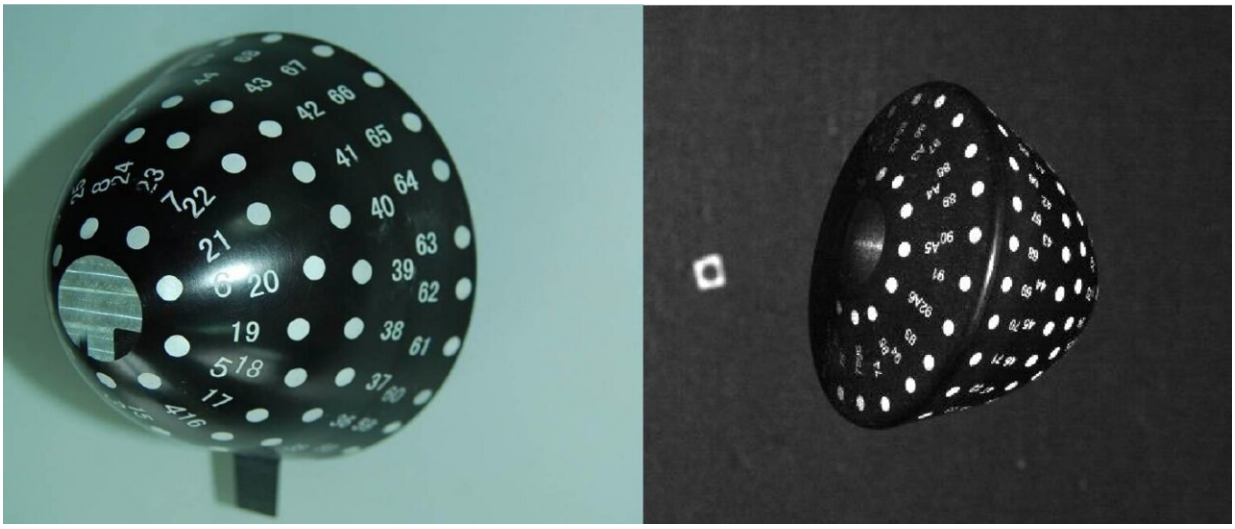
How scientists tested the supersonic dynamic characteristics of the Tianwen-1 Mars Entry Capsule

January 20 2022



The two configurations of the scaled models are shown in the figure. When the flying model with coded marking points on surface entered the measurement field, it would be illuminated by the extended laser beam with the pulse width of smaller than 10 ns; meanwhile, the two images of the target were obtained by the cameras. Credit: Space: Science & Technology editorial office

The Tianwen-1 Mars entry capsule successfully landed on the surface of Mars in southern Utopia planitia on May 14th, 2021 at 23:18 UTC. One of the biggest challenges it faced is that a typical blunt body such as the capsule suffers dynamic instability in during supersonic travel.

Investigating the unstable Mach range of flight and confirming the design of the lander's aerodynamic shape and mass properties was key to achieve the Mars entry. In a research paper recently published in *Space: Science & Technology*, Haogong Wei from the Beijing Institute of Spacecraft System Engineering conducted a ballistic range test to capture the supersonic dynamic characteristics of Tianwen-1.

The blunt body entry capsule of Tianwen-1 was programmed to unfold a trim tab at Mach 2.8 to trim the angle of attack towards 0° before parachute deployment at Mach 1.8. However, transonic and supersonic dynamic characteristics of blunt body entry vehicles are difficult to calculate by numerical methods, because transient and unsteady flow phenomena such as separation, reattachment, wake, and time-delay are hard to capture accurately. Therefore, researchers prefer studying flight dynamics via ground testing methods. There are three types of tests, including forced oscillation, free oscillation, and free-flight. However, it is difficult to capture accurate dynamic characteristics by forced oscillation tests since this method induces considerable disturbance to the flow field. The free oscillation method can only be used to obtain the dynamic response in a single degree of freedom, which is considered as a simplified free-flight method. Thus, the free-flight method, which reflects the real dynamic characteristics of the dynamical model, is an appropriate alternative.

In this work, the authors conducted a free-flight ballistic range test in order to obtain the static and dynamic aerodynamic characteristics of Tianwen-1 in trimmed and untrimmed configurations under typical supersonic conditions and to verify the numerical calculation results of supersonic static and dynamic aerodynamic characteristics of the capsule. The tests were carried out in the 200m Free-Flight Ballistic Range of China Aerodynamics Research and Development Center. The test medium in the chamber was air. The binocular measurement stations were installed along the model flight direction, which would be

calibrated and aligned to the global base reference coordinate system before the test. There were two configurations of scaled test models: trimmed (with trim tab deployed) and untrimmed (with trim tab folded).

The identification algorithm of the aerodynamic parameters for the free-flight ballistic range test was established first: The aerodynamic coefficients of free-flight scaled models were derived by modified linear regression method based on position and attitude data. The Static and dynamic coefficients were established under the assumption of small angle linearization. Afterwards, the analysis of the position and attitude, attitude oscillation, aerodynamic force, static and dynamic stability of the capsule were made and the results demonstrated that the ballistic range test captures the attitude behaviors and aerodynamic characteristics of Tianwen-1 Mars entry capsule. The obtained pitch and yaw moment coefficients were used to discuss the aerodynamic characteristics of the capsule. The capsule in trimmed configuration is dynamically unstable in the pitch and yaw directions, whereas the untrimmed configuration is dynamically stable. In both cases, the capsule is statically stable in pitch and yaw directions.

More information: Haogong Wei et al, Ballistic Range Testing Data Analysis of Tianwen-1 Mars Entry Capsule, *Space: Science & Technology* (2021). DOI: 10.34133/2021/9830415

Provided by Beijing Institute of Technology Press