Taking a billion dreams to the Moon

We Congratulate ISRO on Launching

CHANDRAYAAN-2

PREFACE

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High hopes had been riding on its chandrayaan-2 orbiter. The spacecraft sending a landing vehicle down to the moon - an operation that, if successful, would be the first robotic mission at the moon's unexplored south pole and that would make India only the fourth country in history to make a moon landing. Unfortunately, it was not to be. At the time, the Indian Space Research Organisation didn't offer much explaination for the operation's failure besides an ill-times loss of contact, adding little more for than a terse, "Data is being analyzed." Now, the Indian government has offered its first conclusive statement on the incident, in a brief report responding to a lawmaker's question: put simply, the vikram lander's braking thrusters malfunctioned, and it crashed. "During the second phase of descent, the reduction in velocity was more than the designed value. Due to this deviation , the intial conditions at the start of the fine braking phase were beyond the designed parameters, " said Jitendra Singh, minister of state for the Department of Space, the ISRO's parent Department. "As a result, Vikram hard landed within 500 m of the designated landing site." The statement is believed to be the first formal acknowledgment by India's government that the craft crashed. In the ISRO's previous public updates on Vikram -the latest on its website released back on Sept. 10, several days after the intended landing date- the agency noted only that it had located the lander but had made "no communication with it yet." "Most of the components of Technology demonstration, including the launch, orbital critical ,aneuvers, lander separation , de-boost and rough breaking phase were successfully acccomplished," the minister said. "With regards to the scientific objectives, all the 8 state of the art scientific instruments of the orbiter are performing as per the design and providing valuable scientific data." Still, the failed landing is a disappointment for the chandrayaan-2 project, whose total cost singh estimated at upward of $135 million.

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1. LAUNCHER

Chandrayaan-2 mission is a highly complex mission, which represents a significant technological leap compared to the previous missions of ISRO. It comprised an Orbiter, Lander and Rover to explore the unexplored South Pole of the Moon. The mission is designed to expand the lunar scientific knowledge through detailed study of topography, seismography, mineral identification and distribution, surface chemical composition, thermo-physical characteristics of top soil and composition of the tenuous lunar atmosphere, leading to a new understanding of the origin and evolution of the Moon.

“After the injection of Chandrayaan-2, a series of maneuvers were carried out to raise its orbit and on August 14, 2019, “

following Trans Lunar Insertion (TLI) maneuver, the spacecraft escaped from orbiting the earth and followed a path that took it to the vicinity of the Moon. On August 20, 2019, Chandrayaan-2 was successfully inserted into lunar orbit. While orbiting the moon in a 100 km lunar polar orbit, on September 02, 2019, Vikram Lander was separated from the Orbiter in preparation for landing. Subsequently, two de-orbit maneuvers were performed on Vikram Lander so as to change its orbit and begin circling the moon in a 100 km x 35 km orbit. Vikram Lander descent was as planned and normal performance was observed upto an altitude of 2.1 km. Subsequently communication from lander to the ground stations was lost.

The Orbiter placed in its intended orbit around the Moon will enrich our understanding of the moonâ€™s evolution and mapping of the minerals and water molecules in Polar regions, using its eight state-of-the-art scientific instruments. The Orbiter camera is the highest resolution camera (0.3 m) in any lunar mission so far and will provide high resolution images which will be immensely useful to the global scientific community. The precise launch and mission management has ensured a long life of almost seven years instead of the planned one year.

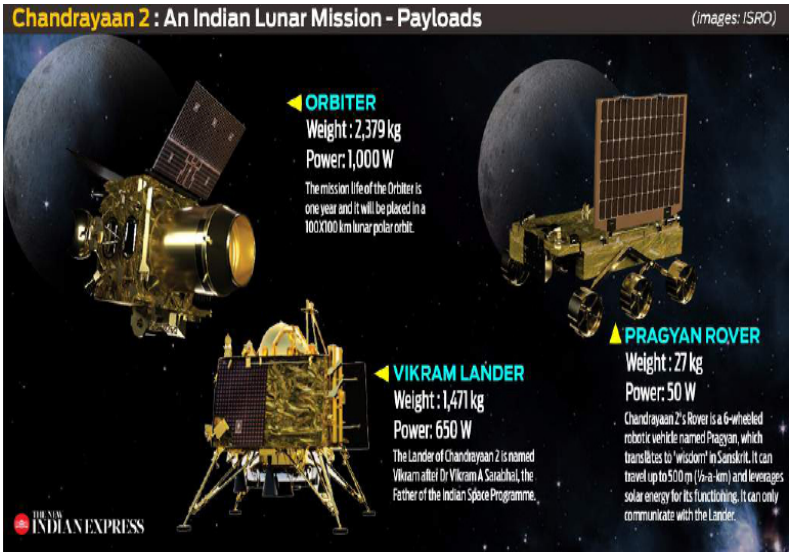
objective:

The primary objectives of the Chandrayaan-2 lander were to demonstrate the ability to soft-land on the surface and operate a robotic rover on the surface.

