CHANDRAYAAN: SURVEY ON THE JOURNEY TO MOON

Abstract

One of the important missions of ISRO is Chandrayaan program to explore moons terrain. Under this Chandrayaan -1 was launched on 22 October 2008 and the mission was planned to work for 2 years but unfortunately it came to an end by 312 days. The mission was successful and gave a hope to explore lunar terrain more which developed the next mission Chandrayaan 2. A robust design was made in order to study the lunar plane compositions, lunar atmosphere and the presence of water in the southern polar area. On July 22, 2019 the craft was launched from SHAR (Satish Dhawan Space Centre) in Andhra Pradesh. The mission was successful to some extent, but lost the communication with the ground. Chandrayaan-3 is the updated lunar mission for exploration on the moon plane interested in exploring the south pole. It is similar to Chandrayaan-2 in that it comprises of a, lander and rover. Lander was named Vikram and a rover named Pragyan, but it lacks an orbiter. This book chapter gives an insight to the three missions, their findings and failures.

Keywords: Chandrayaan, Lander, Shackleton, Monitor experiment, Composite

Authors

Dr. Nellutla Sasikala
Department of Electronics & Communication Engineering
Kamala Institute of Technology & Science
JNTUH
Karimanagar, Telangana, India
kalapraveen.sasi@gmail.com

Dr. K. Praveen Kumar Rao
Department of Computer Science & Engineering
Kamala Institute of Technology & Science
JNTUH
Karimanagar, Telangana, India
praveenkumarrao.k@gmail.com

I. CHANDRAYAAN-1

ISRO has launched its first luna probe under Chandrayaan programme in October 2005 and it worked upto august 2009. The spacecraft used PSLV-XL rocket on 22 October 2008 for launching from SHAR (SatishDhawanSpaceCenter), Sriharikota Andhra Pradesh which include a luna orbiter and an contactor. For this mission, to explore moon, India has done a wide research and tried to develop and indigenous technology in which the country was successful. On 8 November 2008, the vehicle was placed in the luna orbit.. many countries tried to explore the southern polar area of moon , but none succeeded. So it was an aim for the mission is to study the south pole of the moon. The contact probe isolated from the orbiter on 14 November 2008 then hit near crater Shackleton of Southern Polar area in a regularized manner. The mission was planned for 2 years to work on luna plane; however it operated only for 312 days, as it was experiencing several technical issues and stopped communication on 28 august 2009. The mission was successful in one of the scientific objectives aimed, to explore the presence of H_20 on the luna plane.

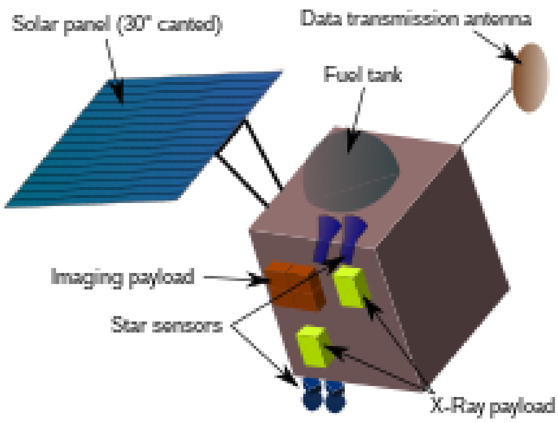

Figure 1: Chandrayaan -1

The mission objectives is to yield a data which can be used that can be used for the design of atlas which is three dimensional for south and north poles moon, mineral and finding the chemical composition of the entire luna plane with a resolution which is high in spatial, to find the existence of chemical compositions and elements like Mg (MAGNESIUM), Al (ALUMINUM), Si(SILICON) , ca (CALCIUM), Fe (IRON), Ti(TITANIUM), Rn(RADON), U(URANIUM) and Th(THORIUM).

The mass of the craft was about 1380kg at the launch, 675 kg at the luna orbit and 523 Kgs without the contactor . Space craft was in Cuboid shape of 4.9ft. for payload data transmission X-Band was used with dual gimbaled parabolic antenna. S band frequency is used for TTC (Telemetry, Tracking & Command) communication. 36 A.h lithium ion batteries were used to store a power of 750W which was intended to use during eclipses. 7.1 x 1.8 ft size solar panels are used in the solar array and this solar array powered the space craft . Bi propellant integrated propulsion system was used by the space craft. The supply of power is through one 440 N engine and eight 22 N thrusters. Two tanks were used for the storage of Fuel and oxidizer and the capacity of the tanks were found to be of 390 liters (100 US gal) each. The craft was 3-axis stabilized with two star sensors, gyros and four reaction wheels. For controlling the height, processing of sensors, orientation of the antenna the craft carried two redundant bus management units. It has taken almost 21 days for chandrayaan 1 to reach the orbit of the moon as it performed manoeuvres in a series of increasing orbits. The insertion of the craft was into GTO (geostationary transfer orbit) at the launch with an apogee of 22,860 km (14,200 mi) and a perigee of 255 km (158 mi). 5 orbit burns were conducted in order to increase the apogee over a period of 13 days after launch.

Other countries also contributed for the payload had 6 instruments and 5 Indian instruments. The scientific payload had a weight of 90kgs

TMC(**Terrain Mapping Camera)** developed by India is a CMOS camera which work in panchromatic band with 5 m (16 ft) resolution and a 40 km (25 mi) was used to generate moon map of highest resolution. The instrument was designed in such a way that it is used to map the topography of the luna plane. Operation of this camera was in visible area of spectrum (Electro Magnetic) which are used to capture White & Black stereo images. Luna Laser Ranging Instrument (LLRI), helped knowing the luna gravitational field. ISRO's SAC (Space Applications Centre) has designed TMC, and it is located at Ahmadabad.

