A Low-Cost Orbiter Mission to Mars

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Abstract. Launch cost is a significant factor for inter-planetary missions and it is essential to minimize the launch cost by reducing the velocity requirements for spacecraft departure to Mars mission from a parking orbit around Earth. A novel approach to deliver maximum payload into a parking orbit for Mars mission is described in this paper. The constraint inherent with the departure from an elliptical orbit is its argument of perigee. The argument of perigee corresponding to maximum payload in the specified orbit, in general, is different from that for minimum velocity at departure. The velocity required for departure from Earth is reduced by injecting the spacecraft into a low earth elliptic orbit by the penultimate stage of the launch vehicle and then coasting for optimum duration to inject the spacecraft into a near GTO by the final stage of the launch vehicle with an argument of perigee corresponding to minimum energy opportunity.

The development cost will be reduced by using a reliable launcher that can lift small to medium payloads in a variety of orbits and proven in many flights as well as by maximal use of existing network facility for tracking the interplanetary spacecraft. Further, it is decided to employ flight proven conventional chemical rockets for Earth escape, trajectory correction and Mars arrival maneuvers to ensure reliability while reducing developmental cost. The advantage of using the same propulsion system and bi-propellant with the existing technology for all the maneuvers is two fold. It reduces development cost and time. Any saving in fuel consumption during the early phase of the interplanetary trajectory will improve the life of the spacecraft in Martian orbit. It is expected that a cost effective mission can be achieved with the existing technology. Hence development time would not be critical to the schedule and is with in the reach in 2013/2014 time frame.

The scientific objectives of the mission are being formulated considering the frame work of low cost space exploration while trying to provide complementary data to the ongoing effort in the international scenario. The mass in Earth parking orbit will be about 0.42% of the lift-off mass. The mass planned to be inserted into a highly elliptical Martian orbit having a period of 3.2 days is about 37.4% of the mass at Earth departure orbit. By the proposed method of delivering payload into earth parking orbit, initial mass in the Martian parking orbit is improved by nearly 100 kg and about 25–30 kg is available for science payload. This method also provides mission flexibility. Any change in argument of perigee requirement can be met with by optimal coast duration. Further by using the near GTO parking orbit, the spacecraft can be deployed ahead of its escape start date and its perigee can be raised in a series of burns. Thus the launch window constraints on departure velocity will be less severe. Elliptic parking orbit method implies opportunity to correct launch errors if any, calibrate the propulsion system and instruments in-flight and minimize burn losses before trans-Mars injection. The advantage of using elliptic parking orbit was demonstrated in Chandrayaan-I mission. Mission design and analysis is carried out for two flight path segments. Constrained
optimal design is done for the ascent trajectory. Trajectory for the inter-planetary segment is calculated using semi-analytical method in the preliminary design phase to identify the parameters which drive the mission and verified subsequently by numerical propagation. Adequate margins are provided in the design. The spacecraft will follow a conjunction class, type-2 trajectory to Mars after escaping from Earth.