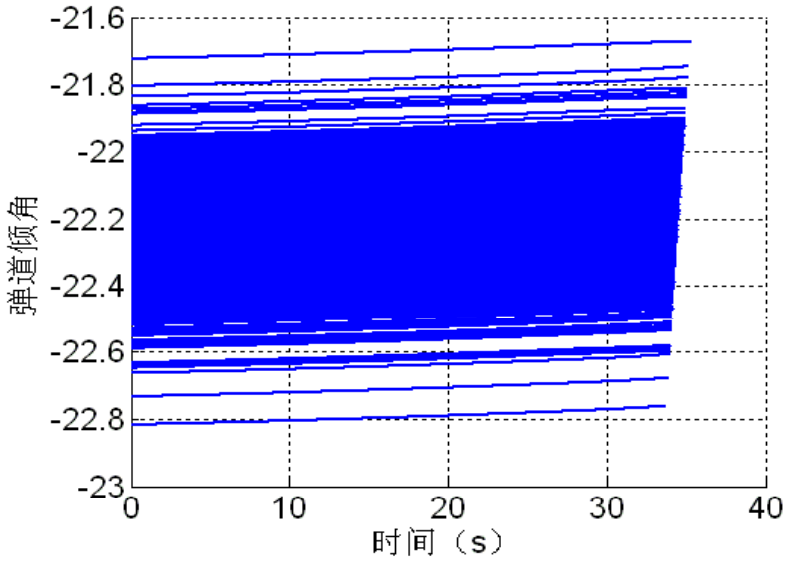
高空飞行轨迹分析 Analysis of high altitude flight path

通过仿真分析，获得了飞行轨迹特性 Flight trajectory characteristics by simulation



速度-高度

Velocity-Height



弹道倾角

Trajectory inclination angle

3.核源气动特征分析

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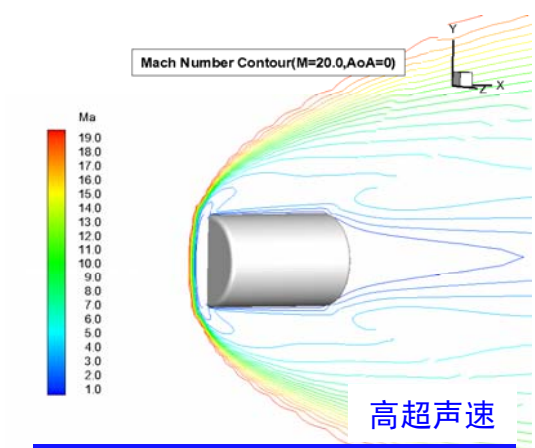
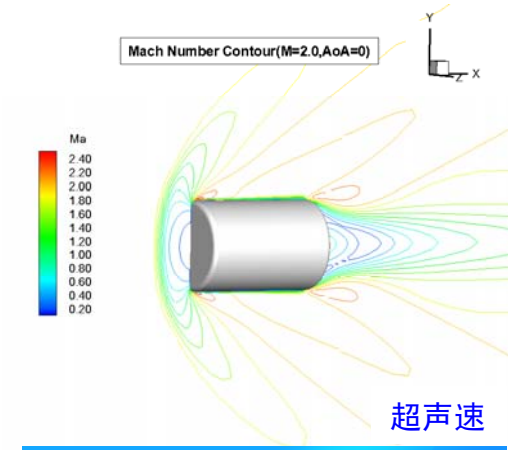
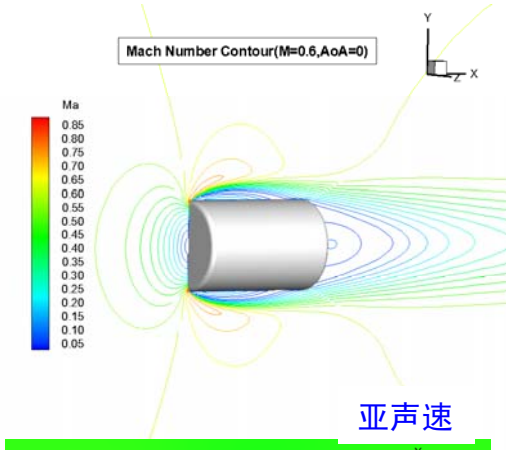
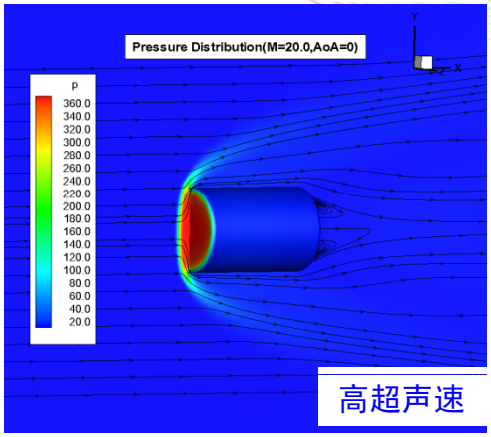
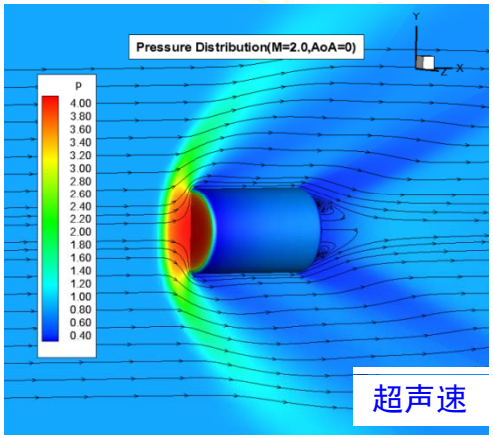
热环境分析 thermal environment analysis