Scientific goals include orbital studies of lunar topography, mineralogy, elemental abundance, the lunar exosphere, and signatures of hydroxyl and water ice. The orbiter will map the lunar surface and help to prepare 3D maps of it. The onboard radar will also map the surface while studying the water ice in the south polar region and thickness of the lunar regolith on the surface.

Design:

The mission was launched on a Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mk III) with an approximate lift-off mass of 3,850 kg (8,490 lb) from Satish Dhawan Space Centre on Sriharikota Island. As of June 2019, the mission has an allocated cost of â,¹ 9.78 billion (approximately US$141 million) which includes â,¹ 6 billion for space segment and â,¹ 3.75 billion as launch costs on GSLV Mk III. Chandrayaan-2 stack was initially put in an Earth parking orbit of 170 km perigee and 40,400 km apogee by the launch vehicle.



Chandrayaan has made a significant breakthrough in the annals of scientific discovery of recent times by detecting the presence of water on the moon. This, I am sure, will have far-reaching effects on man's quest towards undertaking planetary missions through establishment of lunar colonies and using the moon as an immediate base. I am sure this will spur the interest of youngesters.

India achieved a rare feat of sending a satellite to the moon and inserting it in lunar orbit and also placing the Indian tricolour on lunar soil in 2008-09. The chandrayaan projected generated tremendous interest not only among the scientific community, but also among children in our country. The fascinating pictures sent by chandrayaan have enthralled scientists and students alike. It is essential to publicize the achievement of the country in space technology.

2. LUNAR ORBITAL

It comprised an Orbiter, Lander and Rover to explore the unexplored South Pole of the Moon. ... On August 20, 2019, Chandrayaan-2 was successfully inserted into lunar orbit. While orbiting the moon in a 100 km lunar polar orbit, on September 02, 2019, Vikram Lander was separated from the Orbiter in preparation for landing

As of September 2019, the Chandrayaan-2 orbiter was orbiting the Moon on a polar orbit at an altitude of 100 km (62 mi). It carries eight scientific instruments; two of which are improved versions of those flown on Chandrayaan-1. The approximate launch mass was 2,379 kg (5,245 lb).
Launch mass: Combined (wet): 3,850 kg (8,490 ...
Mission type: Lunar orbiter, lander, rover
Mission duration: : Orbiter: ~ 7 years; Elapsed: 4 ...
Launch site: Satish Dhawan Space Centre Se...

The Lunar Orbiter program was a series of five unmanned lunar orbiter missions launched by the United States from 1966 through 1967. Intended to help select Apollo landing sites by mapping the Moon's surface, they provided the first photographs from lunar orbit and photographed both the Moon and Earth.

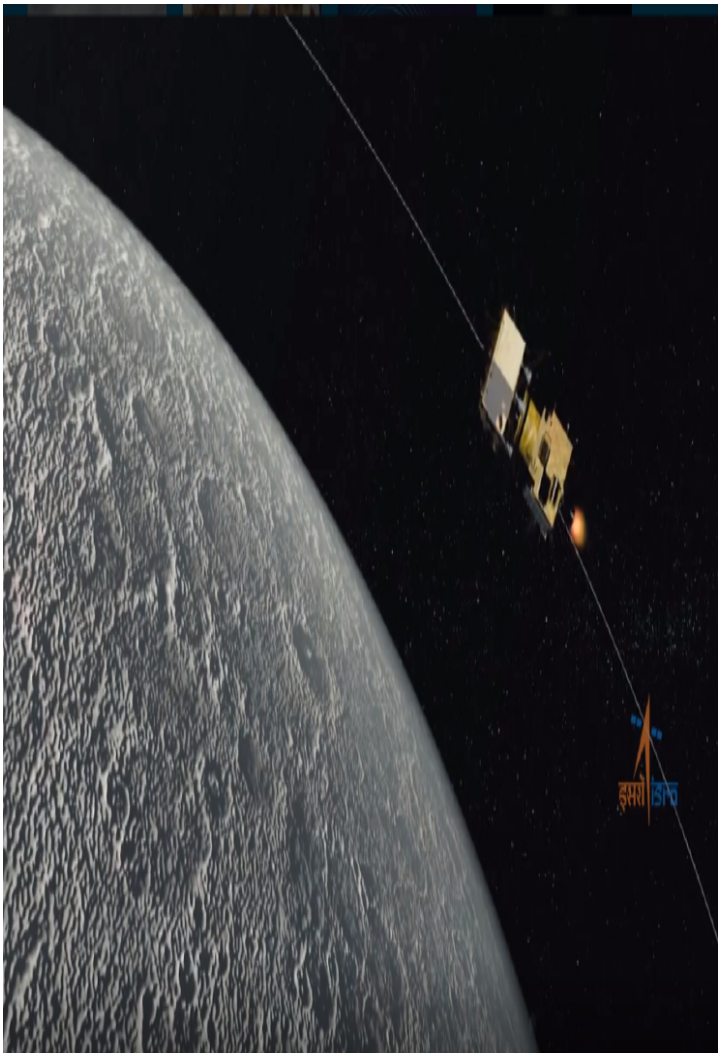
All five missions were successful, and 99 percent of the lunar surface was mapped from photographs taken with a resolution of 60 meters (200 ft) or better. The first three missions were dedicated to imaging 20 potential manned lunar landing sites, selected based on Earth-based observations. These were flown at low-inclination orbits. The fourth and fifth missions were devoted to broader scientific objectives and were flown in high-altitude polar orbits. Lunar Orbiter 4 photographed the entire nearside and nine percent of the far side, and Lunar Orbiter 5 completed the far side coverage and acquired medium (20 m (66 ft)) and high (2 m (6 ft 7 in)) resolution images of 36 preselected areas. All of the Lunar Orbiter spacecraft were launched by Atlas-Agena-D launch vehicles.