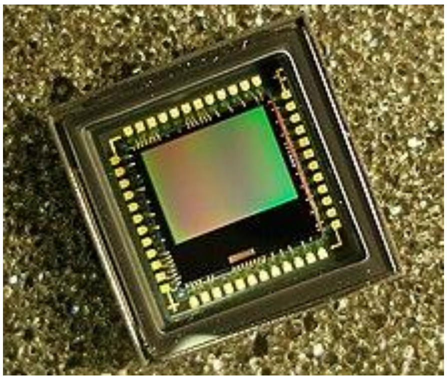

Figure 2: Terrain Mapping Camera

HySI (**Hyper Spectral Imager)** is used for mineral mapping which is a camera which is CMOS and works in the band 400–900 nm band with a spectral resolution of 15 nm and a spatial resolution of 80 m (260 ft).

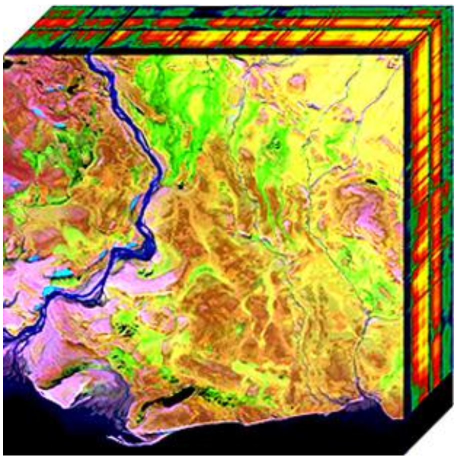

Figure 3: Hyper Spectrum Imager

LLRI or **Luna Laser Ranging Instrument** analyzes the reflected light from the luna plane, and finds the elevation of the plane topography from infrared laser pulses. This instrument designed by Laboratory for Electro Optics Systems of ISRO, Bangalore, collected the data of the moon both day and night, taking 10 readings per second.

.

Figure 4: Luna Laser Ranging Instrument

HEX is a **High Energy aj/gamma x-ray spectrometer** for 30–200 keV measurements with ground resolution of 40 km (25 mi), the HEX measured U, Th, ^{210}Pb, ^{222}Rn degassing, and other radioactive elements.

ISRO made a head wy and designed **MIP** (**Moon Contact Probe)**, which works in C-band and is used as a Radar altimeter for finding the of height, acquisition of images is by video imaging system of the luna plane and study of luna atmosphere is done by a mass spectrometer.

Figure 5: Moon Contact Probe

Instruments from other court space agencies like ESA, NASA, Bulgarian academy of sciences were also used. These included **C1XS** or **X-ray fluorescence spectrometer** covering 1–10 keV, is used for monitoring solar flux and checked for the availability of presence of Manganese, Aluminum, Silicon, Calcium, Titanium and iron at the plane with a ground resolution of 25 km (16 mi), and monitored solar flux. This payload is designed and manufactured by a collaboration of Rutherford Appleton laboratory, U.K, ESA and ISRO.

Figure 6: X-Ray Fluorescence Spectrometer

SARA, the **Sub-keV Atom Reflecting Analyser** from the ESA **used the** mild energy neutral atoms which are ejected from the plane and mapped mineral composition .

M^3, the **Moon Mineralogy Mapper** from Brown University and JPL (funded by NASA) is an imaging spectrometer designed to map the plane mineral composition.

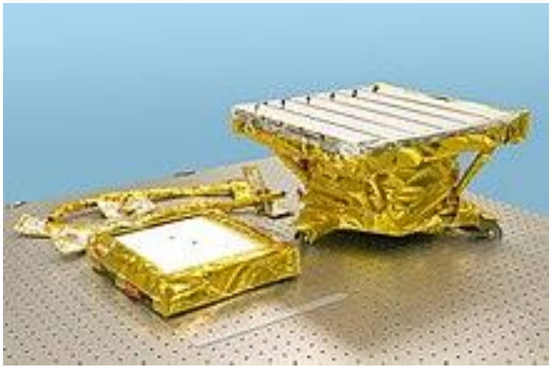

Figure 7: Moon Mineralogy Mapper

SIR-2, Max Planck Institute for Solar System Research, Polish Academy of Science and University of Bergen, designed SIR2, a near infra red spectrometer which found the Mg, Al, Fe etc composition by a infrared grating spectrometer which is similar to that of the Smart-1 SIR.

Mini-SAR, developed, constructed and assessed for NASA by a huge team, participation by Naval Air Warfare Center, Johns Hopkins University Applied Physics Laboratory, Sandia National Laboratories, Raytheo and Northrop Grumman with outer support from ISRO, for finding frozen H2O & H_2O on the luna plane Mini SAR is used which is a active synthetic aperture radar system. The scattered left and right polarized radiations are monitored and analyzed with the instrument which transmitted right polarized radiation of 2.5GHz frequency. The parameters found from this measurements are Fresnel reflectivity and the circular polarization ratio (CPR).

To study about the electromagnetic radiation on Luna **RADOM-7 Radiation Dose Monitor Experiment** was used which was from the Bulgarian Academy of Sciences. Near the Shackleton at South Pole, Moon Contact Probe (MIP) crash landed on the plane of moon on fourteen November 2008. Chandrayaan-1 one of the important payloads is MIP which is scientifically used among 11 payloads.

Findings of Mission

- Moon mineralogy mapper found the presence of iron traces and also found the difference in rock and composition of minerals.
- Mapping of landing site of Apollo fifteen and Apollo seventeen
- 70000 images of luna plane was acquired as the craft completed 3000 orbits.X-ray camera found the traces of aluminium, magnesium and silicon.
- Earth complete image was captured by chandrayaan and was sent.
- H_2O Vapor has been found by NASA's Luna Crater Observation and Sensing Satellite and the H2O molecules in the polar areas were found by Moon Mineralogy Mapper (MP3)

Figure 8: Images of H_2O traces

- ESA payload – Chandrayaan-1 imaging X-ray Spectrometer (C1XS) – found faculae at the time of mission, which were weak and were a dozen in number . Radiation Dose Monitor (RADOM) was a payload from Bulgaria and completely worked till the end of the mission.
- Luna lava tube was found which was like a empty volcanic tube near the luna equator.
- Tectonic activity was observed which was based on the data from mini SAR, processed by software ENVI.