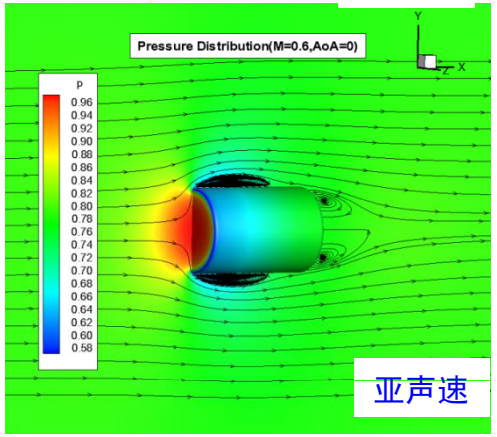












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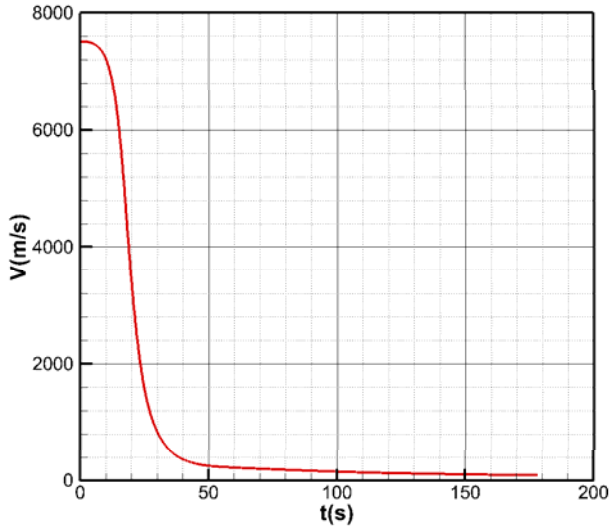
着陆撞击速度 Landing impact velocity

