PSLV-C25 / MARS ORBITER MISSION (MOM)

05 November, 2013

THE MISSION

PSLV-C25 carrying on-board the MARS ORBITER MISSION (MOM) Spacecraft lifted-off from the Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota at 02:36 PM (IST) on November 05, 2013. The challenging PSLV-C25 mission was optimised for the launch of MOM spacecraft into a highly elliptical Earth Orbit with a perigee of 250 km and an apogee of 23,500 km with an inclination of 19.2^0 with respect to the Equator. Following this, the apogee height of the spacecraft's orbit was successively raised through a series of manoeuvres to nearly 1,93,000 km.

Subsequent to six orbit raising manoeuvres around the Earth following the launch, the Trans Mars Injection (TMI) Manoeuvre on December 01, 2013 gave necessary thrust (440 Newton liquid engine fired for about 22 minutes providing a velocity increment of 648 meters / second) to the spacecraft to escape from Earth and to initiate the journey towards Mars, in a Heliocentric Orbit. This journey, of course, was long wherein the spacecraft had to travel 680 million km.

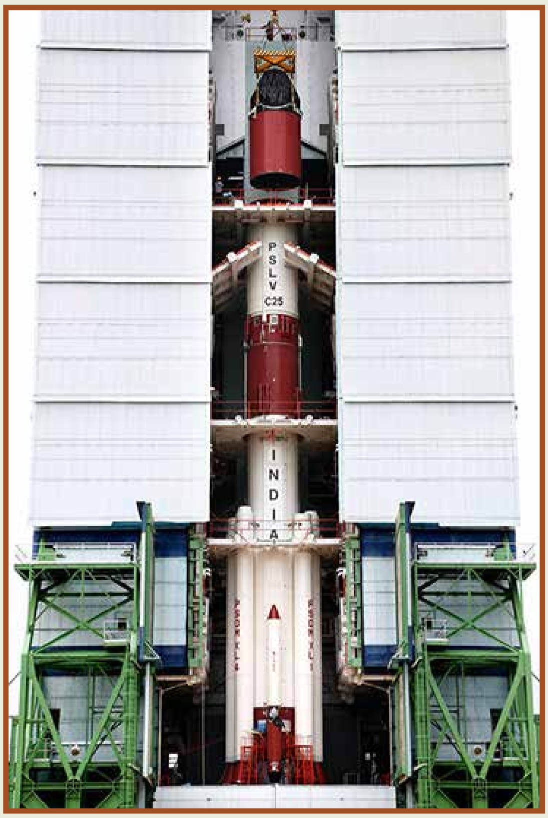
On December 11, 2013, the First Trajectory Correction Manoeuvre (TCM) was conducted. Three more TCM operations were planned around April 2014, August 2014 and September 2014. The propulsion system of the spacecraft was configured for TCMs and the Mars Orbit Insertion (MOI) Operation.

On February 6, 2014, all the five payloads on Mars Orbiter spacecraft were switched 'ON' to check for their health parameters, which were normal. After travelling the remaining

distance of about 490 million km over the next 210 days, the spacecraft was inserted into the Martian Orbit on September 24, 2014.

Mars Orbiter spacecraft successfully entered into an orbit around planet Mars by firing its 440 Newton Liquid Apogee Motor (LAM) along with eight smaller liquid engines. This Liquid Engines firing operation which began at 07:17:32 AM (IST) lasted for 1388.67 seconds which changed the velocity of the spacecraft by 1099 metre/sec. With this operation, the spacecraft entered into an elliptical orbit around Mars. The spacecraft was circling Mars in an orbit whose nearest point to Mars (periapsis) is at 421.7 km and farthest point (apoapsis) at 76,993.6 km. The inclination of orbit with respect to the Equatorial plane of Mars is 150^0, as intended. In this orbit, the spacecraft takes 72 hours 51 minutes & 51 seconds to go around Mars once.