II. CHANDRAYAAN-2

ISRO gave notification officially on 25th November 2008 that Chandrayaan-1's experienced an abnormal thermal/heat that has risen above normal to 50 °C (122 °F), and was much higher than estimated thermal energy in luna orbit. . By switching off some of the instruments and changing the orientation of the spacecraft by 20 degrees, the thermal energy decreased to 10 °C (18 °F) .Loss of communication with the craft was the ultimate failure which occurred because of very high radiation. Because of this computer systems on board failed.

The second luna exploration mission a modified version of chandrayaan 1 is chandrayaan 2 which consists a rover pragyan which was in the Vikram Lander and these two were embed into the orbiter. A robust design was made in order to study the luna plane compositions, luna atmosphere and the presence of H2O in the southern polar area.

On July 22, 2019, at 09:13:12 UTC, an LVM3-M1 rocket from the SHAR (Satish Dhawan Space Centre) in Andhra Pradesh launched the spacecraft from the second launch pad. On 20 August 2019, the spacecraft got into the Moon's orbit and started orbital positioning maneuvers in order to do landing of the Vikram lander. On 6 September,2019, the lander and rover were supposed to touch down on the close end of the Luna plane near the southern polar area at a latitude of around 70° south. There was a software glitch, and the lander hit down hard as it got away from the intended trajectory on 6 September 2019.

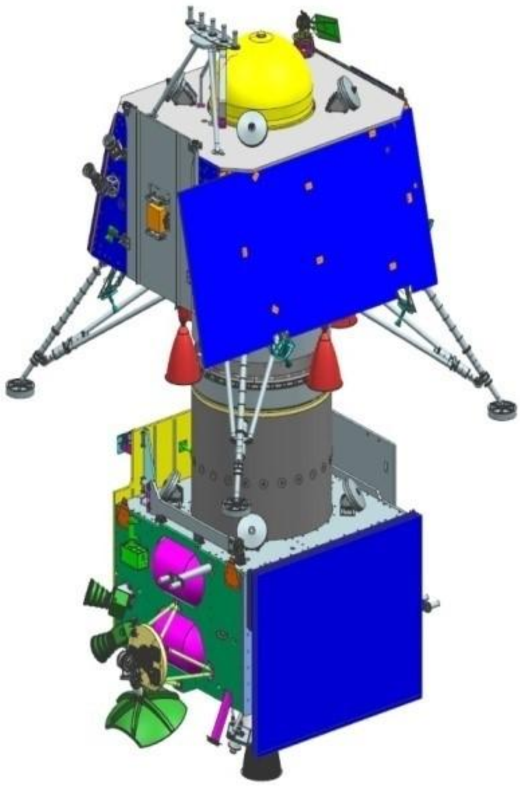

Figure 9: Chandrayaan 2 Composite

The main aim of the Chandrayaan-2 lander is to do a soft landing on the luna plane and make the rover to operate on the suface to study the minerals , atmosphere and H2O in Luna. The research oriented aim of the orbiter is:

- For finding luna topography, elements presence, mineralogy, the luna exosphere, and presence of hydroxyl and H2O frozen H2O.
- For detecting presence H_2O, frozen H_2O in the southern pole area and luna crust density on the luna plane.

- For mapping of luna plane which helps in preparing 3D maps

The mission was launched from the SatishDhawaSpaceCentre(SHAR) on Sriharikota Island in Andhra Pradesh by a Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mk III) M1 with a lift-off mass of 3,850 kg (8,490 lb).The mission budget on June 2019 was estimated allocated budget of 9.78 billion (about US$141 million), which includes 3.75 billion for the GSLV Mk III M1 launch and 6.01 billion for the space segment. The launch vehicle first placed the Chandrayaan-2 stack in an Earth parking orbit with a 170 km perigee and a 40,400 km (25,100 km) apogee.

1. **Orbiter:** At a height of 100 km, the Chandrayaan-2 orbiter is moving in a polar orbit around the Moon. Eight scientific instruments are aboard, including two upgraded designs of those used on Chandrayaan-1. The launch weight was approximately 2,379 kg, before the lander's separation from the orbiter, the landing site observations were made by Orbiter High Resolution Camera (OHRC) which is of high resolution. Hindustan Aeronautics Limited created the orbiter's structure.

Figure 10: Orbiter

2. **Vikram Lander:** With the aid of liquid main engines whose capacity is 800 N, the Vikram lander separated from the orbiter and dropped to a low luna orbit of 30 km 100 km (19 mi 62 km). It attempted a soft landing after validating all of its onboard systems, which would have deployed the rover and allowed it to conduct research for roughly 14 days on Earth. Vikram failed miserably in this endeavor. The lander and rover weighed a total of about 1,471 kg.The design of the Vikram lander was in such a way that it can do safe landing on luna plane slopes up to 12°.

   Other Technologies present are:

   - A high resolution camera, Laser Altimeter (LASA)
   - Lander Hazard Detection Avoidance Camera (LHDAC)
   - Lander Position Detection Camera (LPDC)
   - Lander Horizontal Velocity Camera (LHVC), an 800 N throttleable liquid main engine

- Attitude thrusters
- Ka-band radio altimeters
- Laser Inertial Reference and Accelerometer Package (LIRAP) and the software needed to run these components.

