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Review on Entry, Descent, Landing of Rovers on Mars

[1]Shashank.B.H , [2]Shreesha.R , [3]Vineeth.K.V , [4]Bharath M N
[1,2,3]Student, [4]Assistant Professor
Department of Mechanical Engineering
JSS Science & Technology University, Mysore, Karnataka, India
Email: *[1]shashankbh2900@gmail.com, [2]shreesha2626@gmail.com, [3]vineethkoushik2pm@gmail.com, [4]bmnsjce@gmail.com*

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Abstract

Humans are trying to explore the solar system and the moon was the first. Since the recent decades the interest has shifted towards so called twin planet of Earth. Martian surface having similar features reminiscent both of impact craters of Moon and the various desert and polar ice caps of Earth. Landers and Rovers are the most effective ways to explore Mars in this existing Technology. This is a company's Hercules job of taking the rover or Lander to the surface. The most crucial part of this type of missions is entry Descent and landing of the instruments on the surface. This process involves a lot of complicated technologies and accuracy in execution; this is discussed in the forthcoming papers

Keywords*: Rovers, Supersonic parachute, Angle of Attack, Trajectory, MOLA- Mars Orbiting Laser Altimeter, Viking, Retro rocket, Aero shell, Thrusters, Heat shield.*

INTRODUCTION

Mars exploration Rover mission spirit and opportunity spacecraft landed on martian surface on January 4th and 25th of 2004 respectively. Both the Rovers were delivered to the surface utilizing the same Entry, Descent and Landing scenario that was successfully developed and implemented by Mars Pathfinder the capsules decelerated with the aid of Aeroshell, Supersonic parachute, retro rockets and airbags for safe landing on the surface. Upon mass arrival the Landers separate from their respective Cruise vehicles,15 minutes prior to atmospheric entry. The deployment of the Supersonic parachute is determined by onboard flight software based on vehicle deceleration measurements. Hypersonic deceleration is accomplished using the Aeroshell. And then comes the parachute to reduce the speed drastically, then comes the retro rockets and finally the air bags for safe landing.

The new generation entry Descent landing sequence was first used in Mars science laboratory mission in 2010. Entry Descent landing process begins approximately 10 minutes prior to the atmospheric entry interface after separating from The Cruise stage. After the entry into the atmosphere the drag of the atmosphere decelerates the capsule to a considerable extent. This is followed by deployment of parachute at Supersonic speeds. This brings the capsule to a very low velocity as compared to the entry velocity this is followed by the power descent using opposite thrusters and finally Rover is delivered on the martian surface.

ENTRY

Mars science laboratory capsule utilizes and offset centre of mass to create a nominal 18 degree angle of attack through peak heating and dynamic pressure increasing to 20 degree angle of attack just prior to parachute deployment. This angle of attack generates lift which is used to reduce the landing error ellipse size and increase the parachute deploy altitude. Once the navigated relative velocity drops below about 900 m/s, guidance transitions to a heading alignment phase to minimize residual cross range error before parachute deployment before parachute deployment the vehicle angle of attack is adjusted to zero degree by ejecting balance mass while the azimuth is aligned for better radar performance. The parachute is deployed when the vehicle reaches for more than 450 m/s velocity as shown in Fig.1.

DESCENT

After the parachute is deployed the speed of the capsule is reduced from 450 m/s 100 m per second at backshell separation. So this parachute system burns over 95% of the kinetic energy in just 50 to 90 seconds. This was 21.5 m diameter Supersonic parachute with disc gap band design. Next process is to take this heat Shield out of the capsule for more accurate altitude calculation and to find the trajectory with the new data. Beat the heat Shields operates at this stage because the parachute has already brought the vehicle to velocities below March 0.8 as shown in Fig.1

