REPORT ON THE LOSS OF VIKRAM LANDER OF CHANDRAYAAN 2 MISSION

Malaya Kumar Biswal M[1], Ramesh Naidu Annavarapu[2]
[1]Graduate Researcher, [2]Associate Professor
Department of Physics, Pondicherry University, Puducherry – 605 014, India.
Email: malaykumar1997@gmail.com and rameshnaidu.phy@pondiuni.edu.in

Introduction: India attempted its first-ever science lander mission on 22 July 2019 with the launch of GSLV. This mission is considered to be the first-ever landing mission to the Lunar South Pole Region, that unfortunately lost communication prior to landing at 2.1 km above the lunar surface. The communication issue encountered during the rough breaking of landing phase at 20:23 UTC on 6 September 2019. Subsequent attempt to reestablish the communication from the lander remained unsuccessful. To date, ISRO has not revealed the failure cause behind the failure of Chandrayaan 2 lander "Vikram" along with its micro-rover "Pragyaan". In this paper, we interpreted some possible causes responsible for the loss of lander and its mishap.

Mission Overview: The Chandrayaan 2 mission commenced on 22 July 2019 at 21:21 UTC with the launch of GSLV from SHAR. The orbiter along with lander Vikram approached Moon on 20 August 2019, then performing its 1st Lunar bound maneuver the spacecraft got successfully captured by the Moon orbit. Following successful orbital insertion, the spacecraft performed five additional lunar bound maneuver to initiate lander separation and lunar landing. The Vikram lander got separated from the main bus orbiter on 6 September 2019 at 20:08 UTC and progressed towards landing operation. Up to an altitude of >2.1 km from the lunar surface, all the mission parameters went normal, after attaining the altitude of 2.1 km, the lander unexpectedly lost communication from the ground at 20:23 UTC (15 minutes elapsed of landing phase initiation) resulting in failure of the lunar landing. The complete landing sequence of Vikram lander is shown in Figure 1. Following the search for impact site of lander, Shanmuga Subramanian the first to report the changes in activity on the Lunar surface and resulted in identification of lander and its impact site by NASA. The lander crashed at 70.8810°S, 22.7840°E, 834 m elevation (Source: NASA) shown in Figure 3.

Trajectory Deviation: From the trajectory map of Vikram lander operation, we can see that the lander trajectory path was normal up to 2.2 km, but at an altitude of 2.1 km the lander's trajectory got deviated from usual path resulting in the loss of communication and uncertain mission status. Observed trajectory deviation is from 2.1-0.2 km above the lunar surface. The deviated trajectory path from 0.2-2.1 km is shown in Figure 2.

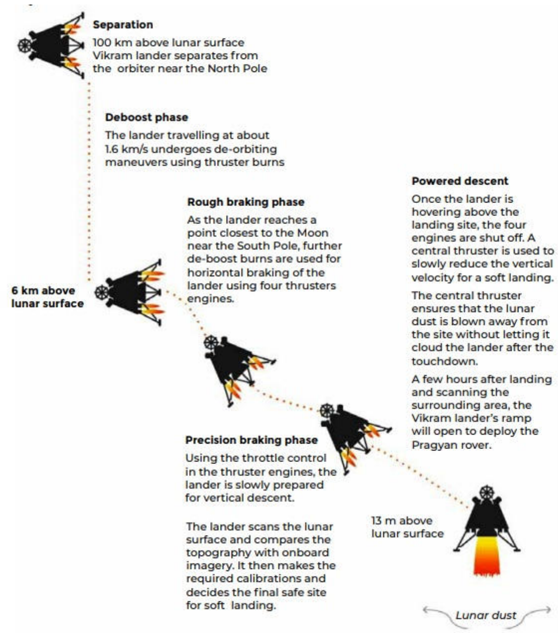

Figure 1 Vikram Lander Sequence (Credit: ISRO)

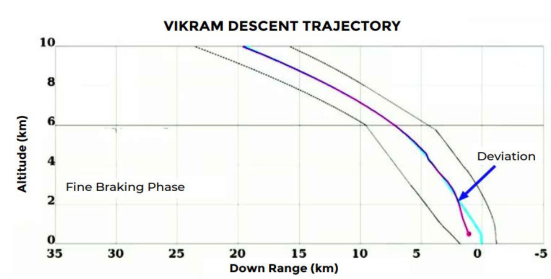

Figure 2 Vikram Lander Trajectory (Credit: ISRO)

Hypothesis on Possible Causes for Lander Failure:

- During the course of rough breaking phase and powered descent phase, the vibrations aroused may have misplaced or unplugged the power cord of the communication system (or antenna) resulting in the loss of communication from the ground.
- At the point of deviation shown in the trajectory graph, the shutdown of thrusters or improper firing of descent thrusts

might have caused the spacecraft to lose control over spacecraft orientation resulting in the crash of lander on to the surface.