3. **Pragyan Rover:** Rover for the mission was known as Pragyan, weighed 60 pounds (27 kg) which worked on solar power. The six-wheeled rover was designed to drive 500 meters (1,600 feet) per second across the luna plane as it conducted on-site assessments. Mission Control on Earth has its communication to lander where it gathered the information on site from rover. The Pragyan rover's electronics were not designed to withstand the cool atmosphere of luna night, its projected functioning time was 1 luna day, or fourteen Earth days. The power system's implementation of a solar-powered sleep/wake cycle, however, may led to a longer servfrozen H2O life than anticipated. The State Emblem of India and the ISRO emblem were engraved on the rover's two rear wheels, which were designed to make imprints on the luna plane as it makes the tracks.

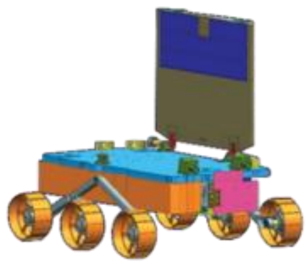

Figure 11: Pragyan Rover

- Measurements: 0.9 × 0.75 × 0.85 m
- Energized power: 50 watts
- Velocity of the flight: 1 cm/sec
- Time of Mission: ~14 Earth days (one luna day)

The orbiter's payloads are as follows:

X-ray fluorescence spectra are used by the Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS) from the ISRO Satellite Center (ISAC) to ascertain the elemental composition of the luna plane.

In order to support the CLASS equipment, the Solar X-ray Monitor (XSM) from the Physical Research Laboratory (PRL), Ahmedabad, supplies solar X-ray spectra and intensity parameters as input. This data will also aid in the research of other high-energy solar coronal processes.

The Space Applications Centre's (SAC) two Frequency L-band and S-band Synthetic Aperture Radar (DFSAR) is used to scan the first few meters of the luna plane for the presence of various materials. Further proof of the existence of H2O frozen H2O and its dispersion under the Moon's shadow was anticipated from DFSAR. It has a 5 m (16 ft) (L-band) luna plane penetration depth.

Imaging IR Spectrometer (IIRS) from the SAC which is used for finding mineral presence, H_2O molecules and hydroxyl present of luna plane using wide wavelength range,. Payloads worked up to 3 µm and had a extended spectral range (0.8 µm to 5 µm), which is an improvement shown over the previous luna missions.

Chandrayaan-2 Atmospheric Compositional Explorer 2 (ChACE-2) Quadrupole Mass Analyzer from Space Physics Laboratory (SPL) to carry out a detailed study of the luna exosphere.

Terrain Mapping Camera-2 (TMC-2) from SAC for the contributing and preparation for a 3D map essential for studying the luna minerals and geological conditions.

Radio Anatomy of Moon Bound Hypersensitive Ionosphere and Atmosphere – Dual Frequency Radio Science experiment (RAMBHA-DFRS) by SPL for the studying electron density in the luna ionosphere.

Orbiter High Resolution Camera (OHRC) by SAC for scouting a hazard-free spot prior to landing. This aids in preparing digital elevation models and high-resolution topographic maps of luna plane. OHRC had a spatial resolution of 0.32 m (1 ft 1 in) from 100 km (62 mi) polar orbit, which was the best resolution among any luna orbiter mission to date.

The Vikram lander's and its payloads were as follows:

LEOS's MEMS-based Instrument for Luna Seismic Activity (ILSA) seismometer for observing Moonquakes close to the landing site.

SPL, the Vikram Sarabhai Space Center (VSSC), and the Physical Research Laboratory (PRL), Ahmedabad together developed the thermal probe known as Chandra's Plane Thermo-physical Experiment (ChaSTE) to measure the thermal characteristics of the luna plane.

In order to calculate the density and changes of luna plane plasma, SPL and VSSC developed the RAMBHA-LP Langmuir probe.

Goddard Space Flight Center's laser retroreflector array (LRA) is used to measure distances precisely between luna spacecraft in orbit and a reflector on the moon's plane. The microreflector was roughly 22 g (0.78 oz) in weight and was ineffective for collecting data from luna laser stations located on Earth.

4. **Rover Pragyan:** To ascertain the amount of components close to the landing location, the Pragyan rover carried two instruments: Laser induced Breakdown Spectroscope (LIBS) from the laboratory for Electro Optic Systems (LEOS), Bangalore. Alpha Particle Induced X-ray Spectroscope (APXS) from PRL, Ahmedabad

Figure 12: Pragyan Rover Instruments

On September 6, 2019, at 20:08:03 UTC, Vikram started making its way toward the Moon. It was planned to touch down there about 20:23 UTC. Mission control was unable to make adjustments, thus Vikram's on-board computers were to carry out the descent and soft landing.The lander's trajectory started to veer off course at around 2.1 km (1.3 mi) above the plane, but the initial descent was thought to stay within mission limitations and pass essential braking procedures as predicted. Vikram's end vertical velocity was 58 m/s (210 km/h) at 330 m (1,080 ft) above the plane, according to the end telemetry readings during ISRO's live feed. A number of experts observed that this was too fast for the luna lander to accomplish a successful landing. K. Sivan, the ISRO chairman, verified the initial claims of a crash, saying that "it must have been a hard landing".