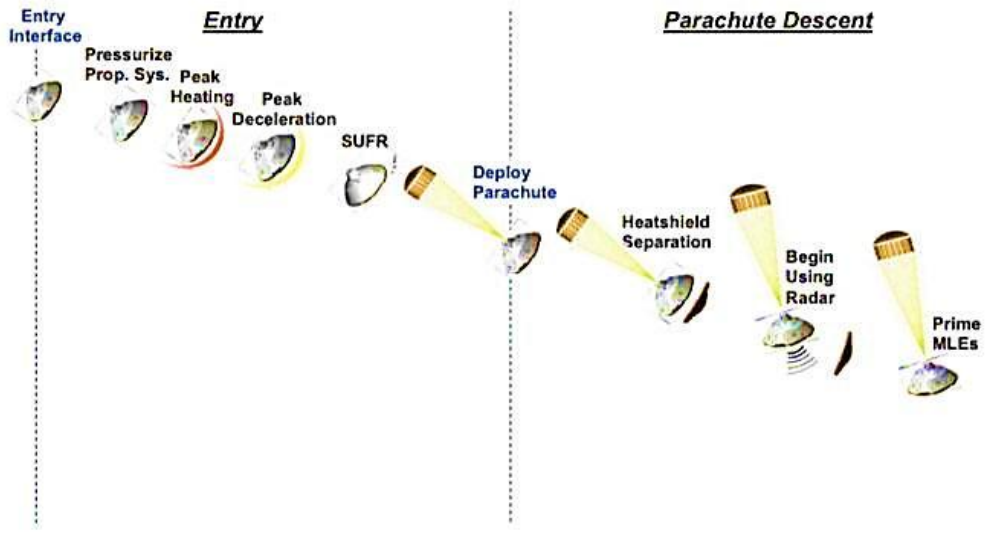

Fig: 1. *Entry and Parachute Descent.*

LANDING

As the power Descent starts the horizontal velocity of the Lander is mostly brought to 0 and the vertical velocity is held constant at 20 m/s.. Next segment starts with constant deceleration and begins at an altitude of 50 m at this height the constant velocity phase ends. Now this constant deceleration phase ends at an altitude of 21m above the surface. This opens the curtain for the throttle down phase. Hazard this stage more than 400 kg of fuel has been consumed the thrusters must be throttled back to the levels of order 20 to 25%. At this throttle setting the efficiency of the thrusters reduces drastically so 4 of VIII thrusters are brought to shutdown condition of about 1% and the rest 4 remains about 50% throttle. As the Touch Down nears the throttle down segment ends at 18.6 M attitude and a constant velocity of 0.75 m/s. Now the skycrane is triggered to lower the rover on a triple bridal. After the Touch Down of the rover happens the chords are taken away from the Rover and the Lander flies away without disturbing the Rover as shown in Fig.2.

