Entry, Descent, and Landing of China’s Tianwen-1 Mars Mission

Zezhou Sun and Wei Rao

Beijing Institute of Spacecraft System Engineering, Beijing 100094, China

Correspondence should be addressed to Wei Rao; rauwei@163.com

Received 16 May 2022; Accepted 16 May 2022; Published 30 June 2022

Copyright © 2022 Zezhou Sun and Wei Rao. Exclusive Licensee Beijing Institute of Technology Press. Distributed under a Creative Commons Attribution License (CC BY 4.0).

1. Main Text

Launched into orbit on July 23, 2020, China’s first Mars mission Tianwen-1 has implemented the key missions of “near-Mars capture and brake,” “entry, descent, and landing (EDL),” and “rover leaving the landing platform” successively in nearly one year. The three major tasks of “orbiting around Mars,” “Mars surface landing,” and “exploration and detection” have also been accomplished. At present, the Zhurong Mars rover is performing exploration and detection tasks as planned. For Tianwen-1, China’s first probe landing on an extraterrestrial planet to carry out such elaborate tasks, EDL is the risk point of the Mars mission that is mostly difficult to accomplish.

This special issue focuses on various innovations in tasks during Tianwen-1’s EDL phase and presents a collection of original works by authors from universities and research institutions. Such institutions include Beijing Institute of Spacecraft System Engineering, Beijing Institute of Control Engineering, Beijing Institute of Space Mechanics and Electricity, Beijing Institute of Technology, China Academy of Aerospace Aerodynamics, and China Aerodynamics Research and Development Center. The total seven articles in this special issue cover a broad spectrum of research topics concerning the first Mars mission, including EDL control [1], analysis of the dynamic characteristics of the entry module [2], design of the Mars exploration parachute and its aerodynamic verification [3], aeroheating mechanism simulation [4], simulation of pressure equilibrium process [5], and test data processing [6]. It also involves technologies for aerodynamic characteristic analysis of the Mars ascent vehicle (MAV) for future Mars sample return [7].

Specifically, the team led by Xiangyu Huang and Maodeng Li contributed a research article [1] on guidance, navigation, and control (GNC) system for the EDL phase. Deducing the GNC system design of Tianwen-1 inversely from mission requirements, their article provided structure and algorithm for a GNC system that fits those requirements. The actual flight results of the whole EDL phase was also presented in the article.

Considering the large blunt-nosed and short body of the Mars entry capsule in terms of its aerodynamic shape, the Mars aerodynamics team from China Academy of Space Technology developed an integrated numerical simulation method of computational fluid dynamics and rigid body dynamics (CFD/RBD) on the basis of detached eddy simulation (DES). This method was applied to study the dynamic characteristics of the Mars entry capsule in free flight from transonic to supersonic release with one degree of freedom (1-DOF) at a low angle of attack, from which the influence of different afterbody shapes on dynamic stability was discussed [2].

Mingxing Huang’s team optimized and verified the parachute design of Tianwen-1 according to the particular open environment of the landing phase. Drawing on various tests and data, the research team predicted and analyzed the aerodynamic characteristic parameters of the parachute in Mars conditions. In addition, the high-altitude flight tests of nine parachutes were carried out in order to verify its aerodynamic characteristics and reliability, serving as an important reference for the Mars exploration parachute design [3].

Wenbo Miao’s team investigated the thermal environment of the interaction region on the heat shield surface of the Mars lander. The flow characteristics of interactions
from protuberances at different parts of the heat shield were studied through numerical simulation. The heating mechanism of interactions from protuberances at different parts was also obtained by analyzing flow velocity, pressure, Mach number, and other characteristic parameters [4].

Rui Zhao’s team from Beijing Institute of Technology numerically simulated the decompression processes of the Mars rover to study the internal-external pressure differences under a changing ambient pressure on the rocket fairing. As for numerical calculations, PROFILE was developed to outlet boundary conditions and to investigate the influences of ambient pressure setting, time step, and grid density to improve the accuracy of simulation results [5]. To further explore the transonic and supersonic dynamic characteristics of the Tianwen-1 lander and rover and verify the aerodynamic shape and mass property design, the team also carried out free flight dynamic simulations with the free flight ballistic range test model under test conditions. The aerodynamic coefficients of the model were obtained by linear regression. A dynamic derivative model was constructed under assumed linearization with a low angle of attack, and the static moment coefficient and the dynamic derivative were thereby identified [6].

To meet the mission requirements of Mars surface takeoff and ascent, researchers including Haogong Wei and Qi Li from the Mars aerodynamics team analyzed the aerodynamic performance requirements of the MAV. In light of literature survey and the results of supersonic static CFD simulation, the team analyzed the influences of the nose and afterbody shapes of the MAV on the aerodynamic drag and static stability. On this basis, they proposed a nose shape with favorable aerodynamic performance and clarified the subsequent improvement direction of the aerodynamic layout. Their research provided necessary theoretical and data support for the aerodynamic model selection of a MAV [7].

To summarize, this special issue reviewed the exciting progress in various fields during the EDL of Tianwen-1, outlined the frontiers of related research worldwide, and shared the thoughts and practices of Chinese scientists with fellow researchers around the globe.

Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this article.

Acknowledgments

We would like to further extend our gratitude to all the authors for their research contribution to this special issue.

Zezhou Sun
Wei Rao

References