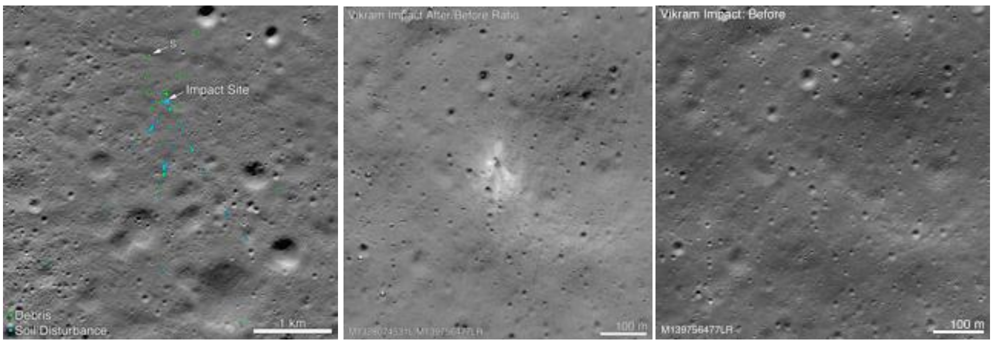

Figure 13: Contact site- Before & after of Vikram Lander

The Vikram contact site was discovered by the LROC team at 70.8810°S 22.7840°E with the assistance of Shanmuga Subramanian, a volunteer from Chennai, Tamil Nadu, who identified spacecraft debris in images made public by NASA. While the first estimate placed the initial contact within 500 m of the planned landing site, bestguess calculations based on satellite images place the initial hit at a distance of around 600 m. The craft broke apart after the contact, leaving debris spread across nearly two dozen spots in a kilometer-wide area.

III. CHANDRAYAAN-3

Chandrayaan-3 is the updated luna mission for exploration on the moon plane interested in exploring the south pole. It is similar to Chandrayaan-2 in that it comprises of a, lander and rover. Lander was named Vikram and a rover named Pragyan, but it lacks an orbiter. Its propulsion system functions like a satellite relaying communications. Up until the spacecraft is in a 100 km luna orbit, the lander and rover configuration is carried by the propulsion module.

Figure 14: Chandrayaan 3 Integrated Module

Chandrayaan-3 was launched on July 14, 2023, at 2:35 IST and phase one of the luna injection of a 100 km circular polar orbit was successfully accomplished. On August 23, 2023, the lander and rover are anticipated to touch down close to the luna south pole.

For the Chandrayaan-3 mission, ISRO has established three key goals, which include:

- Achieving a soft, safe landing of a lander on the Moon's plane.
- Finding and showcasing the rover's moon-based loitering capability.
- For getting more information about the makeup of the Moon, on-site observation and experimentation using elements found on the luna plane are recommended.

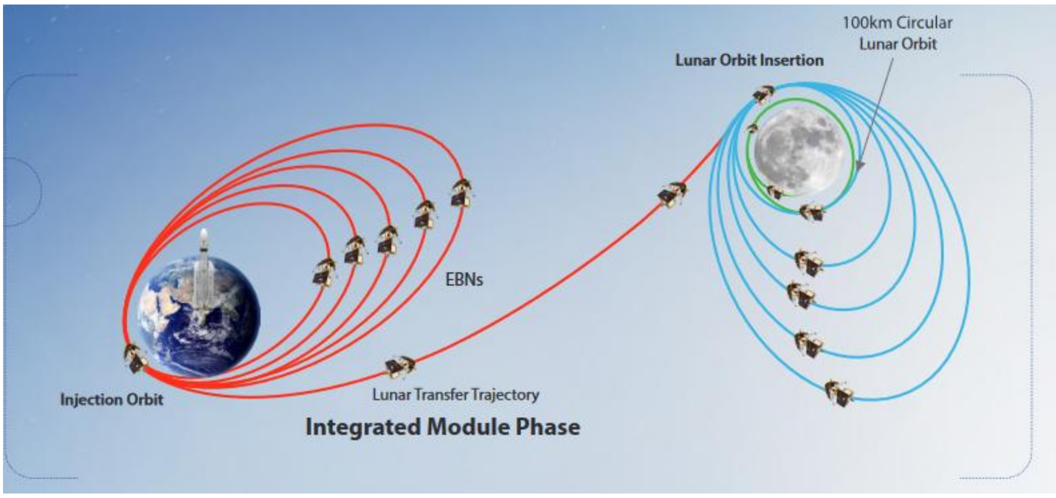

Figure 15: Integrated Module Phase

1. **Propulsion Module:** The indigenous propulsion module is designed in such a way that it carries lander and rover configuration upto 100 km luna orbit. One huge solar panel is mounted by a side , top is a cylindrical structure Intermodular Adapter Cone or called as mounting structure and both are fitted into a box like structure. Spectro-polarimetry of Habitable Planet Earth (SHAPE) is the payload carried additionally with lander. SHAPE is used to do the polarmatric measurements of earth from luna plane in the near-infrared (NIR) wavelength range (1-1.7 µm) and to study the spectrum related to the measurements.

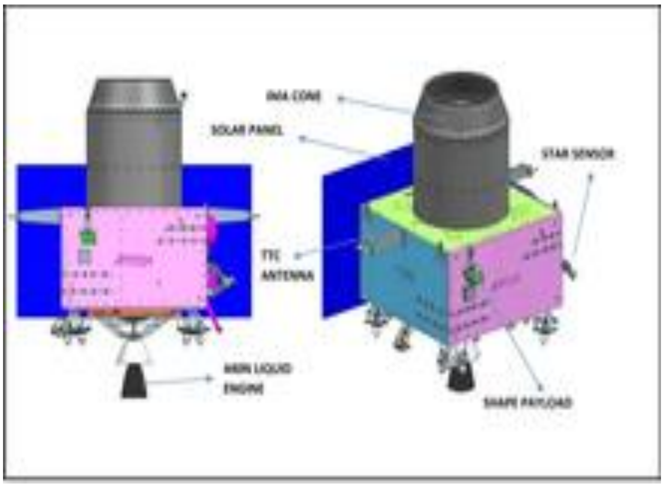

Figure 16: Propulsion Module

2. **Lander:** Lander is in the shape of a box structure with 4 legs for soft landing and 4 landing thrusters of 800 newtons each. The site analysis is performed by all the various scientific instruments and it will also carry rover.