Mars Orbiter spacecraft (MOM) was under 'solar conjunction' at Mars, which means the spacecraft, which was orbiting Mars, was behind the Sun as viewed from the Earth. As a result of this event which happens once in 2.2 years for Mars, communication signals from the spacecraft are severely disrupted by the Sun's corona (outer atmosphere). The reason for this is the charged particles from the Sun are responsible for the reception of noisy signals at the ground antenna from the spacecraft. The conjunction for Mars Orbiter spacecraft began on May 27, 2015 and was extended up to July 01, 2015. No commands were transmitted to the spacecraft during this period for safety reasons and only telemetry (spacecraft's health related information) was monitored. All payload operations were also suspended.



Mars Orbiter Mission Profile

1. Geocentric Phase

The spacecraft is injected into an Elliptic Parking Orbit by the launcher. With six main engine burns, the spacecraft is gradually maneuvered into a departure hyperbolic trajectory with which it escapes from the Earth's Sphere of Influence (SOI) with Earth's orbital velocity + ΔV boost. The SOI of Earth ends at 918347 km from the surface of the Earth beyond which the perturbing force on the orbiter is mainly due to the Sun. One primary concern is how to get the spacecraft to Mars, on least amount of fuel. ISRO uses a method of travel called a Hohmann Transfer Orbit or a Minimum Energy Transfer Orbit to send a spacecraft from Earth to Mars with the least amount of fuel possible.

2. Heliocentric Phase

The spacecraft leaves Earth in a direction tangential to Earth's orbit

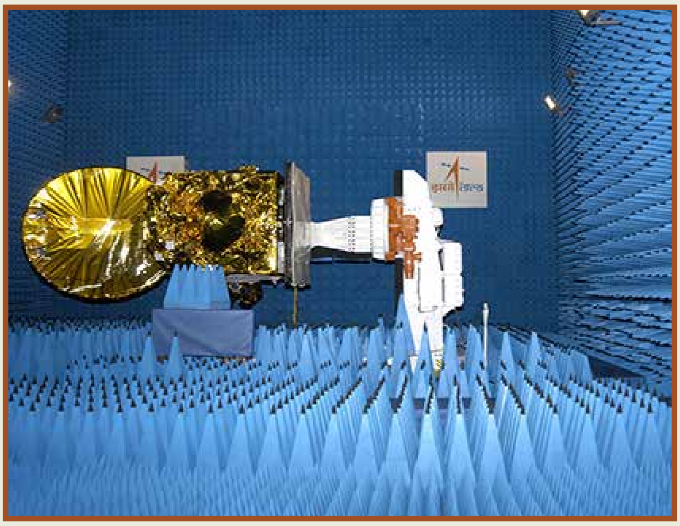
and encounters Mars tangentially to its orbit. The flight path is roughly one half of an ellipse around sun. Eventually, it will intersect the orbit of Mars at the exact moment when Mars is there too. This trajectory becomes possible with certain allowances when the relative position of Earth, Mars and Sun form an angle of approximately 44^0. Such an arrangement recurs periodically at intervals of about 780 days. Minimum energy opportunities for Earth-Mars occur in November 2013, January 2016, May 2018 etc.

3. Martian Phase

The spacecraft arrives at the Mars Sphere of Influence (around 573473 km from the surface of Mars) in a hyperbolic trajectory. At the time, the spacecraft reaches the closest approach to Mars (Periapsis), it is captured into planned orbit around mars by imparting ΔV retro which is called the Mars Orbit Insertion (MOI) manoeuvre. ISRO launched the Mars Orbiter Mission during the November 2013 window utilizing minimum energy transfer opportunity.

Mission Objectives

One of the main objectives of the first Indian mission to Mars is to develop the technologies required for design, planning, management and operations of an interplanetary mission. Following are the major objectives of the mission:



A. Technological Objectives

- Design and realisation of a Mars Orbiter with a capability to survive and perform Earth bound manoeuvres, cruise phase of 300 days, Mars Orbit Insertion / capture, and on-orbit phase around Mars.
- Deep Space Communication, navigation, mission planning and management.
- Incorporate autonomous features to handle contingency situations.