The Lunar Orbiters had an ingenious imaging system, which consisted of a dual-lens camera, a film processing unit, a readout scanner, and a film handling apparat

lenses, a 610 mm (24 in) narrow angle high resolution (HR) lens and an 80 mm (3.1 in) wide angle medium resolution (MR) lens, placed their frame exposures on a single roll of 70 mm film. The axes of the two cameras were coincident so the area imaged in the HR frames were centered within the MR frame areas. The film was moved during exposure to compensate for the spacecraft velocity, which was estimated by an electro-optical sensor. The film was then processed, scanned, and the images transmitted back to Earth.

During the Lunar Orbiter missions, the first pictures of Earth as a whole were taken, beginning with Earth-rise over the lunar surface by Lunar Orbiter 1 in August, 1966. The first full picture of the whole Earth was taken by Lunar Orbiter 5 on 8 August 1967. A second photo of the whole Earth was taken by Lunar Orbiter 5 on 10 November 1967.

The Vikram lander will be measuring the vertical temperature gradient and thermal conductivity of the lunar surface. Named as 'Chandraâ€™s Surface Thermo-physical Experiment' or ChaSTE, itâ€™s essentially a thermal probe that includes a sensor and a heater.

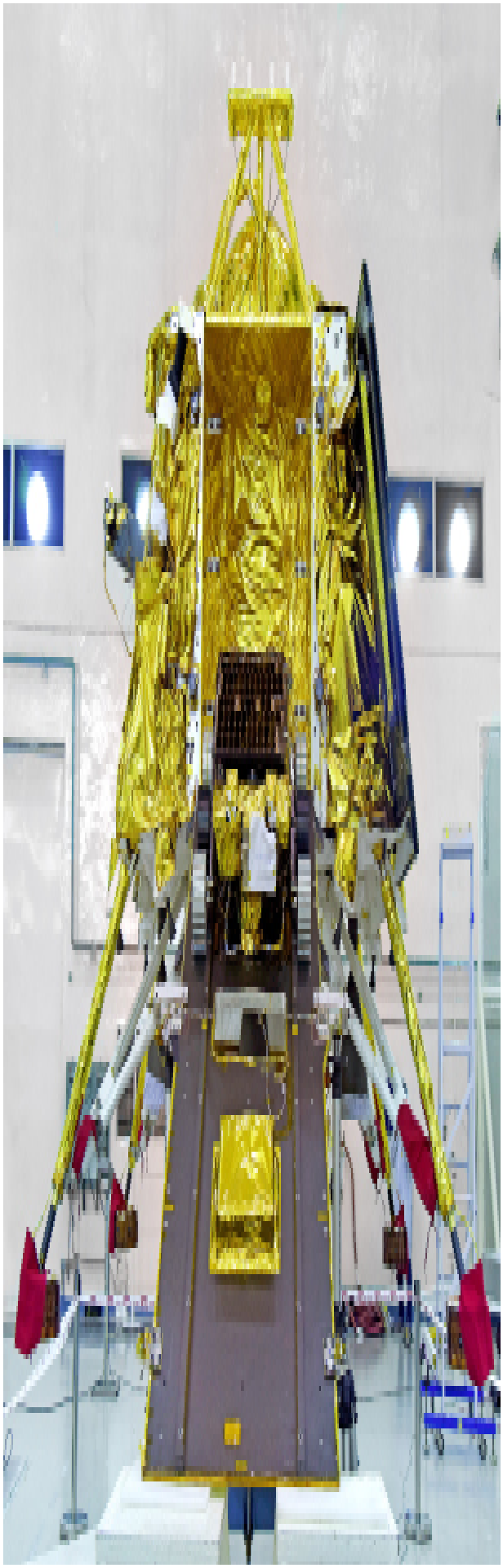


On 16 November 2019, the Failure Analysis Committee released its report to the Space Commission, concluding that the crash was caused by a software glitch. Phase one of descent from an altitude of 30 km to 7.4 km above the Moon surface went as intended with velocity being reduced from 1,683 m/s to 146 m/s. But velocity reduction during the second phase of descent was more than expected. This deviation from nominal was beyond the designed parameters of on-board software, causing Vikram to hard land, though it managed to impact relatively near the intended landing site. The complete findings have not been made public

Before it begins its Entry-Descent-Landing manoeuvre, the stacked Orbiter and Vikram Lander will enter the lunar orbit. The OHRC is attached to the orbiter that will image and scan the landing site to find the exact descent point. Once determined, the lander will detach from the orbiter. After detaching, the lander will carry around 10 cm. It will operate in a passive and active mode. When in its passive mode, it will continuously measure the temperature at different depths of the lunar surface. In the active mode, ChaSTE will measure the temperature variations over a set period of time and the therma.

