Government of India
Department of Space

Dr S V SHARMA

Deputy Director, ISRO Satellite Centre, Bengaluru

Space Science & Interplanetary Missions- Chandrayaan-1 to MOM And Beyond

OUTLINE

1. Indian Space Programme
2. Space Science & Planetary Exploration
   - Chandrayaan-1 – India's First Mission to Moon
   - Indian Mars Orbiter Mission – Challenges & Success Story
3. Space Science Missions – On the Anvil
   - Astrosat
   - Chandrayaan-2
   - Aditya

The Facets Of Indian Space Programme

Space Exploration

Satellite Navigation

Advanced Space Systems

Satellite Communications

इसरो ISRO

1962

Launch Vehicles

Earth Observation

Space Commerce

Space Applications

VISION

Harness space technology for national development
…… we must be second to none in the applications of advanced technologies to the real problems of man and society. – Dr.Vikram Sarabhai

127 MISSIONS

Dec 2015

30 successive successful flights

Heavy Lift Launcher

Indigenous Cryo Stage

ACCOMPLISHMENTS IN SPACE

75+ 2

Remote Sensing
Communication
Navigation
Chandrayaan-1
Mars Orbiter

Satellites

50

SLV
ASLV
PSLV
GSLV
LVM3-X

Launch Vehicles

Space Capsule Recovery Experiment

01

Crew Module Atmospheric Re-entry Experiment

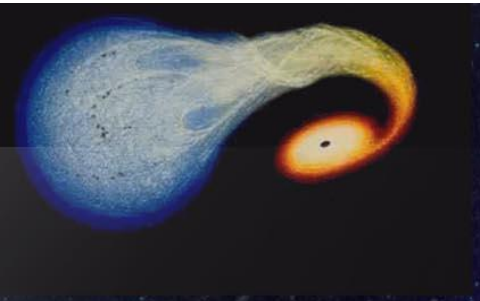
01

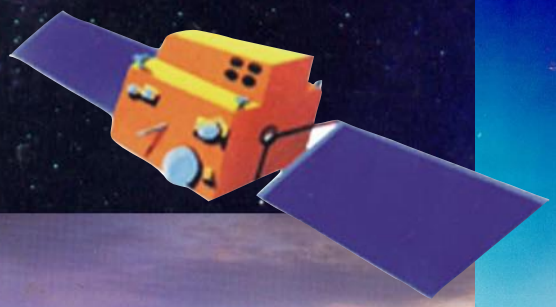
PSLV launched - 40 Satellites of 19 countries

Space Science & Planetary Exploration

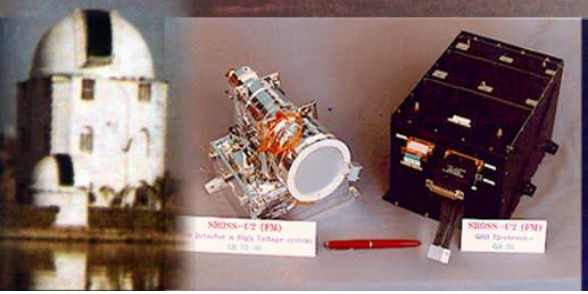
Space Science - The Quest For Knowledge

Much before applied science and technological applications enriched human lives astronomy (Space science of yesteryear) and its applications held sway over humans.





- X-RAY ASTRONOMY
- GAMMA RAY BURSTS
- IONOSPHERIC PLASMA
- MIDDLE ATMOSPHERIC DYNAMICS
- EQUATORIAL ELECTROJET
- SOLAR FLARES AND STORMS
- IONOSPHERIC TOPOGRAPHY
- PLANETARY EXPLORATION



- ASTRONOMY AND ASTROPHYSICS
- AERONOMY AND PLANETARY ATMOSPHERES
- EARTH SCIENCES AND SOLAR SYSTEM STUDIES
- THEORETICAL PHYSICS

CHANDRAYAAN-1

- PINNACLE OF ISRO'S INTERNATIONAL COOPERATION

- High resolution remote sensing in the visible, near infrared, microwave & X-ray regions
- Preparation of a 3D atlas & chemical mapping of entire lunar surface

Ground Segment

- Indian Deep Space Network (IDSN)
- Spacecraft Control Centre (SCC)
- Indian Space Science Data Centre (ISSDC)

Terrain Mapping Camera (TMC)

Hyperspectral Imager (HySI)

Lunar Laser Ranging Instrument (LLRI)

High Energy X-ray Spectrometer (HEX)

Moon Impact Probe (MIP)

Chandrayaan-1 Imaging X-ray Spectrometer (C1XS)

Smart Near Infrared Spectrometer (SIR-2)

Sub keV Atom Reflecting Analyser (SARA)

Radiation Dose Monitor (RADOM)

Mini Synthetic Aperture Radar (MiniSAR)

Moon Mineralogy Mapper (M3)