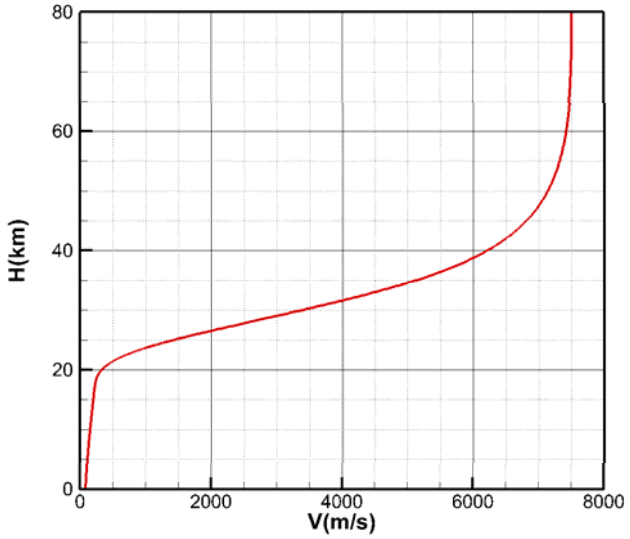
获得了再入过程中速度随时间、下落高度的变化

The variation of velocity with time and falling height during reentry



再入速度变化

reentry velocity varies with time



再入速度随高度变化

reentry velocity varies with altitude

3.核源气动特征分析

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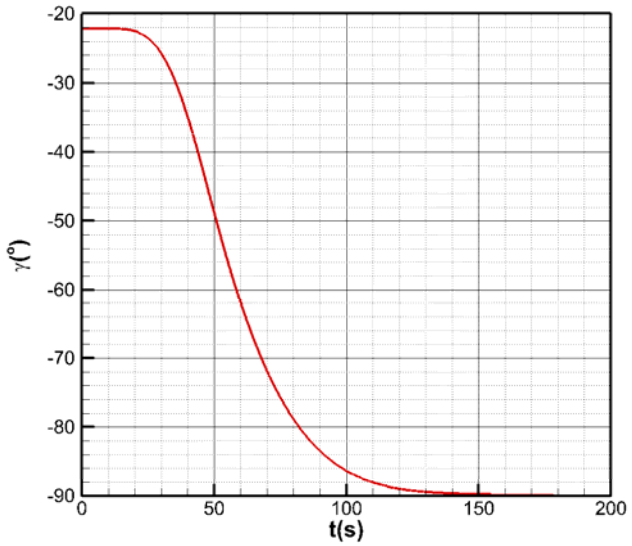
着陆撞击角度 Landing impact angle