3. VIKRAM LANDER

The Vikram Lander is a module that will enable the delivery of the Pragyan Rover to the lunar surface while conducting a few experiments of its own. The rover will roll out once the lander has successfully landed at the desired spot. It also consists of several instruments or payloads that will be constantly carrying out experiments throughout its mission time.



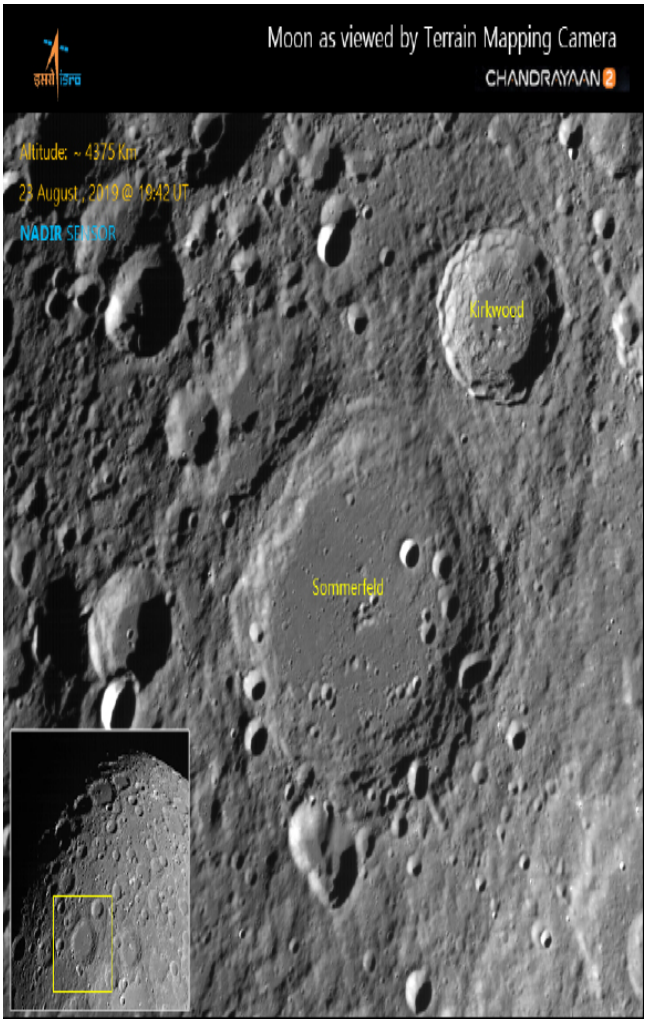
Itâ€™s named â€˜Vikramâ€™ to honour the late Dr Vikram Sarabhai, who was the former chairman of ISRO and is widely regarded as the â€˜Father of the Indian Space Programmeâ€™. It has been developed to operate for 14 days or one Lunar day. During this time period, the Vikram Lander will be constantly communicating with the Indian Deep Space Network (IDSN) in Byalalu near Bengaluru. The same network will be used by the Orbiter and Rover for communications. The lander weighs 1,471 kg including the Pragyan Rover (27 kg) inside and itâ€™s capable of generating about 650 W of electricity.

Initially, Russiaâ€™s Federal Space Agency known as Roscosmos was commissioned with developing the lander in collaboration with ISRO back in 2007. However, the delivery was postponed as Russia wasnâ€™t able to build the lander within the deadline. After Roscosmos failed in its Fobos-Grunt mission to Mars, Russia pushed back the delivery and wasnâ€™t able to provide the lander even by 2015. At the end, ISRO had no choice and decided to take up its development on its own.

“A soft landing is actually a technical term to indicate a landing technique that prevents any kind of damage to sensitive instruments onboard”.

The Vikram Lander will be making a soft landing on the lunar surface. A soft landing is actually a technical term to indicate a landing technique that prevents any kind of damage to sensitive instruments onboard. On the contrary, hard landings are those that donâ€™t need to worry about delicate instruments, for example, aeroplanes and space shuttle landings. With the onboard central-mounted propulsion system, the lander will make a vertical descent to the predetermined landing site near the South Polar region of the moon

ISROâ€™s Space Applications Centre (SAC) is developing several sensors to ensure that the lander can navigate and touch down safely. It includes an Orbiter High-Resolution Camera (OHRC), Ka-band Altimeter, Lander Position Detection Camera (LPDC) and Lander Hazard Detection and Avoidance Camera (LHDAC).