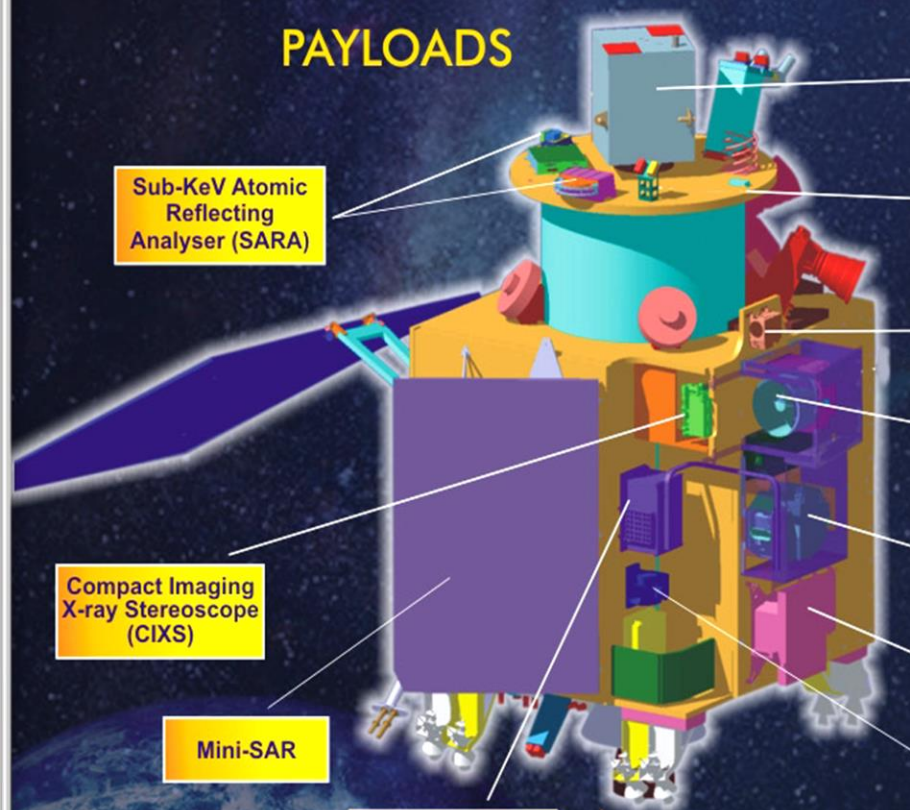
चन्द्रयान-1

भारत का पहला चन्द्र मिशन

CHANDRAYAAN-1

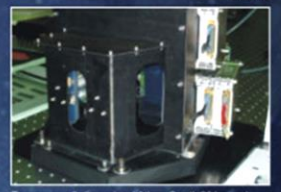
INDIA'S FIRST MISSION TO MOON

PAYLOADS



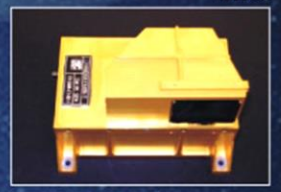
- Sub-KeV Atomic Reflecting Analyser (SARA)
- Compact Imaging X-ray Stereoscope (CIXS)
- Mini-SAR
- High Energy X-ray Spectrometer (HEX)
- Moon Impact Probe (MIP)
- Radiation Dose Monitor (RADOM)
- Shortwave Infrared Radiometer (SIR-2)
- Lunar Laser Ranging Instrument (LLRI)
- Terrain Mapping Camera (TMC)
- Moon mineralogy Mapper (M3)
- Hyper Spectral Imager (HySI)

TMC



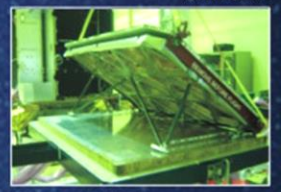
To prepare a 3-dimensional Atlas - Swath 20 km and Resolution 5m, Spectral Range 0.5 to 0.6 µm

SWIM



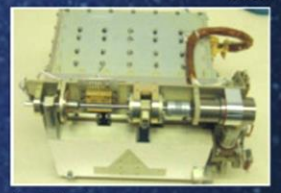
To image Solar Wind - Lunar surface interaction

Mini-SAR



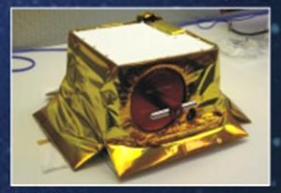
To detect Lunar Polar Water Ice

CIXS



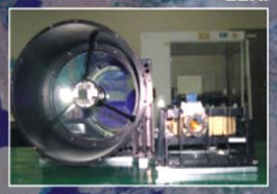
Chemical Mapping

SIR-2



Mineral Mapping

LLRI



To Determine Global Topographic Field of Moon
Supplement TMC and HySI
Improved model of lunar gravity field