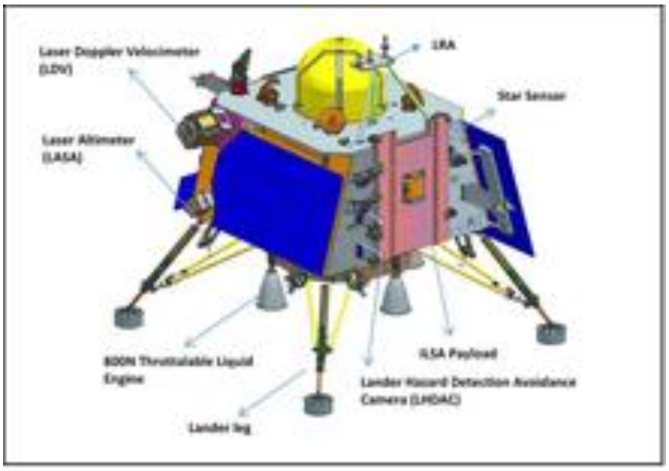

Figure 17: Lander

The lander is having 3 payloads. RAMBHA_LP, Langmuir probe which is used to find the near plane plasma (ions and electrons) denseness and how it converts with respect to time. ChaSTE(Chandra’s Plane Thermo Physical Instrument) is designed to carry out the measurement and heating properties of luna plane near pole area. ILSA (Instrument for Luna Seismic Activity) which is designed to find the seismicity within the area of landing and maps out the structure of the luna surface & mantle.

3. Rover

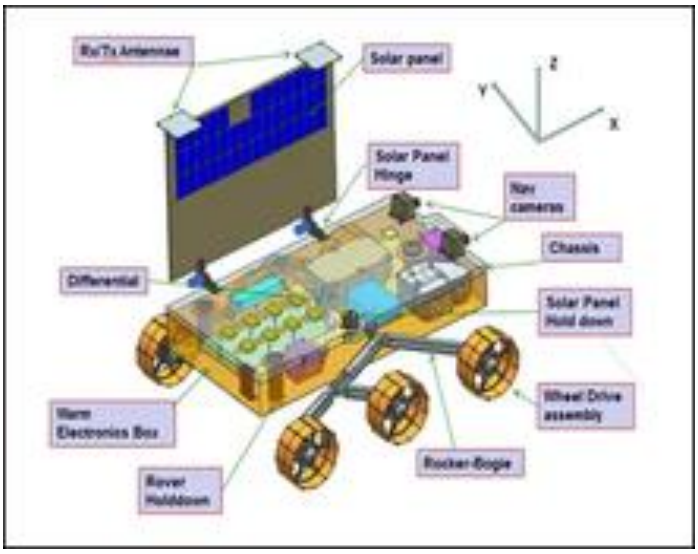

Figure 18: Pragyna Rover

- 6-wheeled design
- Mass of 26 kilograms (57 pounds)
- Distance of 500 meters (1,600 ft)
- Research tools includes cameras, spectrometers, and a drill
- Estimated lifespan of one luna day (14 Earth days)
- Communication with the lander and ground control team in India

The rover has two payloads. They are APXS (Alpha Particle X-Ray Spectrometer) which is used to find the chemical composition and infer mineralogical composition to increase the understanding of luna plane. Another payload LIBS (Laser Induced Breakdown Spectroscope) which is designed to find the mineral constitution of Manganese , Aluminum , Silicon , potassium ,Calcium ,Titanium ,Iron of luna soil and rocks around the luna landing site.