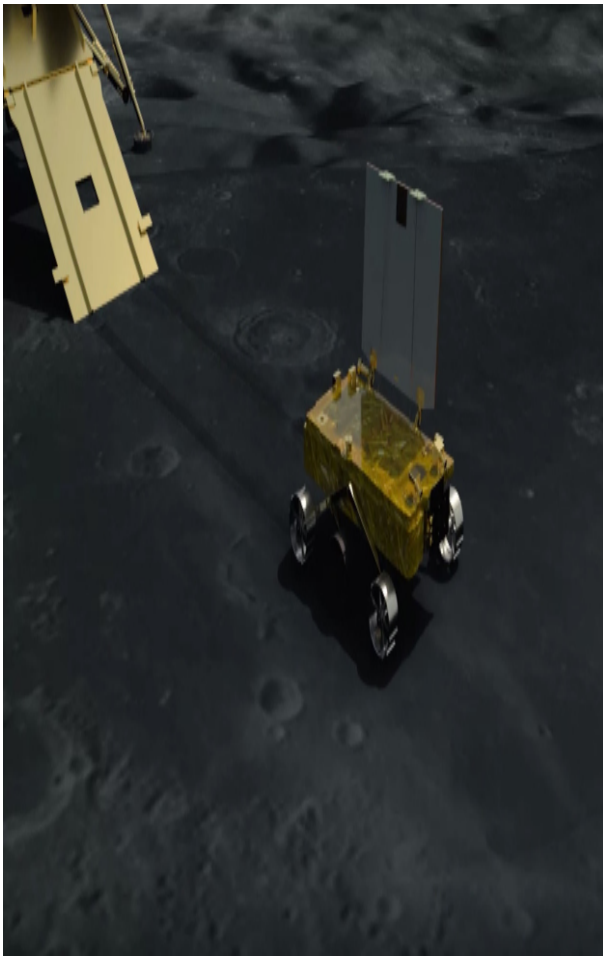
Before it begins its Entry-Descent-Landing manoeuvre, the stacked Orbiter and Vikram Lander will enter the lunar orbit. The OHRC is attached to the orbiter that will image and scan the landing site to find the exact descent point. Once determined, the lander will detach from the orbiter. After detaching, the lander will carry out complex manoeuvres using the other sensors and it will make use of rough braking and fine braking to stabilise the landing at the descent point. This entire complex operation will go on for a nail-biting 15 minutes. The landing sequence is scheduled on 6 September 2019.

Just like the other modules, the Vikram lander will contain several payloads to carry out science experiments during its mission. Three payloads will be making their way to the lunar surface onboard the lander consisting of a Langmuir probe, thermal probe and a seismometer

The Vikram lander will be measuring the vertical temperature gradient and thermal conductivity of the lunar surface. Named as 'Chandraâ€™s Surface Thermo-physical Experiment' or ChaSTE, itâ€™s essentially a thermal probe that includes a sensor and a heater. In order to measure the vertical temperature gradient, the probe will be inserted into the lunar regolith or the loose layer of the lunar surface up to a depth of around 10 cm. It will operate in a passive and active mode. When in its passive mode, it will continuously measure the temperature at different depths of the lunar surface. In the active mode, ChaSTE will measure the temperature variations over a set period of time and the thermal conductivity of the lunar regolith

This is going to be the first time India is going to land on the surface of the Moon, including its first lander and rover mission. The overall objective of the Chandrayaan 2 mission, according to ISRO, is to conduct a â€œdetailed study of topography, seismography, mineral identification and distribution, surface chemical composition, thermo-physical characteristics of the top soil and composition of the tenuous lunar atmosphere, leading to a new understanding of the origin and evolution of the Moon.â€ Both the lander and rover will conduct its set of experiments for 14 days or one lunar day while the Orbiter will continue its mission for a year. Both the lander and rover will conduct its set of experiments for 14 days or one lunar day while the Orbiter will continue its mission for a year.

4. PRAGYAN LUNAR ROVER



Pragyan (rover)Pronunciation (helpÂ·info)) was the rover of Chandrayaan-2, a lunar mission developed by the Indian Space Research Organisation (ISRO). The rover was never deployed. The Vikram lander carrying the rover crashed-landed and was destroyed upon impact with the Moon's surface.
Mission type: Lunar rover
Deployed from: Chandrayaan-2/Vikram lander
Mission duration: â‰¤ 14 days (intended); Achie...
Deployment date: Intended: 7 September 2019;

The rover's mass was about 27 kg (60 lb) and was designed to operate on solar power. The rover was to move on 6 wheels traversing 500 meters on the lunar surface at the rate of 1 cm per second, performing on-site analysis and sending the data to the Vikram lander, which would have relayed it to the Earth station. For navigation, the rover was equipped with:

Stereoscopic camera-based 3D vision: two 1 megapixel, monochromatic NAVCAMs in front of the rover to provide the ground control team a 3D view of the surrounding terrain, and help in path-planning by generating a digital elevation model of the terrain.[citation needed] IIT Kanpur contributed to the development of the subsystems for light-based map

"The orbiter part of the mission, with eight scientific instruments, remains operational, and will continue its seven-year mission to study the Moon".

generation and motion planning for the rover.
Control and motor dynamics: the rover design has a rocker-bogie suspension system and six wheels, each driven by independent brushless DC electric motors. Steering is accomplished by differential speed of the wheels or skid steering.
The expected operating time of Pragyan rover was one lunar day or around 14 Earth days, as its electronics were not designed to endure the frigid lunar night. Its power system had a solar-powered sleep/wake-up cycle implemented, which could have resulted in longer service time than planned.

