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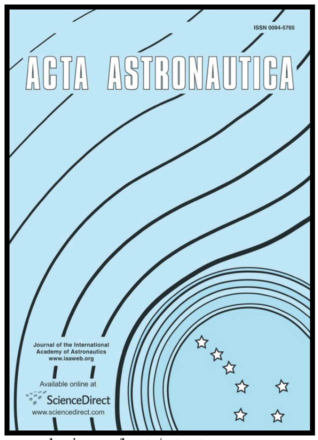

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Xiuqiang Jiang, Shuang Li

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Enabling Technologies for Chinese Mars Lander Guidance System

Xiuqiang Jiang [a,b,†] and Shuang Li [a,b,‡]

a. College of Astronautics, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

b. Laboratory of Space New Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

Abstract

Chinese first Mars exploration activity, orbiting landing and roaming collaborative mission, has been programmed and started. As a key technology, Mars lander guidance system is intended to serve atmospheric entry, descent and landing (EDL) phases. This paper is to report the formation process of enabling technology road map for Chinese Mars lander guidance system. First, two scenarios of the first-stage of the Chinese Mars exploration project are disclosed in detail. Second, mission challenges and engineering needs of EDL guidance, navigation, and control (GNC) are presented systematically for Chinese Mars exploration program. Third, some useful related technologies developed in China's current aerospace projects are pertinently summarized, especially on entry guidance, parachute descent, autonomous hazard avoidance and safe landing. Finally, an enabling technology road map of Chinese Mars lander guidance is given through technological inheriting and improving.

1. Introduction

As one of Earth's nearest neighbors, Mars has attracted much attention for decades. Mars landing exploration missions have been implemented since the 1970s. The Mars-2, launched by the Soviet Union in 1971, is the first lander reached the surface of Mars, although it finally crashed on the Martian surface. Mars-3 and Mars-6 also succeeded in reaching the Martian surface in 1971 and 1973 respectively, but their transmissions soon disappeared after landing [1]. In 1976, the National Aeronautics and Space Administration (NASA) launched the Viking-1 and Viking-2, and both successfully landed on the surface of Mars [2]. The Mars entry, descent and landing (EDL) technologies developed by Viking missions are the major inheritance technologies for the later Mars landing mission of NASA. On this basis, NASA's subsequent Mars landing missions, such as Mars Pathfinder (MPF), Mars Exploration Rovers (MER), Phoenix, and Mars Science Laboratory (MSL), succeeded in landing on Mars [2,3]. The European Space Agency (ESA) launched the Mars Express in 2003, and some indices lead to think that its lander Beagle-2 successfully landed north of the equator of Mars, but it fell silent after landing [4]. Besides, as representative alone orbiting exploration mission, Mars Global Surveyor (MGS), Mars Odyssey (MO), and Mars Reconnaissance Orbiter (MRO) are respectively launched by NASA in 1999, 2001, and 2005 [5]. India launched its first Mars orbiter Mangalyaan in 2013, and the latter successfully reached Mars orbit in 2014 [6]. In addition, ESA's ExoMars mission, launched on 14 March 2016, is implemented as a new orbiting and landing collaborative mission [7].

As one of the vital roles in the whole Mars mission-cycle, the EDL commences at the Mars atmospheric interface with a velocity of around Mach 25 and ends with a safe touchdown. Fig.1 shows the sequence of phases for representative Mars EDL baseline scenario [8]. So far, all Mars landers, except for MSL/Curiosity, have flown an unguided atmospheric entry and adopted the Viking-like EDL systems, which aimed at safely landing on Mars without considering the scientific value of landing sites [2,3]. The MSL realized the most precise landing (landing error ellipse in the order of ~10km), while others Mars lander's landing error in the order of hundred kilometers [2,8]. In order to obtain more scientific return, Chinese Mars exploration missions are also desired to have the capability of autonomously safely landing on hazardous sites with high scientific value pre-selected by scientists, as well as realize relatively precise landing.

† Corresponding author, Ph.D. candidate, Department of Astronautics Engineering, E-mail: jiangxq@nuaa.edu.cn.

‡ Professor, Department of Astronautics Engineering.