CHANDRAYAAN-2 : THE SECOND INDIAN MISSION TO THE MOON. M. Vanitha, P. Veeramuthuvel, K. Kalpana and G. Nagesh, vani@ursc.gov.in, U R Rao Satellite Centre, Indian Space Research Organisation (ISRO), Bengaluru (India).

Introduction: Chandrayaan-2 is the second Indian lunar mission launched on the 22nd of July 2019. Chandrayaan-2 was placed in a 170 x 45438 km Elliptic Parking Orbit (EPO) by ISRO's GSLV MK-III launch vehicle. The major objectives of the mission are:

(1) To develop and demonstrate the key technologies for end-to-end lunar mission capability, including soft-landing and roving on the lunar surface.

(2) To expand the lunar scientific knowledge through detailed study of topography, mineralogy, surface chemical composition, thermo-physical characteristics and tenuous lunar atmosphere leading to a better understanding of the origin and evolution of the Moon.

Chandrayaan-2 configuration: Chandrayaan-2 as an integrated module comprises of an Orbiter, Lander named Vikram and Rover named Pragyan. The photographs of the Integrated Module, Orbiter, Vikram and Pragyan are shown in Figure-1. The orbiter weighs 2369 kg, Vikram weighs 1477 kg (inclusive of Pragyan 25kg) and the integrated module weighs 3846 kg.

The Orbiter through a series of Earth Burns (EBN) increased the apogee height and brought the orbit close to the Moon as depicted in Figure-2. At the appropriate time, Trans Lunar Injection (TLI) and Lunar Orbit Insertion (LOI) were carried out and the Integrated Module entered the Moon's orbit. After insertion in Moon's orbit, the propulsion system of Orbiter was used to reduce the orbit of the integrated module to 130 x 116 km orbit, following which, Vikram was successfully separated from the Orbiter. Subsequently, two deboost maneuvers were carried out on the Vikram to achieve a 100 x 35 km orbit. Vikram spent around 4 days in this orbit. The entire maneuver strategy was designed such that the orbital plane contains the desired landing site and the day of launch and position of insertion into the Lunar Orbit were timed so as to maximize the life of the Lander and Rover mission. Powered descent of Vikram was initiated using an Autonomous landing Sequencer (ALS) to the designated landing site using a closed loop Navigation, Guidance and Control system to ensure a precise soft landing at touchdown. Most of the new technologies developed for Vikram were demonstrated during powered descent except for soft landing.

Orbiter: The orbiter has deployable, sun tracking panels capable of generating ~1000W of power. The propulsion system is of bi-propellant type and has a centrally mounted 440 N engine along with 8 numbers of 22N AOCS thrusters. The attitude and orbit control electronics of the orbiter receives the absolute attitude data from the star sensors and the body rates/incremental velocity from Inertial Reference Unit and Accelerometer Package (IRAP) for spacecraft control. The telemetry system provides the health information of the spacecraft while the tele-command system handles the command execution and distribution. The payloads are interfaced to the base band data handling system for formatting and further recording in Solid State Recorder for play back at a later time. The RF system consists of S band TTC transponder for telecommand and telemetry data transfer and X band transmitter for Payload data transmission to Indian Deep Space Network (IDSN) station/ Deep Space Network (DSN).

Vikram: Vikram has body mounted solar panels which can generate ~680 W of power. It has 4 no's of 800 N throttle-able engines, a fixed thrust 800N central engine and 8 numbers of 58N AOCS thrusters. LIRAP (Laser gyro based Inertial Reference Unit and Accelerometer Package) sensor provides attitude referencing for the lander after it separates from the orbiter till landing. The accelerometers provide velocity increment for the liquid engine cutoff during orbit maneuvers. It also provides inertial navigation information (position, velocity & quaternions) from lander separation till touchdown. The RF and baseband systems are similar to orbiter.

A Hazard Detection and Avoidance (HDA) system was also developed for the mission. It comprises of several sensors like Orbiter High Resolution Camera (OHRC) for characterization of Landing Site, Cameras for horizontal velocity computation, Camera for pattern matching and position estimation and Microwave and Laser Altimeter for altitude measurement. The Lander Leg Mechanism that helps in achieving soft landing and maintain the structural integrity of the Lander – Rover post landing were also developed. Several special tests were conceived and conducted to validate the new technologies.

Rover: Rover has a deployable solar panel capable of generating ~50 W of power. Rover chassis houses all the electronics and has two navigation cameras to generate stereo images for path planning. The rocker bogie mechanism along with the six wheels ensure a rugged mobility system over obstacles and slopes along the identified path for exploration of the lunar surface. The Rover communicates to IDSN via the Lander.