Dimensions: 0.9 Ã— 0.75 Ã— 0.85 m
Power: 50 W
Travel speed: 1 cm/sec.
Planned mission duration: â‰¤14 days (one lunar day

Two landing sites were selected, each with a landing ellipse of 32 km x 11 km.[4] The prime landing site (PLS54) was at 70.90267 S 22.78110 E (~350 km north of the South Pole-Aitken Basin rim, and the alternate landing site (ALS01) was at 67.874064 S 18.46947 W. The prime site was on a high plain

6,900 ft) above the surface. The final telemetry readings during ISRO's live-stream show that Vikram's final vertical velocity was 58 m/s (210 km/h) from 330 meters above the surface which, according to the MIT Technology Review, is "quite fast for a lunar landing." Initial reports suggesting a crash, have been confirmed by ISRO chairman K. Sivan, stating that the lander location had been found, and "it must had been a hard landing". The Lunar Reconnaissance Orbiter took images of the crash site, showing that the lander and the Pragyan rover inside the lander had been destroyed by the impact, creating an impact site and debris field spanning kilometres.

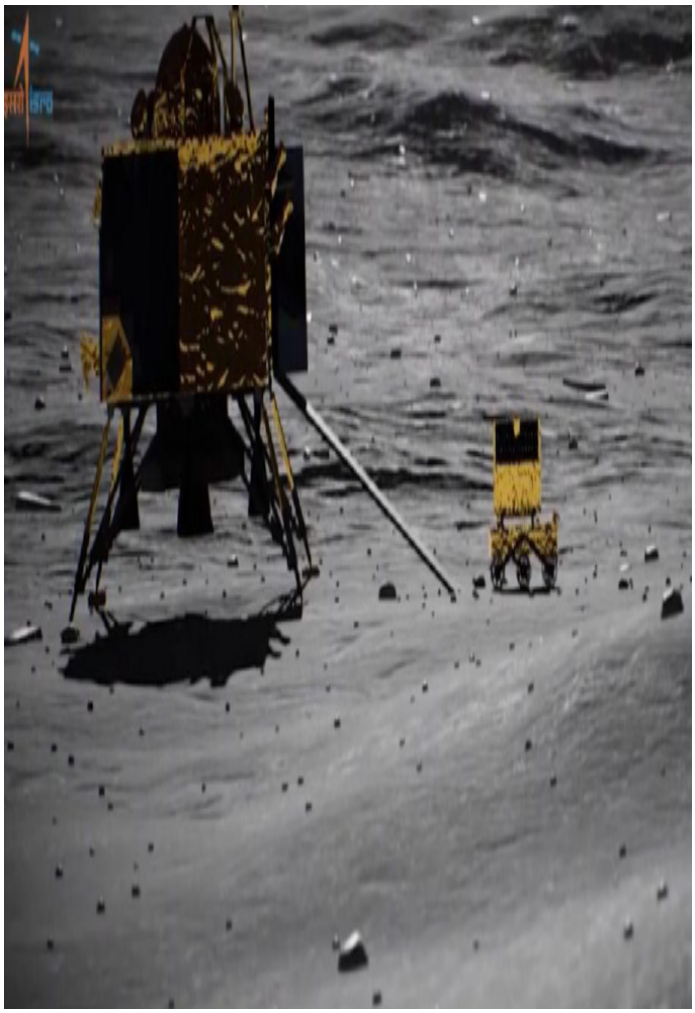
The orbiter part of the mission, with eight scientific instruments, remains operational and will continue its seven-year mission to study the Moon. This is going to be the first time India is going to land on the surface of the Moon, including its first lander and rover mission. The overall objective of the Chandrayaan 2 mission, according to ISRO, is to conduct a â€œdetailed study of topography, seismography, mineral identification and distribution, surface chemical composition, thermo-physical characteristics of the top soil and composition of the tenuous lunar atmosphere, leading to a new understanding of the origin and evolution of the Moon.

near side of the Moon. The criteria used to select the landing zones were: south polar region, on the near side, slope less than 15 degrees, boulders less than 50 cm (20 in), crater and boulder distribution, sunlit for at least 14 days, nearby ridges do not shadow the site for long durations.