获得了再入过程中着陆撞击角度随时间的变化

The variation of landing impact angle with time during reentry



着陆角度随时间变化

angle varies with time

3.核源气动特征分析

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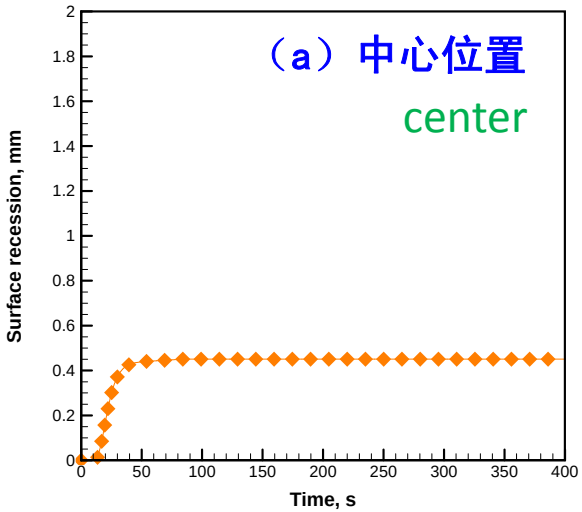
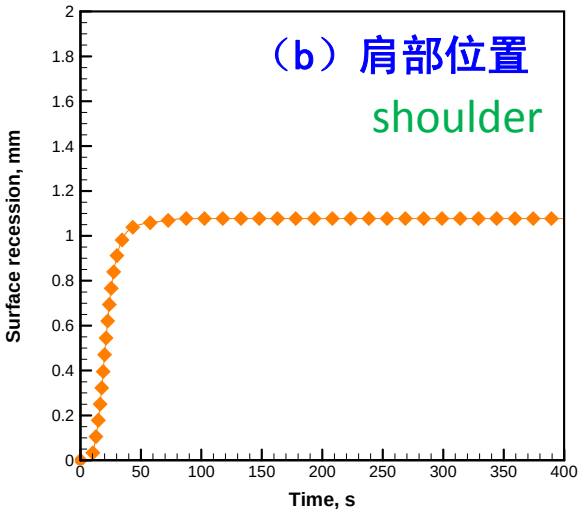
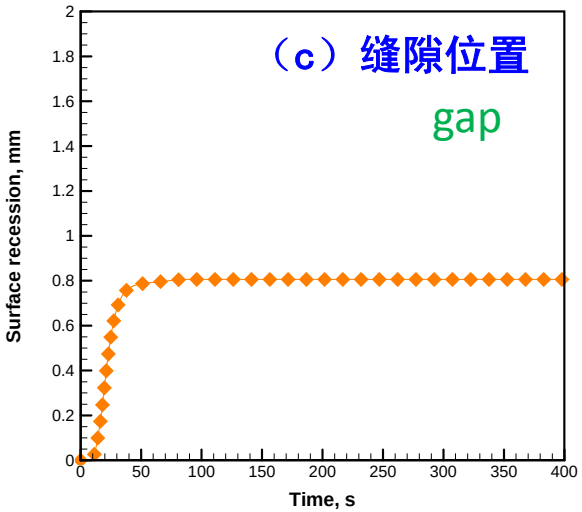
同位素热源烧蚀特性分析 RHU ablation characteristic

通过仿真分析和试验验证，获得了同位素核源烧蚀层的烧蚀后退变化

Through simulation analysis and experimental verification, the ablation regressive change of C ablation layer in isotopic nuclear source is obtained







烧蚀后退变化

ablation regressions

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结论
conclusion

（1）获得了RHU再入过程飞行时间，及海平面高度的飞行速度和弹道倾角。The flight time during the reentry process of RHU, the flight velocity at sea level and the trajectory inclination angle were obtained.

（2） 获得了再入过程铱、铂铑合金包壳最高温度，以及落地时刻铱、铂铑合金包壳温度范围。The maximum temperature range of iridium and platinum rhodium alloy during reentry and the temperature at landing time were obtained.

（3）获得了碳烧蚀层不同位置的烧蚀后退量。The ablation regressions at different positions of C layers.

分析结果表明，落地时刻同位素核源是安全未泄露的。

The results show that the RHU at the moment of landing is safety and not leaked.

4.总结和说明 Summary & description

嫦娥四号着陆器同位素温差电池是我国首个成功在航天器上应用的同位素电源，在嫦娥三号的基础上，结合我国的航天技术以及地面核安全管理的相关管理要求，圆满的完成了放射性同位素产品的安全工作。

The CE-4 Lander isotope thermoelectric battery is the first isotope power source successfully applied on spacecraft in China. On the basis of CE-3, combined with China's space technology and the relevant management requirements of nuclear safety, the safety work of radioactive isotope products has been successfully completed.

4.总结和说明 Summary & description

在发射前针对同位素产品开展了专项技术攻关，如发射故障异常再入分析等，开展了专项验证试验，确保同位素产品使用安全。

在探测器的设计寿命期内，放射性同位素产品工作正常，实现了维持探测器月夜温度的设计要求，同时完成了月面温度的采集。

Prior to the launch, special research was carried out on the radioisotope products, such as reentry analysis of abnormal launch faults, and special verification tests were conducted to ensure the safety of the isotope products.

During the design life, the radioisotope products worked normally, which fulfilled the design requirements of maintaining the lunar night temperature of probe and completed the lunar surface temperature acquisition.

谢　谢！

Thanks

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