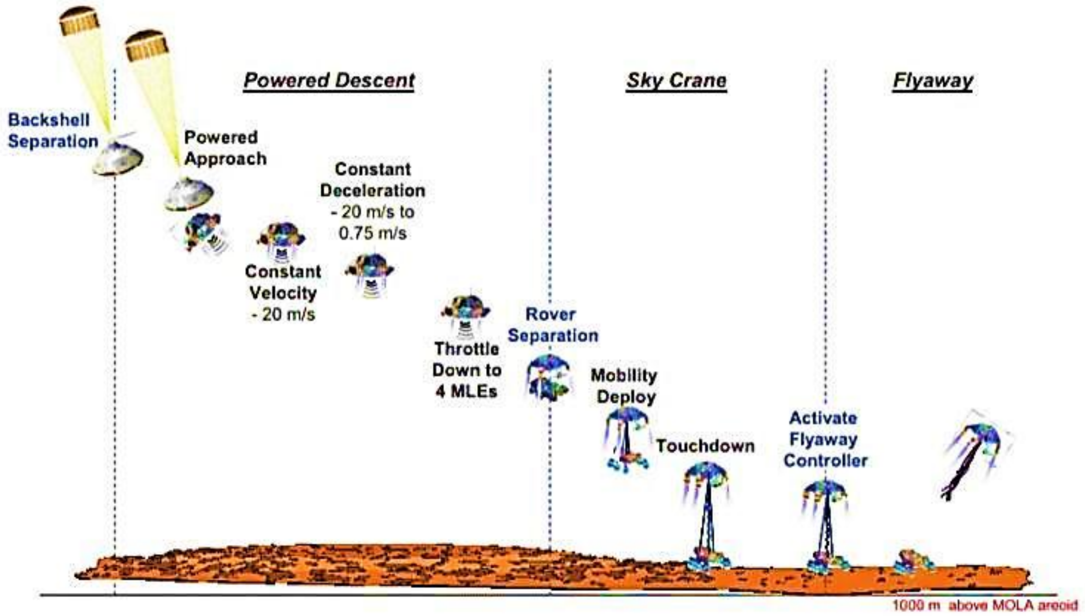

Fig: 2. *Landing of Rover*

LITERATURE SURVEY

Robert D Braun and Robert. M. Manning[1] completed survey during which they have told that the U.S. nation has already with success landed five robotic system on the surface of mars. They landed the system that had a mass of 0.6tons, and that was landed on the order of thousands of kilometre and landed at below -1.4km MOLA(Mars Orbiting Laser Altimeter) elevation from the purpose wherever they have mounted. Robotic exploration systems engineers were struggling for increase the mass to one tons and to extend the landing accuracy within the order of tens of kilometre and landing at a site as high as +2 kilometre MOLA elevation. At the time 2010 these engineers have planned to extend the mass into certain additional extant .i.e., about 2 tons. As they're in Viking era EDL technology, they want to boost the landing capability. EDL technology encompasses a challenges .i.e.,

to get adjusted for Mars atmosphere, (ii)to get adjust for surface atmosphere of Mars like complex rocks, mud and terrain patterns, (iii)To prepare high cost of replicating a Mars relevant surroundings for space flight qualification of latest EDL Technologies. Robotic exploration technology may improve the EDL system delivery limits by increasing diameter of parachutes that deploy at Mach numbers as high as two.7 inflatable/deployable aerodynamic decelerators that greatly reduces ballistic coefficient and additionally pinpoint landing technology forced on robust terrain-relative navigation.

Ravi Prakash , P. Dan Burkhart and his teammates[2] did a review about EDL systems overview thaurkhart EDL sequence is a result of more stringent and complicated requirements than any it’s predecessors. Many designing architecture challenges have to be solved for the mission to be successful. Among them the notable one is landing a 900 kg rover than previous mars lander. They stated that several pieces of EDL design are technological firsts, such as guided entry and entire sky crane maneuver. EDL system triggers many notable advancements of mars surface science, extends delivery capabilities in terms of mass delivered, altitude attained and landing accuracy than ever before to the surface of mars.

Eric M. Queen[3] has surveyed about guidance concept for a Mars Ascent Vehicle first stage. A steerage formula for the primary stage of a projected Mars Ascent Vehicle has been developed. This formula is predicated on a calculus of variations approach, exploitation influence coemcients to drive the vehicle state to a desired terminal state. The formula is designed to produce smart performance with terribly little on-board computation. Whereas the precise configuration is subject to alter, this algorithm is doubtless helpful across a good vary of applications.

The projected steerage formula has been enforced and tested in an exceedingly 3DOF Monte Carlo simulation. The results show that the formula controls the vehicle to relatively tight tolerances beneath cheap environmental dispersions, keeping the ultimate condition among a few quarter degree in inclination and 3 kilometres point of apoapsis.

Prasun N. Desai and Philip C Knocke[4] had analysed about The Mars Exploration Rover (MER) mission with success landed 2 rovers on Mars. The entry trajectory design as well as definition of the suitable trajectory dispersions were crucial within the development of the entry, descent, and landing (EDL) system. Monte Carlo dispersion analyses were used to statistically assess the robustness of the MER entry design to off-nominal conditions. Pre-entry analyses showed that the MER entry design satisfied all EDL needs. Comparison of preliminary post-landing reconstruction results indicates that each entries met the EDL needs and were within the variations defined by the pre-entry Monte Carlo dispersion analyses.