The planned landing site and its alternate site, are located within the polar LQ30 quadrangle. The surface likely consists of impact melt, possibly mantled by ejecta from the massive South Poleâ€“Aitken basin and mixing by subsequent nearby impacts. The nature of the melt is mostly mafic,meaning it is rich in silicate mineral, magnesium and iron. The region could also offer scientifically valuable rocks from the lunar mantle if the basin impactor excavated all the way through the crust.

The Vikram lander, carrying the Pragyan rover, separated from the Chandrayaan-2 orbiter on 7 September 2019 and was scheduled to land on the Moon at around 1:50 a.m. IST. The initial descent was considered within mission parameters, passing critical braking procedures as planned. The descent and soft-landing was to be done by the on-board computers on Vikram, with mission control unable to make corrections.

The lander's trajectory be



5. MISSION PROFILE

Launch:

Chandrayaan-2 launch was initially scheduled for 14 July 2019, 21:21 UTC (15 July 2019 at 02:51 IST local time). However, the launch was aborted 56 minutes and 24 seconds before launch due to a technical glitch, so it was rescheduled to 22 July 2019. Unconfirmed reports later cited a leak in the nipple joint of a helium gas bottle as the cause of cancellation.

Finally Chandrayaan-2 was launched on board the GSLV MK III M1 launch vehicle on 22 July 2019 at 09:13 UTC (14:43 IST) with better-than-expected apogee as a result of the cryogenic upper stage being burned to depletion, which later eliminated the need for one of the apogee-raising burns during the geocentric phase of mission. This also resulted in the saving of around 40 kg fuel on board the spacecraft.

Immediately after launch, multiple observations of a slow-moving bright object over Australia were made, which could be related to upper stage venting of residual LOX/LH2 propellant after the main burn

Geocentric phase:

After being placed into a 45,475 Ã— 169 km parking orbit by the launch vehicle, the Chandrayaan-2 spacecraft stack gradually raised its orbit using on-board propulsion over 22 days. In this phase, one perigee-raising and five apogee-raising burns were performed to reach a highly eccentric orbit of 142,975 Ã— 276 km followed by trans-lunar injection on 13 August 2019. Such long Earth-bound phase with multiple orbit-raising manoeuvres exploiting the Oberth effect was required because of the limited lifting capacity of the launch vehicle and thrust of the spacecraft's on-board propulsion system. A similar strategy was used for Chandrayaan-1 and the Mars Orbiter Mission during their Earth-bound phase trajectory. On 3 August 2019, the first set of Earth images were captured by the LI4 camera on the Vikram lander, showing North American landmass

Selenocentric phase:

After 29 days from its launch, the Chandrayaan-2 spacecraft stack entered lunar orbit on 20 August 2019 after performing a lunar orbit insertion burn for 28 minutes 57 seconds. The three-spacecraft stack was placed into an elliptical orbit that passes over the polar regions of the Moon, with 18,072 km (11,229 mi) aposelene and 114 km (71 mi) periselene. By 1 September 2019 this elliptical orbit was made nearly circular with 127 km (79 mi) aposelene and 119 km (74 mi) periselene after four orbit-lowering maneuvers followed by separation of Vikram lander from the orbiter on 7:45 UTC, 2 September 2019.

The flat highland between craters Manzinus C and Simpelius N was the planned landing zone for the Vikram lander.

Two landing sites were selected, each with a landing ellipse of 32 Ã— 11 km. The prime landing site (PLS54) is at 70.90267 S 22.78110 E (600 km (370 mi) from the south pole), and the alternate landing site (ALS01) is at 67.874064 S 18.46947 W. The prime site is on a high plain between the craters Manzinus C and Simpelius N, on the near side of the Moon.

The orbiter part of the mission, with eight scientific instruments, remains operational and will continue its seven-year mission to study the Moon.

Loss of vikram:

Vikram began its descent at 20:08:03 UTC, 6 September 2019 and was scheduled to land on the Moon at around 20:23 UTC. The descent and soft-landing were to be done by the on-board computers on Vikram, with mission control unable to make corrections.
The initial descent was considered within mission parameters, passing critical braking procedures as expected, but the lander's trajectory began to deviate at about 2.1 kilometres (1.3 mi; 6,900 ft) above the surface. The final telemetry readings during ISRO's live-stream show that Vikram's final vertical velocity was 58 m/s (210 km/h) at 330 meters above the surface, which a number of experts noted, would have been too fast for the lunar lander to make a successful landing. Initial reports suggesting a crash were confirmed by ISRO chairman K. Sivan, stating that "it must have been a hard landing".

Radio transmissions from the lander were tracked during descent by analysts using a 25-meter radio telescope owned by the Netherlands Institute for Radio Astronomy. Analysis of the doppler data suggests that the loss of signal coincided with the lander impacting the lunar surface at a velocity of nearly 50 m/s (180 km/h) (as opposed to an ideal 2 m/s (7.2 km/h) touchdown velocity).

The powered descent was also observed by NASA's Lunar Reconnaissance Orbiter (LRO) using its Lyman-Alpha Mapping Project (LAMP) instrument to study changes in the lunar exosphere due to exhaust gases from the lander's engines.