IV. PAY LOAD ACCOMMODATION

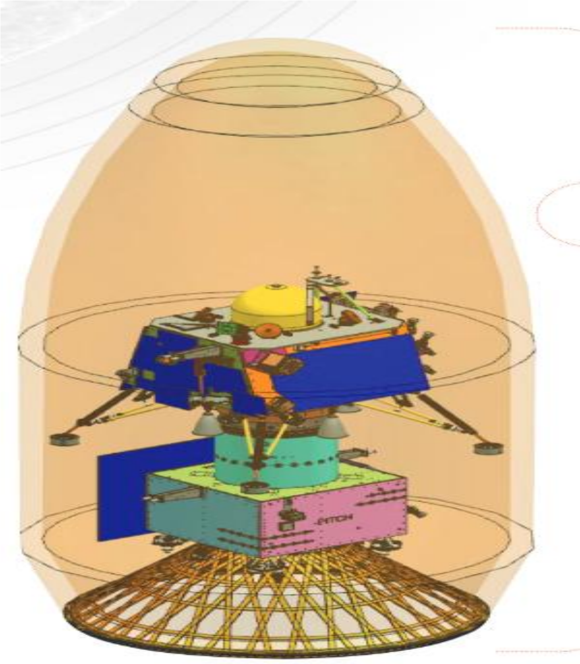

Figure 19: Complete Model

Figure 20: Stages of Chandrayaan

REFERENCES

[1] "Chandrayaan-1 Successfully Enters Luna Orbit". ISRO. Archived from the original on 30 June 2014. Retrieved 8 November 2008.
[2] Laxman, Srinivas (15 November 2008). "Chandrayaan-I Contact Probe lands on moon". Times Of India. Retrieved 14 November 2008.
[3] "Luna 2". US National Space Science Data Center. Retrieved 3 December 2013.
[4] "Ranger 3". US National Space Science Data Center. Retrieved 3 December 2013.
[5] "Hiten". NASA Space Science Data Coordinated Archive (NSSDCA). Retrieved 12 April 2019.
[6] "Probe crashes into Moon's plane". BBC News. 3 September 2006. Retrieved 23 May 2010.
[7] "China's luna probe Chang'e-1 contacts moon_English_Xinhua". news.xinhuanet.com. Archived from the original on 2 March 2009.
[8] "Chandrayaan-1 starts observations of the Moon". www.esa.int. Retrieved 29 July 2022.
[9] "An afterthought". frontline.thehindu.com. 18 December 2008. Retrieved 29 July 2022.
[10] "Chandrayaan team over the Moon". The Hindu. 15 November 2008. Archived from the original on 16 December 2008.
[11] "081125 Chandrayaan1 Moon probe a big hit". www.astronomynow.com. Archived from the original on 29 July 2022. Retrieved 29 July 2022.
[12] "8.4 Chandrayaan-1 Mission The New Face of the Moon by J.N. GOSWAMI". From Fishing Hamlet To Red Planet. Harper Collins. 2015. p. 506. ISBN 978-9351776895. Archived from the original on 9 September 2017. Retrieved 28 March 2019. The landing site of the MIP was named 'Jawahar Sthal' to commemorate the birthday of India's first Prime Minister, Jawaharlal Nehru, which also falls on 14 November coinciding with the date of the MIP contact.
[13] Acharya, Prasanna; Singh, Jitendra (3 August 2017). "Question No. 2222: Status of Chandrayaan Programme" (PDF). Rajya Sabha.
[14] Bhandari N. (2005). "Title: Chandrayaan-1: Science goals" (PDF). Journal of Earth System Science. **114** (6): 699. Bibcode:2005JESS..114..701B. doi:10.1007/BF02715953. S2CID 55469375.
[15] VOA News – Chandrayaan Luna Probe detects H2O on Moon

[16] "Chandrayaan-2 Latest Update". Indian Space Research Organisation. 7 September 2019. Archived from the original on 8 September 2019. Retrieved 7 September 2019.
[17] Nair, Avinash (31 May 2015). "ISRO to deliver "eyes and ears" of Chandrayaan-2 by 2015-end". The Indian Express. Archived from the original on 15 February 2018. Retrieved 7 August 2016.
[18] "Launch Kit of GSLV Mk III M1 Chandrayaan-2" (PDF). Indian Space Research Organisation. 19 July 2019. Archived (PDF) from the original on 19 July 2019. Retrieved 21 July 2019.
[19] "Chandrayaan-2 to Be Launched in January 2019, Says ISRO Chief". NDTV. 29 August 2018. Archived from the original on 29 August 2018. Retrieved 29 August 2018.
[20] "ISRO to send first Indian into Space by 2022 as announced by PM, says Dr Jitendra Singh" (Press release). Department of Space. 28 August 2018. Archived from the original on 28 August 2018. Retrieved 29 August 2018.
[21] "Chandrayaan-2: All you need to know about India's 2nd Moon mission". The Times of India. 21 July 2019. Archived from the original on 14 July 2019. Retrieved 22 July 2019.
[22] "Chandrayaan-2". Indian Space Research Organisation. Archived from the original on 29 July 2019. Retrieved 20 June 2019.
[23] "Launch kit at a glance". Indian Space Research Organisation. Archived from the original on 23 July 2019. Retrieved 23 July 2019.
[24] "Chandrayan-2 Launch Rescheduled on 22 July 2019, AT 14:43 HRS". Indian Space Research Organisation. 18 July 2019. Archived from the original on 30 August 2019. Retrieved 18 July 2019.
[25] Singh, Surendra (5 August 2018). "Chandrayaan-2 launch put off: India, Israel in luna race for 4th position". The Times of India. Archived from the original on 19 August 2018. Retrieved 15 August 2018.
[26] Shenoy, Jaideep (28 February 2016). "ISRO chief signals India's readiness for Chandrayaan II mission". The Times of India. Archived from the original on 20 July 2019. Retrieved 7 August 2016.
[27] Ratcliffe, Rebecca (22 July 2019). "India's Chandrayaan-2 moon mission lifts off a week after aborted launch". The Guardian. Archived from the original on 22 July 2019. Retrieved 23 July 2019.
[28] "GSLV-Mk III – M1 / Chandrayaan-2 Mission". Indian Space Research Organisation. Archived from the original on 12 September 2019. Retrieved 21 July 2019.
[29] Kiran Kumar, Aluru Seelin (August 2015). Chandrayaan-2 – India's Second Moon Mission. youtube.com. Inter-University Centre for Astronomy and Astrophysics. Retrieved 7 August 2016.
[30] "ISRO aims for Chandrayaan-2 landing at 1.55 AM on September 7, says Dr K. Sivan" (Press release). Delhi. Press Information Bureau. Archived from the original on 20 August 2019. Retrieved 24 August 2019.
[31] Madhumathi, D. S. (9 June 2019). "ISRO gears up for Chandrayaan-2 mission". The Hindu. Archived from the original on 19 June 2019. Retrieved 10 June 2019.
[32] Chand, Manish (12 November 2007). "India, Russia to expand n-cooperation, defer Kudankulam deal". Nerve. Archived from the original on 13 January 2014. Retrieved 12 January 2015.
[33] Sunderarajan, P. (19 September 2008). "Cabinet clears Chandrayaan-2". The Hindu. Archived from the original on 20 July 2021. Retrieved 23 October 2008.
[34] "ISRO completes Chandrayaan-2 design". Domain-b.com. 17 August 2009. Archived from the original on 8 June 2019. Retrieved 20 August 2009.
[35] "Payloads for Chandrayaan-2 Mission Finalised" (Press release). Indian Space Research Organisation. 30 August 2010. Archived from the original on 13 May 2019. Retrieved 4 January 2010.
[36] Ramachandran, R. (22 January 2013). "Chandrayaan-2: India to go it alone". The Hindu. Archived from the original on 1 August 2017. Retrieved 21 January 2013.
[37] Laxman, Srinivas (6 February 2012). "India's Chandrayaan-2 Moon Mission Likely Delayed After Russian Probe Failure". Asian Scientist. Archived from the original on 8 June 2019. Retrieved 5 April 2012.
[38] "India's next moon mission depends on Russia: ISRO chief". NDTV. 9 September 2012. Archived from the original on 8 June 2019. Retrieved 2 April 2016.
[39] "Chandrayaan-2" (Press release). Department of Space. 14 August 2013. Archived from the original on 5 August 2019. Retrieved 26 August 2017. Chandrayaan-2 would be a lone mission by India without Russian tie-up.
[40] "How ISRO modified a luna orbiter into Mars orbiter Mangalyaan, India's "Moon Man" recalls". Zee News. 25 October 2020. Archived from the original on 26 October 2020. Retrieved 25 October 2020.
[41] Clark, Stephen (15 August 2018). "Launch Schedule". Spaceflight Now. Archived from the original on 16 August 2018.
[42] "Chandrayaan-2 launch postponed to October: ISRO chief". India Times. 23 March 2018. Archived from the original on 11 July 2019. Retrieved 16 August 2018.