Juan Dai, Ai Gao, Yuanqing Xia[5] reviewed about ,the trajectory tracking control problem of the Mars atmospheric entry steerage with Mars atmospheric density uncertainty and lift-to-drag ratio disturbance existing within the spacecraft system has been studied using TSMC related to the second-order differentiator. The second-order differentiator is applied to estimate the entire disturbances of system, that has the high potency in accomplishing the nonlinear dynamic estimation, by that terminal sliding mode controllers are designed combing the 2 approaches severally to force the state variables of the closed-loop system to converge to the reference trajectory. The planned terminal sliding mode control law by using second-order differentiator give finite-time convergence, robustness, higher control preciseness. Meanwhile, the analysis of the applied math results of the Monte Carlo runs shows that the planned algorithm performs well underneath perturbations and create is appropriate for real-time implementation.

Zhenhua Zhao and his teammates[6] reviewed about a new finite-time STW controller has been planned for the longitudinal dynamic models of the Mars entry trajectory tracking. It's been shown that the actuator constraint problem within the entry trajectory pursuit system is sufficiently addressed by the planned technique with appropriately chosen control parameter λ and α. The planned technique has not solely achieved good longitudinal entry trajectory tracking performances, good robustness against parameter perturbations, external disturbances and initial state errors, however additionally alleviates the high-frequency switching of control action with efficiency. A 500-run Monte carlo simulation is additionally performed to evaluate the tracking errors of altitude and downrange at the deployment position, and also the radius of the landing error ellipse is just 3.4 km that is smaller than those of most of the previous controllers.

Eric M Queen and Ben Raiszadeh[7] did survey about a multiple rigid-body parachute simulation model for the Mars smart Lander entry phase has been developed. The model includes dynamics caused by interacting lines in a means that's easily incorporated into an end-to-end simulation of the entry phase. The model has been wont to examine a nominal trajectory from entry till the lander drops from the subsonic parachute. the loads on every of the lines connecting the various bodies were calculated and found to be less than 120 kN for every line. it had been seen that the line masses closely followed the parachute drag force, evidently. The main distinction between the line load and also the parachute drag was because of inertial loads as the parachute was deployed. The attitude of every body was computed and seen to be affordable for this vehicle. Finally, the separation distance between the lander and backshell was computed and it had been determined that, for this case, recontact wasn't a problem, however further analysis is needed.

David W Way, Richard W Powell and his teammates[8] had reviewed about the MSL EDL system discussed in this paper is a new EDL architecture which can meet level-1 requirements to deliver a rover of 850 kg in mass safety to the mass surface at an altitude upto 10 km above the MOLA defined aeroid. This development of this system will continue for the next three years. They want to design the system to land in largest scientific payload to the highest altitude and with the greatest accuracy of any missions to Mars.

Viking is the only Mars mission which has flown a lifting trajectory. These entries provide several advantages over ballistic entries. Due to the 0.24 hypersonic L/D, the MSL nominal trajectory requires up to 2 minutes in anear level flight condition between 5 and 15 km of altitude relative to the MOLA definer areoid. In this 2 minute, the vehicle traverses nearly 200 km of downrange distances. And finally their aim is to make system with the large mass and, having least landing altitude distance and zero error when they will land.

CONCLUSION

The centre of interest of humans has shifted towards Mars. As this paper concentrates on entry descent and landing of rover on Mars. It involves a lot of complicated technology and high precision. The earlier EDL system employees a technology which supports low precision and less capacity .But the EDL system has a high precision rate and high payload capacity and also more efficient than its predecessors. Using this stringent EDL system we can land the rover on martian surface more safely than ever. This system enable a notable extension in the advancement of technologies of rovers on the martian surface. In The future this would help in landing humans on Mars to colonise it by delivering higher technically advanced payloads to the surface of Mars than ever before.

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