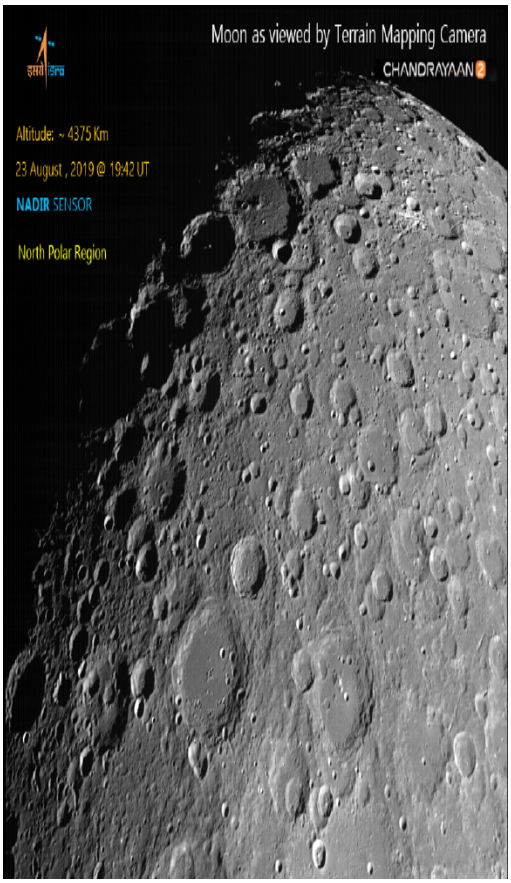
ISRO's Chairman, K. Sivan, tasked senior scientist P. S. Goel to head the Failure Analysis Committee to look into the causes of the failure.

Both ISRO and NASA attempted to communicate with the lander for about two weeks before the lunar night set in, while NASA's Lunar Reconnaissance Orbiter.

Vikram's impact site was located at 70.8810Â°S 22.7840Â°E by the LROC team after receiving helpful input from Shanmuga Subramanian, a volunteer from Chennai, Tamil Nadu, who located debris from the spacecraft in pictures released by NASA. While initially estimated to be within 500 meters of the intended landing site, best guess estimates from satellite imagery indicate initial impact about 600 meters away. The spacecraft shattered upon impact, with debris scattered over almost two dozen locations in an area spanning kilometres.

The orbiter part of the mission, with eight scientific instruments, remains operational, and will continue its seven-year mission to study the Moon.
(LRO) flew over on 17 September 2019 and acquired some images of the intended landing zone. However, the region was near dusk, causing poor lighting for optical imaging. NASA's LRO images, showing no sight of the lander, were released on 26 September. The LRO flew over again on 14 October under more favorable lighting conditions, but was unable to locate it.

Planned landing site:
Pragyan (rover)
Landing site Coordinates
Prime landing site 70.90267Â°S 22.78110Â°E
Alternate landing site 67.87406Â°S 18.46947Â°W

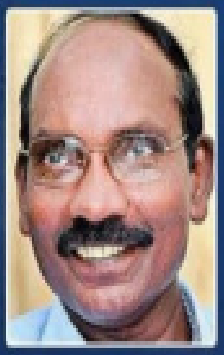


6. SCIENTIST'S INVOLVED IN MISSION

CHANDRAYAAN 2

MUTHAYYA VANITHA
PROJECT DIRECTOR
- First ever woman project director at ISRO
- Responsible for handling data operations for the country's remote sensing satellites

RITU KARIDHAL
MISSION DIRECTOR
- Will navigate Chandrayaan2
- With 22 years at ISRO, she helped navigate ISRO's Mangalyaan Mission (2013)

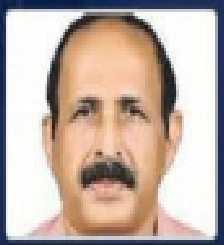


DR K SIVAN
ISRO CHAIRMAN
- Helped create a world record by launching >100 satellites into space in one go in 2017

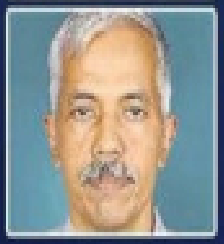
P KUNHIKRISHNAN
DIRECTOR OF UR RAO SATELLITE CENTER, ISRO
- Chandrayaan-2 was given finishing touches under his watch

DR S SOMANATH
VSSC DIRECTOR
- Resolved the glitch with the cryogenic engine which led to calling off the launch

DR ANIL BHARADWAJ
DIRECTOR, PHYSICAL RESEARCH LABORATORY
- Was a key player in India's Mangalyaan Mission.
- Lead the charge on the scientific front for Chandrayaan 2



J JAYAPRAKASH
MISSION DIRECTOR FOR LAUNCH



RAGHUNATHA PILLAI
VEHICLE DIRECTOR

- Both played a key role in averting a disaster in the previous launch

About 30%
of the workforce at ISRO are Women

price
₹350/-