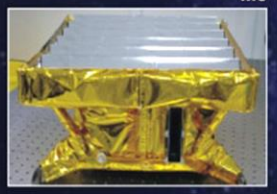
HySI

Spectral range 0.4 to 0.95 µm range ;
64 Bands, 80m resolution, 40km Swath

HEX

Volatile Transport on Moon
Th and U map of Polar and U-Th-rich regions

M3



Mineral mapping
256 bands of 10 nm resolution

CENA

To image the Moon surface using
low energy neutral atoms

RADOM

To measure Radiation Environment in Lunar
Orbit and enroute to the moon

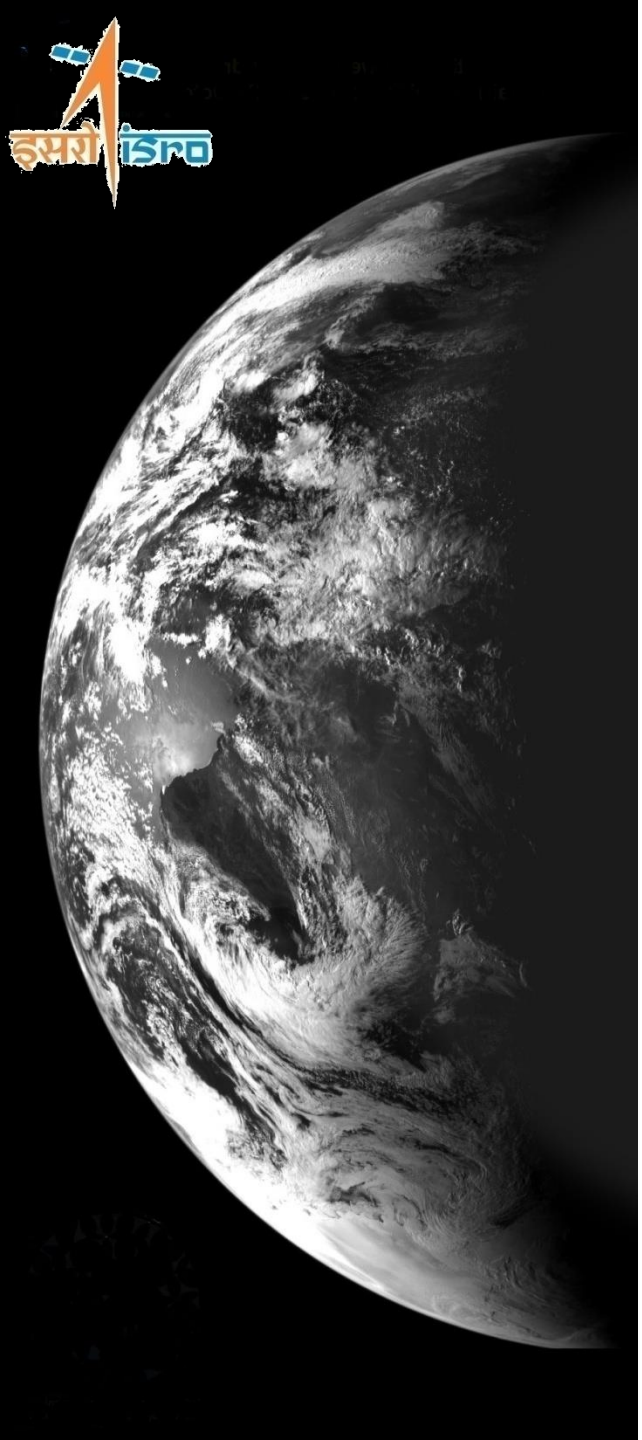
Indian Deep Space Network (IDSN)

18m Terminal is operational

Adequate for Chandrayaan-1

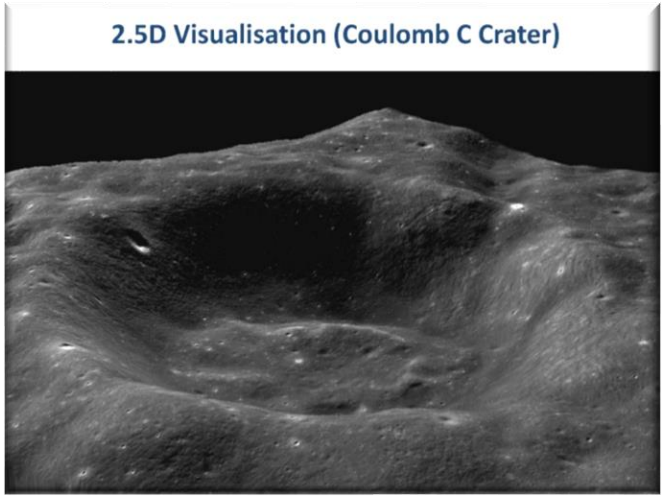
32m Terminal Cater to future interplanetary Missions beyond Moon

Both are Co-located near Bangalore (BYALALU)

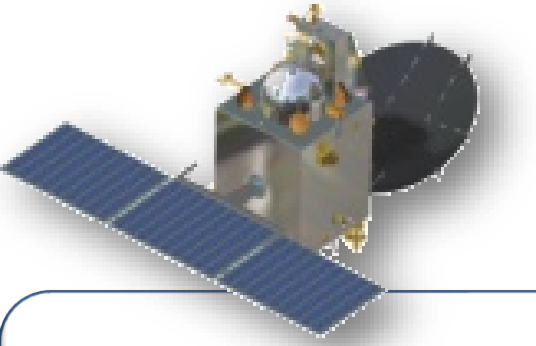


Earth as viewed by Chandrayaan-1 TMC on 29 Oct. 2008 Distance ~ 70000 Km. from Earth

IMAGES FROM MIP



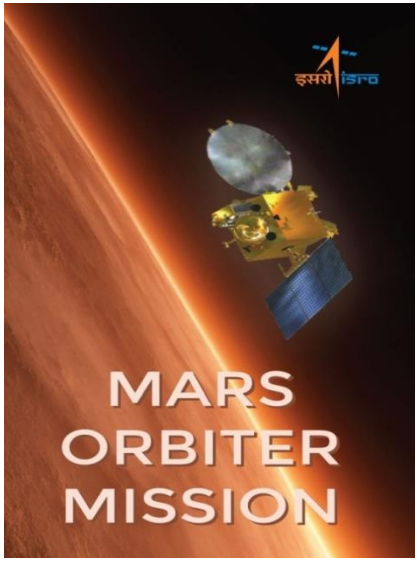
Discovered Hydroxyl and Water molecule on the Lunar surface