B. Scientific Objectives

- Exploration of Mars surface features, morphology, mineralogy and Martian atmosphere by indigenous scientific instruments.

PSLV-C25

THE LAUNCH VEHICLE

PSLV-C25 was the 25th mission of PSLV and the 5th in 'XL' configuration. The major technical challenges for the launch vehicle arise from the larger Argument of Perigee (AOP) requirement ranging from 276.4^0 to 288.6^0 compared to 178^0 from earlier missions. This AOP minimises the energy required in transferring the satellite from Earth to Mars. In this regard, the launch vehicle right regime is extended to 2657s (against 1200s for regular PSLV missions) with a long coasting (1580-1800s) before the ignition of the PS4 stage. The long coasting necessitated specific modification and validation of the coast phase guidance algorithm, on-board battery capacity augmentation, assessment on the performance of inertial systems for extended flight duration and deployment of two Ship-borne Terminals to capture the critical telemetry data during flight in the non-visibility zone. Additional provisions are made for the thermal management of Vehicle Equipment Bay, PS4 stage and also the spacecraft elements considering the longer exposure to extreme cold space. Another unique task associated with management of this mission is the generation and Configuration Control of multiple Initialization Files for the on-board computers corresponding to the different launch dates.

The launch vehicle is tracked during its flight from lift-off till spacecraft separation by a network of ground stations, which receive the telemetry data from the launch vehicle and transmit it in real-time to the mission computer systems at Sriharikota, where it is processed. The ground stations at Sriharikota, Port Blair, Brunei provide continuous tracking of the PSLV-C25 from lift-off till burnout of the third stage of PSLV-C25. Two ships carrying Ship Borne Terminals (SBT) are being deployed at suitable locations in the South Pacific Ocean, to support the tracking of the launch vehicle from PS4 ignition till spacecraft separation.

SPECIFICATIONS

Height	44.4 m
Lift-Off Mass	320 t
No of Stages	4
Payload	Mars Orbiter Mission (MOM)
Inclination (deg)	19.2^0
Launch Azimuth	104^0
Apogee	23500 km
Perigee	250 km
Launch Pad	First Launch Pad (SDSC, SHAR)

STAGE CHARACTERISTICS					
	STAGE-1	**PSOM-XL**	**STAGE-2**	**STAGE-3**	**STAGE-4**
Propellant	Solid (HTPB Based)	Solid (HTPB Based)	Liquid (UH25 + N_2O_4)	Solid (HTPB Based)	Liquid (MMH + MON-3)
Propellant Mass (t)	138	12.2	42	7.6	2.5
Peak Thrust (kN)	4800	718	799	247	7.3 x 2
Burn Time (sec)	103	50	148	112	525
Diameter (m)	2.8	1	2.8	2.0	2.8
Length (m)	20	12	12.8	3.6	2.7

MARS ORBITER MISSION (MOM)

THE SPACECRAFT

MOM was primarily technological mission considering the critical mission operations and stringent requirements on propulsion and other bus systems of spacecraft. It has been configured to carry out observation of physical features of Mars and carry out limited study of Martian atmosphere with following five payloads: Three electro-optical payloads operating in the visible and thermal infrared spectral ranges and a photometer to sense the Mars atmosphere & surface. One additional backup payload is planned in case of non-availability of the identified payloads.

- **Methane Sensor for Mars (MSM)**
  MSM is designed to measure Methane (CH4) in the Martian atmosphere with PPB accuracy and map its sources. Data is acquired only over illuminated scene as the sensor measures reflected solar radiation. Methane concentration in the Martian atmosphere undergoes spatial and temporal variations. Hence, global data is collected during every orbit.

- **Mars Colour Camera (MCC)**
  This tri-colour Mars Colour Camera gives images & information about the surface features and composition of Martian surface. They are useful to monitor the dynamic events and weather of Mars. MCC will also be used for probing the two satellites of Mars – Phobos & Deimos. It also provides the context information for other science payloads.

