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Entry descent and landing systems for small planetary missions: Parametric comparison of parachutes and inflatable systems for the proposed Vanguard Mars mission

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Abstract

Here, the feasibility of a post-Beagle2 robotic Mars mission of modest size, mass and cost with a high scientific return is assessed. Based on a triad of robotics comprising a lander, a rover and three penetrating moles, the mission is astrobiology focussed, but also provides a platform for technology demonstration. The study is investigating two Entry, Descent and Landing Systems (EDLS) for the 120 kg—mission based on the conventional heatshield/parachute duo and on the use of inflatable technologies as demonstrated by the IRDT/IRDT2 projects. Moreover, to make use of existing aerodynamic databases, both EDLS are considered with two geometries: the Mars pathfinder (MPF) and Huygens/Beagle2 (B2) configurations. A versatile EDL model has been developed to provide a preliminary sizing for the different EDL systems such as heatshield, parachute, and inflatables for small to medium planetary missions. With a landed mass of 65 kg, a preliminary mass is derived for each system of the mission to provide a terminal velocity compatible with the use of airbags. On both conventional and inflatable options, the MPF configuration performs slightly better mass-wise since its cone half-angle is flatter at 70°. Overall, the inflatable braking device (IBD) option performs better than the conventional one and would provide in this particular case a decrease in mass of the EDLS of about 15–18% that can be redistributed to the payload.

1. Introduction

By the end of 2003 and early 2004, Mars will be reached by a new generation of landers ranging from the small Beagle2 to the twin Mars Exploration Rovers. These will provide the scientists with a whole new picture of the planet and perhaps with some evidences of past or present lifeforms. Vanguard is a proposed post-Beagle2 mission to Mars, focussed on astrobiology, developed with modest mass

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Abbreviations: DGB, disk-gap-band parachute; EDL, entry/descent/landing; EDLS, entry descent and landing system; IBD, inflatable braking device; IRDT, inflatable reentry and descent technology; MER, Mars exploration rover; MPF, Mars pathfinder; PIBD, primary inflatable braking device; SIBD, second inflatable braking device; TIBD, third inflatable braking device; TPS, thermal protection system

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Nomenclature

A	vehicle cross-sectional area
α	thermal diffusity
BC	ballistic coefficient
C_d	drag coefficient
C_p	pressure coefficient
δ	ablator thickness
γ	flight path angle
γ_e	entry flight path angle
g	Earth gravitational acceleration
k	thermal conductivity
$\dot{q}_s$	heating rate at stagnation point
m	mass of the vehicle
ρ	fluid density
r_n	hemispherical nose radius
T_s	temperature surface
T_i	initial temperature
V_e	entry velocity
V_∞	stream velocity

requirements and cost. The system is based on a triad of robotics devices comprising a base station, a rover and three penetrating moles with a total landed mass baselined at 65 kg. The mission is thought to use a Mars-Express-type bus with a mass in orbit of 120 kg. This paper details the trade-off between the use of parachute system and inflatable technologies for a candidate mission—Vanguard—and provide a preliminary insight into the development of future small planetary missions by comparing the required EDLS mass for traditional and novel EDL systems.

2. EDLS systems

Landing onto the planet is a tough engineering challenge and is achieved in many different ways. The entry, descent and landing system (EDLS) is the key element to ensure its safe landing. The following Fig. 1 illustrates the different options available. EDLS based on the conventional approach (*left branch*) benefits from a strong heritage, but requires the use of a heavy heatshield to sustain the fierce entry as well as a dedicated landing system. Nevertheless, some new development based on inflatable technologies (*right branch*) use a single system (*shaded area*) to replace part or all of the aeroshell, the parachute and in some instances replace the landing system by cushioning the final impact.

This study concentrates on the two distinct options—conventional and inflatable—but hybrid solutions may also be investigated to provide a wider picture of the EDLS options available.

2.1. Conventional EDLS

The hard aeroshell and parachute configuration has been used since the beginning of planetary exploration. On Mars, the Viking and Mars pathfinder (MPF) missions use this technique to enter Mars atmosphere [1], but where Viking uses retro-thrusters to land, MPF chose airbags for the first time on Mars. The Beagle2 and the Mars Exploration Rovers are set to use airbags again with two different configurations: tetrahedral for MER, heritage from the MPF mission [2], and spherical for Beagle2. The aeroshell/heatshield geometry is again based on heritage from previous developments and past missions. MPF and MER are based on a scaled version of the Viking aeroshell [3] with a cone of 70° half angle, where Beagle2 is mainly based on the 60° Huygens aeroshell design. The parachute design is also where possible, scaled from previous mission, hence, the extensive use of disk-gap-band (DGB) parachutes for Viking and subsequently MPF [1] and MER. These two missions also uses a rocket assisted descent (RAD) system that stops the probe above the ground just before impact. This facilitates the use of airbags and make sure the impact velocity is not above design values.

Beagle2 was initially based on the same DGB-type of parachute, but some redevelopment has changed it from a DGB to a ringsail-type parachute that provides greater deceleration since Beagle2 does not use any RAD.

2.2. Inflatable EDLS

Inflatable technologies have started under the form of ballutes by the Goodyear company. Cross between a balloon and parachute, this balloon-shaped device was inflated through a number of inlets with the external airflow. Since, the Babakin Research Centre