Mars Orbiter Mission

– Challenges & Success story

Mars Orbiter Mission - Overview



India's Pride -

- **First** Indian Interplanetary mission to Mars.
- **Fourth Space agency** to successfully reach Mars.
- **First country** to reach Martian orbit in its maiden attempt
- **Most economical** interplanetary mission
- **Realized in a record time** of 15 Months.
- **Successful accomplishment** of Mission Objectives

- **MoM,** was conceived as a logical **extension of Chandrayaan-1** with the objective to **Study surface features, morphology, topology, mineralogy of Mars and constituents of Martian atmosphere**
- **Develop & Demonstrate technologies** required for design, planning, management and operations of an interplanetary mission.
- **Constraint on Launch opportunity** : Once in 26 months. If September 2013 target is missed, next launch window is January 2016.

MOM team won the US based National Space Society's "Space Pioneer Award" for science and engineering category for the year 2015.

Indira Gandhi Prize for Peace, Disarmament & Development in recognition of path breaking achievement ,culminating in MOM & Strengthening International Cooperation in Peaceful use of Outer Space

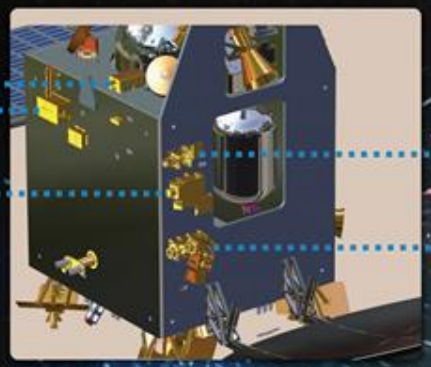
Mars Orbiter Mission - Overview Contd..

SCIENTIFIC PAYLOADS

Lyman Alpha Photometer (LAP)
Measures the relative abundance of deuterium and hydrogen from Lyman-alpha emission in the Martian upper atmosphere. allows us to understand especially the loss process of water from the planet.

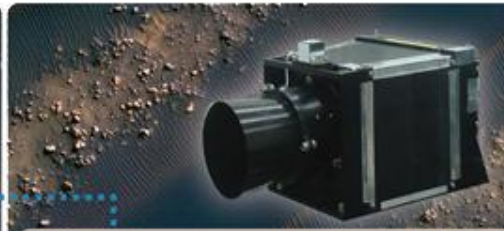
Methane Sensor for Mars (MSM)
Designed to measure Methane (CH4) in the Martian atmosphere with PPB accuracy and map its sources. Global data is collected during every orbit.

Atmospheric studies



Mars Exospheric Neutral Composition Analyser (MENCA)
quadruple mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 amu with unit mass resolution.

Plasma and particle environment studies



Mars Color Camera (MCC)
This tri-color camera gives images & information about the surface features and composition of Martian surface. Useful to monitor the dynamic events and weather.

Thermal Infrared Imaging Spectrometer (TIS)
measures thermal emission. Many minerals and soil types have characteristic spectra in TIR region. TIS can map surface composition and mineralogy of Mars.

Surface Imaging Studies

Mars Orbiter Mission - Challenges Contd..

MOM REALISATION CHALLENGES

SPACECRAFT CONFIGURATION

- Launch vehicle Limitation
- Short realization time

RISK MANAGEMENT

- Technical judgment
- Qualification of Systems

SPACECRAFT REALISATION

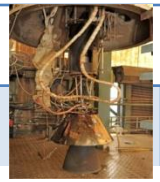
- New technology developments
- Mission Planning & Management
- Long lead items procurement
- Tweaking of existing systems

PROJECT MANAGEMENT

- Schedule & Budget Constraint
- Optimum Launch Opportunities
- JPL /NASA Navigation Support
- Ground Segment & Ship-borne Transportable Terminal readiness

Mars Orbiter Mission - Challenges

PROPULSION SYSTEM



Challenges:	Solutions:
To **restart the Liquid Engine** after 10 months for Martian Orbit Insertion (MOI) manoeuvre.	Two Liquid Engine hardware were ground tested in ISRO facility, IPRC at Mahendragiri after subjecting them for near flight conditions.

POWER SYSTEM

Challenges:	Solutions:
No power generation during MOI due to eclipse.	The ground battery identical to the one used in MOM was characterized .
Very low temperature of solar panels during eclipse periods (-185 Deg C).	Prior to launch, the low temperature qualification test was conducted at coupon level to qualify it for -210 deg C.

COMMUNICATION SYSTEM

Challenges:	Solutions:
Communication management in Earth bound phase, cruise phase, MOI and Martian orbit phase.	Analysis for MOI using Thermal Mathematical Model carried out

Mars Orbiter Mission - Challenges

Contd..

SPACECRAFT AUTONOMY

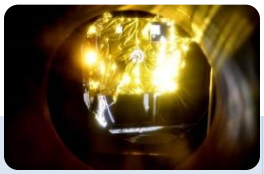
Challenges:

- **Limited visibility** of the spacecraft
- **Limited uplink and downlink** volume

Solutions:

On-board autonomy is achieved through

- Autonomous Fault Detection, Isolation and Reconfiguration (FDIR) logics
- Master Recovery Sequencer(MRS)
- Putting it in Safeguard Mode
- The command modules meant for execution of MOI autonomously were tested extensively for its correctness in an exclusive ground hardware simulation set up.