[43] "Soft-landing challenges keep Chandrayaan-2 grounded". The Times of India. 5 August 2018. ISSN 0971-8257. Archived from the original on 29 December 2021. Retrieved 9 July 2023
[44] "ISRO to launch moon mission Chandrayaan-3 on July 14. Check details". Hindustan Times. 6 July 2023. Archived from the original on 8 July 2023. Retrieved 6 July 2023.
[45] "Chandrayaan-3 Launch LIVE Updates: Chandrayaan 3 successfully separated from LVM, injected to internal orbit". mint. 14 July 2023. Archived from the original on 17 July 2023. Retrieved 14 July 2023.
[46] "Chandrayaan-3 launch on July 14; August 23-24 preferred landing dates". THE TIMES OF INDIA. 6 July 2023. Archived from the original on 8 July 2023. Retrieved 7 July 2023.
[47] "ANI on Twitter". 14 July 2023. Archived from the original on 17 July 2023. Retrieved 14 July 2023.
[48] "Mission homepage". Archived from the original on 23 June 2023. Retrieved 29 June 2023.
[49] "India launches Chandrayaan-3 mission to the luna plane". Physicsworld. 14 July 2023. Archived from the original on 17 July 2023. Retrieved 15 July 2023.
[50] "Chandrayaan-3 to cost Rs 615 crore, launch could stretch to 2021". The Times of India. 2 January 2020. Archived from the original on 19 November 2021. Retrieved 3 January 2020.
[51] "NASA - NSSDCA - Spacecraft - Details". Archived from the original on 8 June 2022. Retrieved 10 June 2022.
[52] Guptan, Mahesh (16 November 2019). "How did Chandrayaan 2 fail? ISRO finally has the answer". The Week. Archived from the original on 19 February 2021. Retrieved 3 January 2020.
[53] "Chandrayaan-3". www.isro.gov.in. Archived from the original on 10 July 2023. Retrieved 14 July 2023.
[54] "Chandrayaan 3 Launch Live: India's Chandrayaan-3 moon mission lifts off from Sriharikota". The Times of India. 14 July 2023. Archived from the original on 17 July 2023. Retrieved 14 July 2023.
[55] "Chandrayaan-3 launch on 14 July, luna landing on 23 or 24 August". The Hindu. 6 July 2023. ISSN 0971-751X. Archived from the original on 11 July 2023. Retrieved 14 July 2023.
[56] 'ISRO Launches Chandrayaan-3 Moon Mission'. Scientific European. Retrieved 2023-07-14
[57] "Chandrayaan-3 a shot in the arm for Gaganyaan-1". The Times of India. 15 July 2023. Archived from the original on 17 July 2023. Retrieved 15 July 2023.
[58] Singh, Surendra (5 August 2018). "Chandrayaan-2 launch put off: India, Israel in luna race for 4th position". The Times of India. Archived from the original on 19 August 2018. Retrieved 15 August 2018.
[59] Shenoy, Jaideep (28 February 2016). "ISRO chief signals India's readiness for Chandrayaan II mission". The Times of India. Archived from the original on 20 July 2019. Retrieved 3 January 2020.
[60] "ESA and Indian space agency ISRO agree on future cooperation". www.esa.int. Archived from the original on 21 March 2022. Retrieved 16 April 2022.
[61] "Indian Space Research Organisation". www.isro.gov.in. Archived from the original on 2 October 2019. Retrieved 14 July 2023.
[62] Kumar, Chethan (19 November 2019). "Chandrayaan-3 plans indicate failures in Chandrayaan-2". The Times of India. Archived from the original on 21 November 2019. Retrieved 15 September 2020.
[63] After 4 Years, ISRO Reveals Why Chandrayaan 2 FAILED, retrieved 10 August 2023
[64] Sharma, Shaurya (21 October 2022). "Chandrayaan-3 To Be More Robust, Have Contingency Systems Onboard, Says ISRO Chief". News18. Archived from the original on 22 October 2022. Retrieved 22 October 2022.
[65] "ISRO Chandrayaan 3 brochure" (PDF).Archived 10 July 2023 at the Wayback Machine
[66] "ISRO Chandrayaan 3 brochure" (PDF).Archived 10 July 2023 at the Wayback Machine
[67] "Chandrayaan-3: Historic India Moon mission sends new photos of luna plane". 7 August 2023. Retrieved 7 August 2023.
[68] "Chandrayan-3 lifts off on mission to the moon". 14 July 2023. Archived from the original on 17 July 2023. Retrieved 14 July 2023.
[69] "Chandrayaan 3: Know why July is important for ISRO". News9live. 14 July 2023. Archived from the original on 17 July 2023. Retrieved 14 July 2023
[70] Image courtesy: https://en.wikipedia.org/wiki/Chandrayaan-1
[71] Image courtesy: https://en.wikipedia.org/wiki/Chandrayaan-2
[72] Image courtesy: https://en.wikipedia.org/wiki/Chandrayaan-3
[73] Image Courtesy: https://www.isro.gov.in/Chandrayaan3_New.html