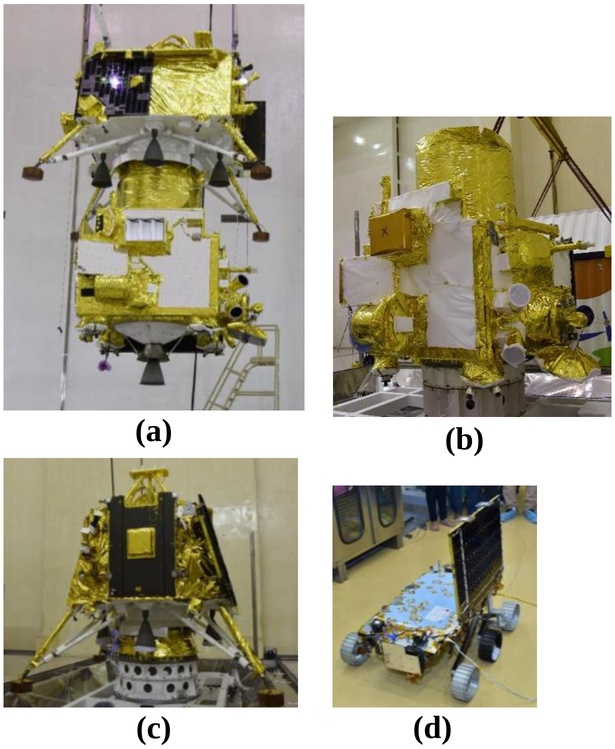

Figure-1: Photographs of Chandrayaan-2;
(a) Integrated Module, (b) Orbiter,
(c) Lander - Vikram & (d) Rover-Pragyan

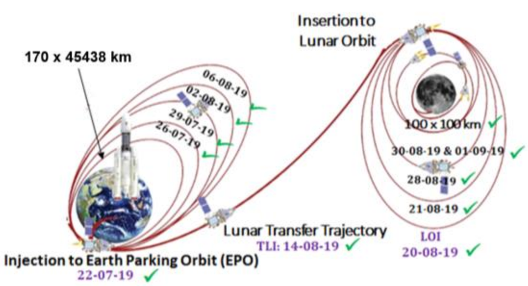

Figure-2: Mission Profile with critical events

Payloads in Chandrayaan-2 and their science objectives: Chandrayaan-2 aims at understanding the origin and evolution of the Moon using instruments onboard Orbiter and in-situ analysis of lunar surface using instruments on the Lander and Rover. The instruments on the Orbiter are the following:

1. Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS) along with Solar X-ray Monitor (XSM) to map the major elements on the lunar surface.
2. L and S Band Synthetic Aperture Radar (SAR), will image the lunar surface to understand the scattering characteristics of surface and subsurface features including water ice in the Polar Regions.
3. Imaging Infra-Red Spectrometer (IIRS) will image and measure spectra of the lunar surface in the spectral range of 0.8 to 5.0 µm to investigate minerals and signatures of water and hydroxyl molecules.
4. Terrain Mapping Camera (TMC-2) will provide a three-dimensional map of lunar surface.
5. Neutral Mass Spectrometer (ChACE-2) will carry out a detail study of lunar exosphere.
6. Dual Frequency Radio Science (DFRS) will measure the total electron content of lunar ionosphere.
7. Orbiter High Resolution Camera (OHRC) will provide high resolution images for regions of interest.

The instruments on Vikram are the following:

1. Instrument for Lunar Seismic Activity (ILSA) will measure seismicity around the landing site.
2. Chandra's Surface Thermo physical Experiment (ChaSTE) will carry out the measurements of thermal properties of lunar surface.
3. Radio Anatomy of Moon Bound Hypersensitive ionosphere and Atmosphere (RAMBHA-Langmuir Probe) will measure near surface plasma density and its diurnal changes.

The two payloads on the Rover are Laser Induced Breakdown Spectroscope (LIBS) and Alpha Particle X-ray Spectroscope (APXS) to carry out elemental analysis of the lunar surface around the landing site.

Orbiter operations: Orbit maneuver operations are being carried out whenever required to maintain the orbit and to take care of payload requirements. Based on Dawn-Dusk, Noon-Midnight orbit of the orbiter with respect to the Sun, payload operations are optimally planned to ensure systematic coverage of the lunar surface.

Conclusion: There has been renewed interest in lunar exploration across the globe and India's Chandrayaan-2 mission has a suite of payloads for better understanding of the moon. A number of new technologies were developed for Vikram and were demonstrated successfully during the powered descent phase of Vikram except for the soft landing.

Acknowledgements: The authors wish to thank Director, URSC / ISRO management for their guidance & support and the team members of Chandrayaan-2 for their valuable technical contribution for this mission.