THERMAL SYSTEM

Challenges:

The spacecraft needs to cope with a **wide range of thermal environment.**

Solutions:

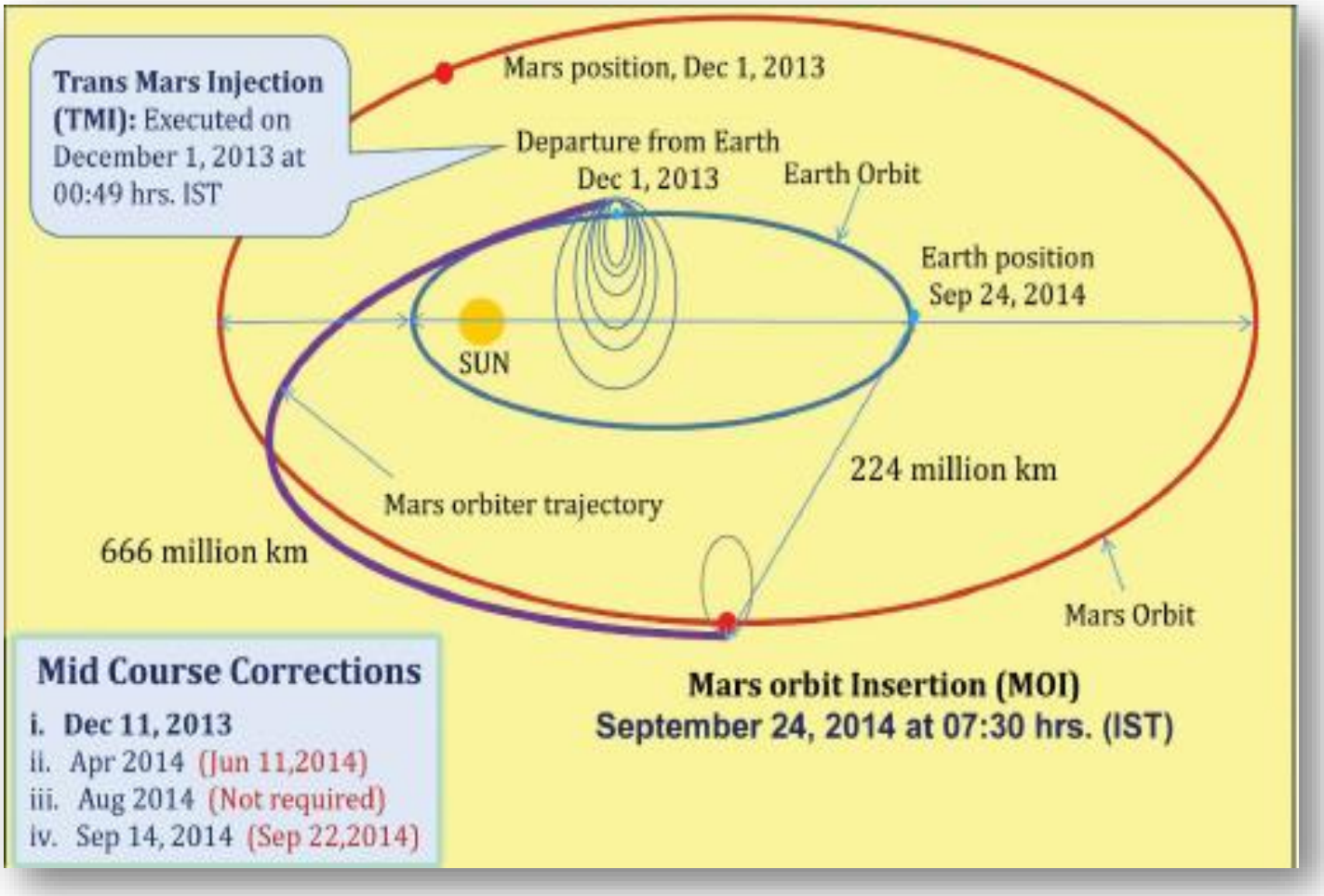
Analysis for MOI using Thermal Mathematical Model carried out.

Mars Orbiter Mission - Challenges Contd..

Mission Planning

- Trajectory generation for all phases of Mission
- Maneuver strategy design and analysis package
- Attitude steering profile generation for all phases & Attitude analysis
- Orbital events generation
- Orbit determination system considering range, doppler & DDOR measurements for various phases of the Mission
- Onboard orbit models for Heliocentric and Martian Phases
- Onboard attitude steering for Heliocentric and Martian Phases
  - Model based as well as coefficients based
  - Verification of OIL's results completed
- Proximity analysis with asteroids in Cruise phase and Phobos & Deimos in Martian Orbit phase & with Comet A13

Mars Orbiter Mission - Journey to Mars

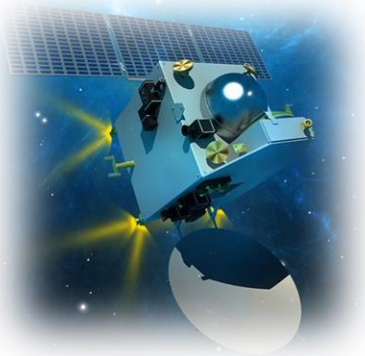


GEO CENTRIC PHASE	HELIO CENTRIC PHASE	MARTIAN PHASE
21.10.13 to 3.12.13	3.12.13 to 22.9.14	22.09.14 Onwards Till EOL
44 Days	298 Days	298 Days

