SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration - Part 2 (3B)

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LANDING ON MARS WITH THE EXOMARS DESCENT MODULE

Abstract

ExoMars is the first European mission of the Aurora program led by European Space Agency. ExoMars will demonstrate key flight and in situ enabling technologies: among them Entry Descent and Landing (EDL) capability. The ExoMars architecture and design is currently undergoing its advanced C/D phase with Thales Alenia Space Italy as Industrial Prime Contractor. It is also responsible of the Descent Module (DM), including its Guidance Navigation Control (GNC) system and the so-called DM EDL End-to-End (E2E) Simulator for a safe land on Mars. From 1/2 hour to 2 hours before the expected instant of impact with the red planet, the DM is separated from the Carrier. From this instant, it is neither able to rely on direct measurements of the attitude nor in the condition to have support from the Mission Control Center. Its knowledge is given step by step by the integration of the measurements supplied by the on-board Inertial Measurement Units (IMUs). Once the interaction with the particles of the Martian atmosphere becomes important in terms of mechanical loads, the capsule experiences a different environmental scenario much more perturbed than the coasting one, i.e., where the load factor reaches levels in the order of 10 g. This is the Entry event. The separation among these two environments occurs rather progressively, so that it is possible to define a conventional Entry Interface Point indicatively related to the g-load amount. The Entry phase terminates when, reaching a sufficiently low velocity thanks to the braking effect of the air, the capsule velocity is stabilized by the deployment of two parachutes that are opened in sequence. The opening of the first (supersonic drogue) parachute individuates the initiation of the Descent phase. The second stage parachute (subsonic main) deployed at Mach 0.8, achieves the main braking and verticalisation functions. Under stabilized main parachute, the front-shield is jettisoned in order to free the view of Mars surface to the Radar-Doppler Altimeter (RDA), active from an altitude of about 2500 m. Thanks to the RDA measurements fused with the IMU ones, the instant in which the DM engines must be switched ON can be determined as well as when, few seconds later, the descent profile must be engaged. In between these two events, the main parachute is released. In the terminal descent phase the capsule, that in the meanwhile has reached a vertical velocity of about 50 m/s and an altitude of less than 400 m, is progressively driven to the Lander release conditions closing the control loop through the activation of a set of four liquid throttable retrorockets. As far as the landing is concerned, the DM is controlled to reach an altitude (computed at Lander reference frame) of 14.4 m with null velocity components and attitude errors with respect to the local vertical. Then the Lander (600 kg) is separated from the Back-shell and drops to ground. In addition to the design constraints, the drop time of 2.3-2.9 s (3) takes into account the maximum terrain inclination of 18 as prescribed for the candidate landing site. After 1 s of free drop, the vented airbag in the bottom of the Lander is suddenly inflated to supply its protection at touchdown. Each of the six chambers of the airbag is independently vented the instant when it touches the ground. Once landed on the Mars surface, the Rover may egress after deployment of the Lander petals. Finally, after the egress of the Rover, the Lander science surface can

start. This paper describes the consolidation of the Exomars DM EDL in the light of the engineering and landing site constraints and illustrates the GNC algorithms and control loops implemented for a safe landing on Mars based on the Descent Module design definition presented to the Agency at the ExoMars I-PDR in February 2009.