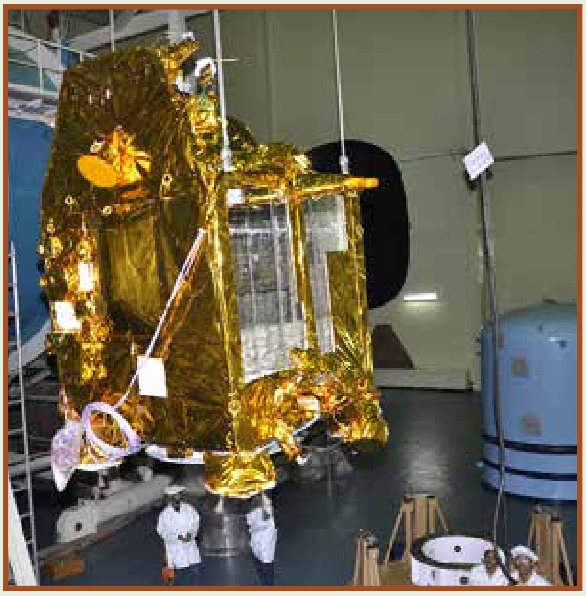
- **Lyman Alpha Photometer (LAP)**
  Lyman Alpha Photometer (LAP) is an absorption cell photometer. It measures the relative abundance of deuterium and hydrogen from Lyman-alpha emission in the Martian upper atmosphere (typically Exosphere and Exobase). Measurement of D/H (Deuterium to Hydrogen Abundance Ratio) allows us to understand especially the loss process of water from the planet.

  The objectives of this instrument are as follows:
  a. Estimation of D/H ratio
  b. Estimation of escape flux of H2 corona
  c. Generation of Hydrogen and Deuterium coronal profiles

- **Thermal Infrared Imaging Spectrometer (TIS)**
  TIS measure the thermal emission and can be operated during both day and night. Temperature and emissivity are the two basic physical parameters estimated from thermal emission measurement. Many minerals and soil types have characteristic spectra in TIR region. TIS can map surface composition and mineralogy of Mars.

- **Mars Exospheric Neutral Composition Analyser (MENCA)**
  MENCA is a quadruple mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 amu with unit mass resolution. The heritage of this payload is from Chandra's Altitudinal Composition Explorer (CHANCE) payload aboard the Moon Impact Probe (MIP) in Chandrayan-1 mission.

After satellite separation from the launch vehicle, the spacecraft operations are controlled from the Spacecraft Control Centre in Bangalore. To ensure the required coverage for carrying out the mission operations, the ground stations of ISTRAC at Bangalore, Mauritius, Brunei, and Biak are being supplemented by Alcantara and Cuiaba TTC stations of INPE, Brazil, Hartebeestoek TTC station of SANSA and the DSN network of JPL, NASA.



SPECIFICATIONS

Weight	1337 kg
Power	Single Solar Array – 1.8m X 1.4 m 3 panels 840 W Generation (in Martian orbit), 36 Ah Li-Ion Battery
Structures	Aluminium and Composite Fibre Reinforced Plastic (CFRP) sandwich construction modified I-1 K Bus
Attitude and Orbit Control System	AOCE with MAR31750 Processor Sensors: Star Sensors (2), Solar Panel Sun Sensor (1), Coarse Analogue Sun Sensor. Actuators: Reaction Wheels (4), Thrusters (8), 440 N Liquid Engine
Propulsion	Bi propellant system (MMH + N_2O_4) with additional safety redundancy features for MOI Propellant Mass: 852 kg
Thermal System	Passive Thermal Control System
Antenna	Low Gain Antenna (LGA), Mid Gain Antenna (MGA), High Gain Antenna (HGA)
Type of Satellite	Science & Exploration
Payloads	• Mars Colour Camera (MCC) • Thermal Infrared Imaging Spectrometer (TIS) • Methane Sensor for Mars (MSM) • Mars Exospheric Neutral Composition Analyser (MENCA) • Lyman Alpha Photometer (LAP)
Mission Life	4 Years (The designed mission life of MOM was 6 months)