Mars Orbiter Insertion was carried out successfully on Sept, 24, 2014

September 24, 2014 – A Historic Day for India

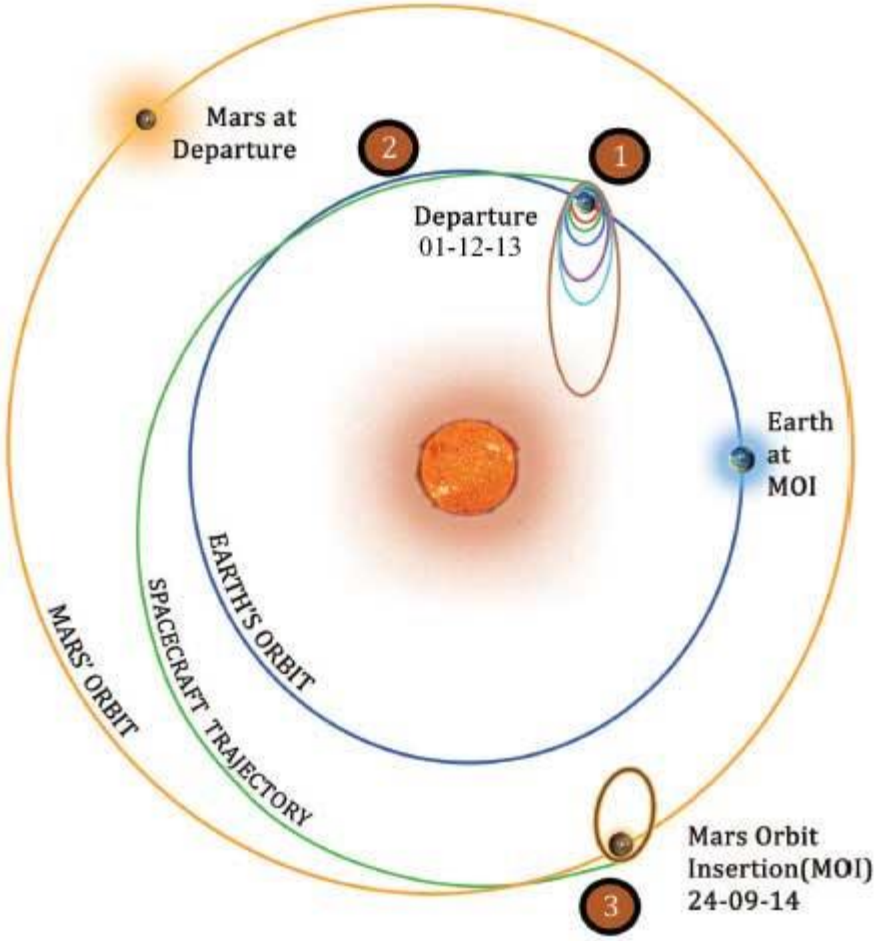
India's first Inter-Planetary Probe reached Mars Orbit



Technological Achievements

- Realized a spacecraft to reach Mars and orbit around Mars
- Radiation shielding for prolonged exposure
- Built high level of onboard autonomy within the Orbiter
- Robustness and reliability of propulsion system
- Precisely inserted into Martian orbit after 300 days voyage
- Currently undertaking a few scientific studies using 5 instruments