- During the descent phase, there was no indication of the spacecraft power. So, power depletion from either battery or solar panel might have turned-off the spacecraft computer ultimately shutting down the thruster parallel to the loss of communication. It is because the lander is programmed to perform automatic landing if there might be a problem with only communication the lander would have performed safe and soft landing on Moon. But the status of the lander is crashed asserting the cause of power depletion during the descent phase.
- The depletion of spacecraft power may be due to the unavailability or minimal presence of solar irradiance at the south polar region of Moon.

Recommendations: From the mishap report of Lander "Vikram", we recommend space firms to use Nuclear Thermoelectric Generators (NTG) or Radioisotope Thermoelectric Generator (RTG) as a secondary power source as a back-up option for the spacecraft attempting to the destination like South Lunar Region or beyond Mars orbit. It is because the availability of sunlight or solar irradiance evinces causing loss of power and battery depletion. In addition to this, we suggest to use direct communication system from both lander and rover missions to any interplanetary destinations. So that we can confirm the mission status if any one of the communication systems gets impaired.

Conclusion: Despite the first lander mission failure, ISRO proposed another landing demonstration mission "Chandrayaan 3" which will carry a lander and rover. Further, it will be the third polar lunar exploration mission of India. The lessons learned from the precursor lander "Vikram" is considered and several improvements. This mission will demonstrate the landing capabilities for exploration of the polar region of Moon. Concerning the collaboration with Japan, ISRO will provide lander and Japanese Aerospace Exploration Agency will provide both launcher and a rover for the mission. Different to the previous mission, Chandrayaan 3 will be having additional equipment of Laser Doppler Velocimeter (LDV) along with night survival technologies for site sampling exploration. The proposed launch for the Chandrayaan 3 mission is March 2021 (tentative).

Legacy of Chandrayaan 2 and Future Prospect: Vikram lander named in honour of the father of Indian Space Program "Dr Vikram Sarabhai" and this is the first lander mission of India to an interplanetary destination. Despite the mishap, the lander trajectory data and its demonstration will remain a pioneer to future lander mission of India to Mars and beyond. Since the Mars Orbiter Mission 2 (Mangalyaan 2) may have possible inclusion of a lander and a rover which is proposed to launch in the next five years.

Note: This results and findings depicted here is interpreted from the experiences and studies made on lunar and Mars probe failures and does not direct the exact cause of lander mishap. Since, ISRO have not revealed the mishap investigation report of Vikram lander, the study is performed to understand the extent of possibility for the failure of Indian lander "Vikram". In the view of the context that failure report is significant for future prospect, we discussed the possible causes responsible for the failure of Chandrayaan 2 lander.

Acknowledgement: The authors would like to thank ISRO for providing live coverage of Chandrayaan 2's Vikram Lander operation to understand and learn the hurdles and of performing a successful landing on any other planetary surface. This live coverage inspired us to interpret and write this report.

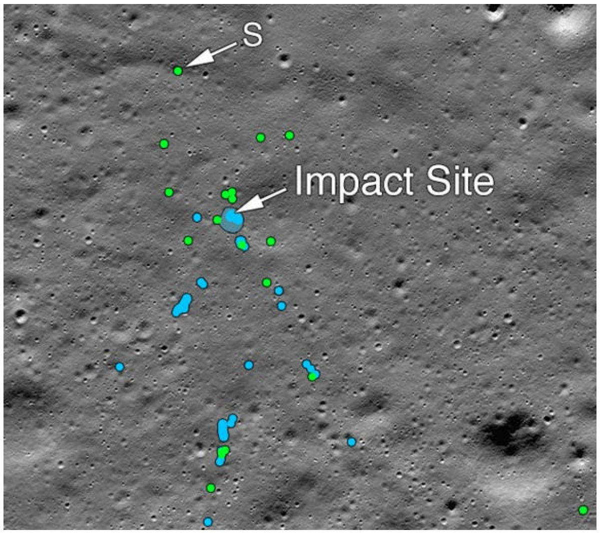

Figure 3 Impact Site of Vikram Lander (Credit: LRO, NASA)

(Colour Code: Green – Debris ; Blue – Soil Disturbance S – Debris found by Subramanian)

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