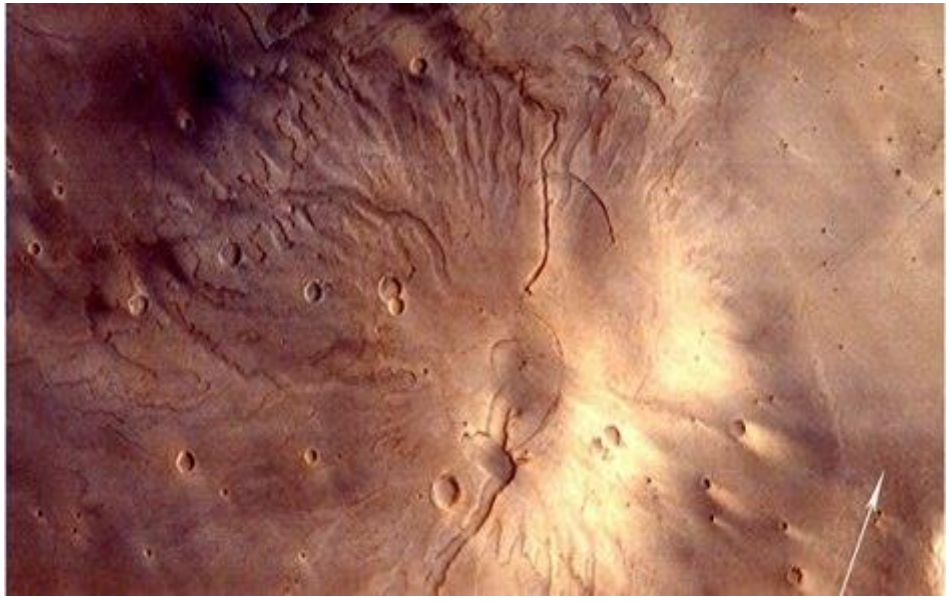
HOW WE REACHED MARS



Phases of MOM's Journey

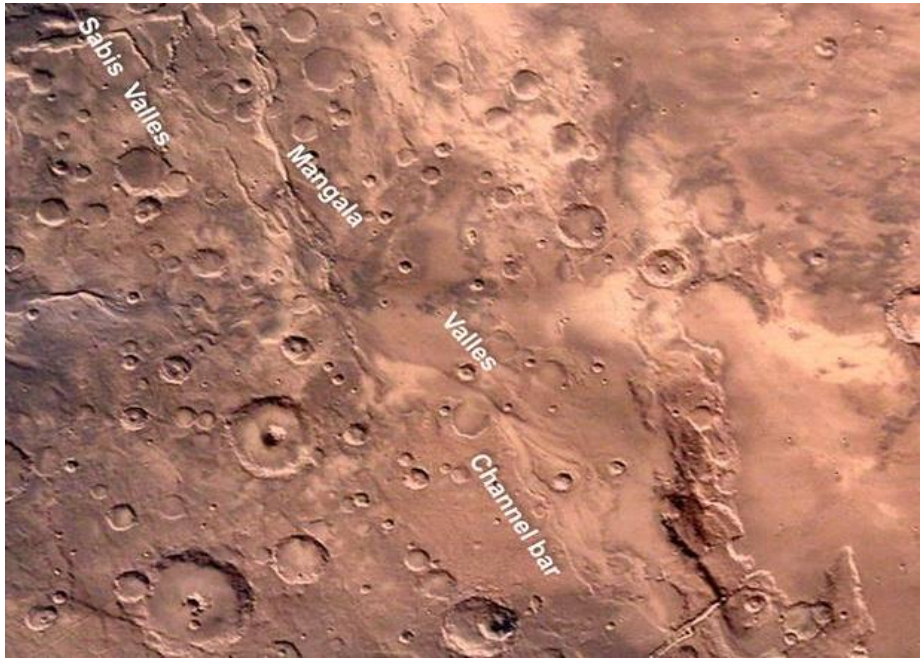
1. Earth-centric phase
2. Sun-centric phase
3. Martian phase

Tyrrhenus Mons



Parts of Valles of Marineris

Flow Patterns in Mangala Valles Region



Pital Crater

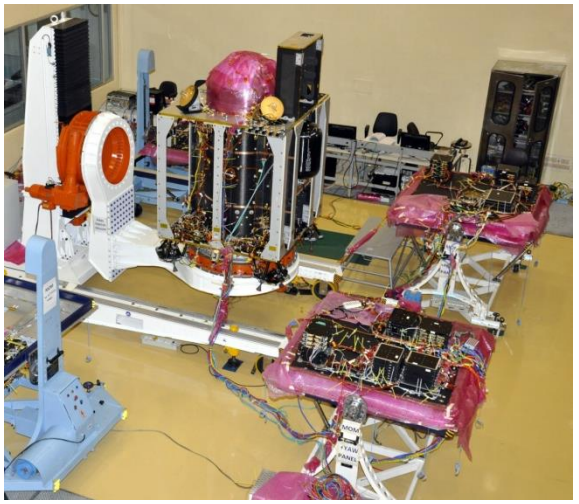
Mars Orbiter Mission

Solar Conjunction prevents the communication between spacecraft and earth– All Payload operation suspended till July 15, 2015…

Mars Orbiter Mission – Making of Mars

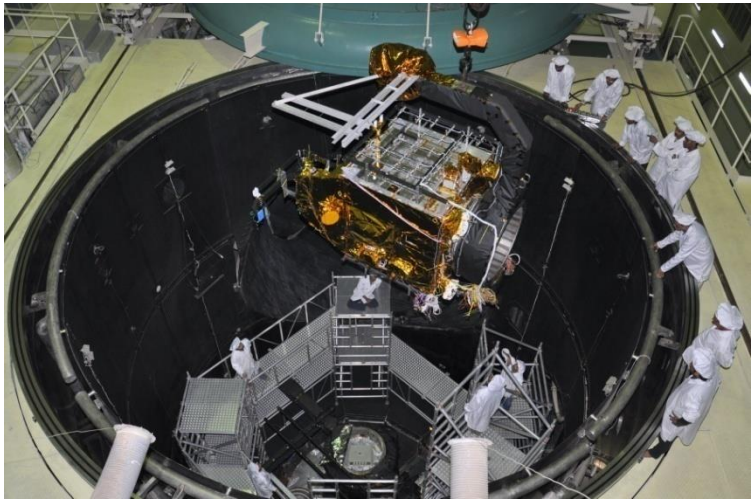
Contd..

Structure Delivery & Start of Integration activity Clean Room



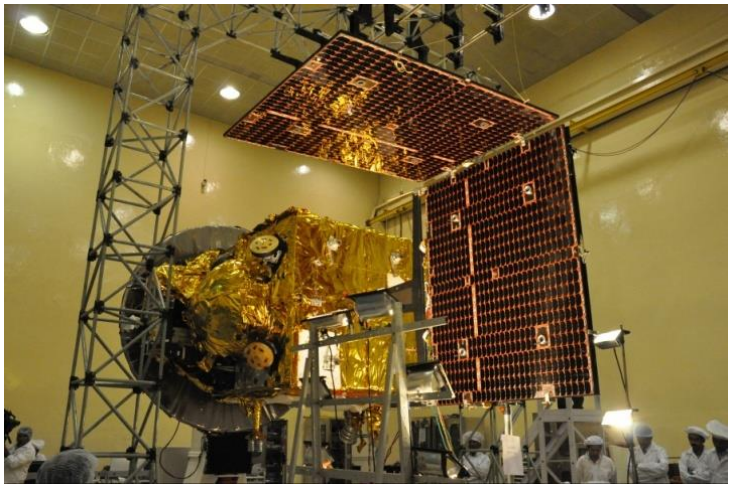
Subsystem Integration activities in Clean Room

Spacecraft Integration activities in Clean Room

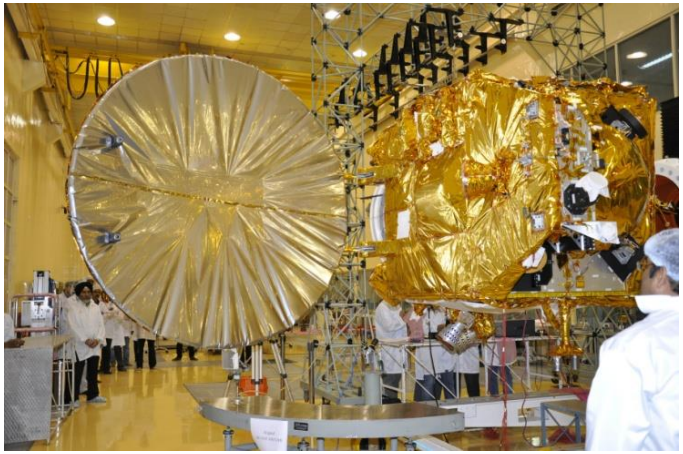


Loading into Thermovac Chamber

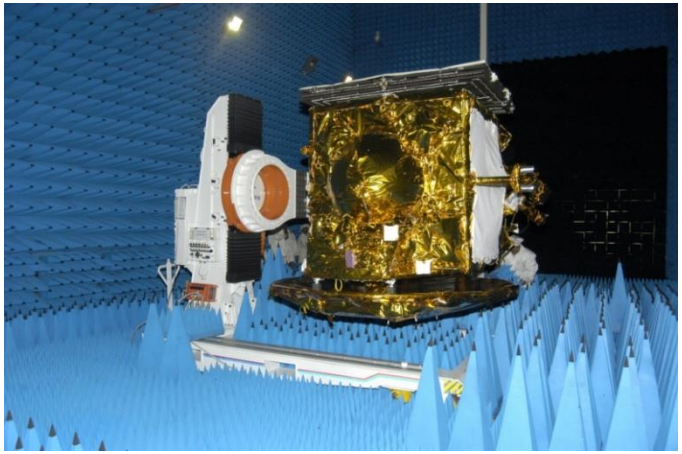
Mars Orbiter Mission – Making of Mars



Solar Panel Testing



HGA-Antenna Deployment Test



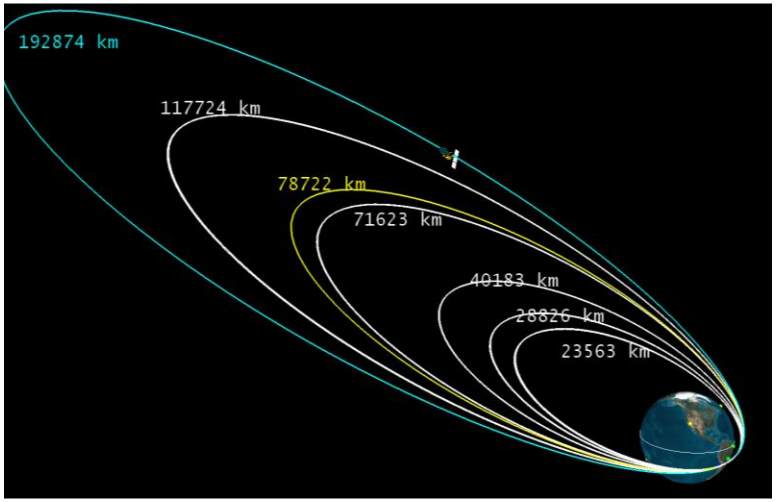
EMI/EMC Test

Vibration Test

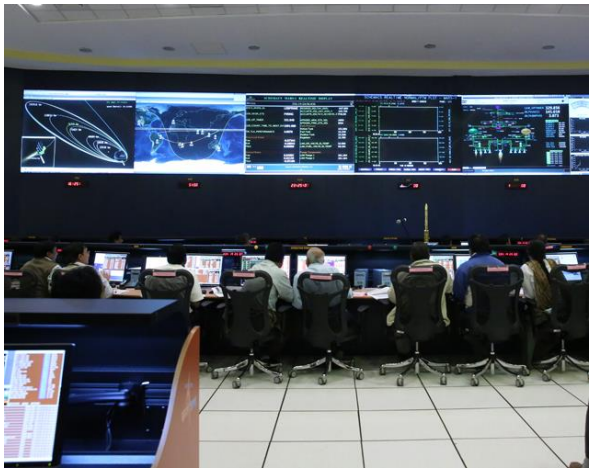
Mars Orbiter Mission – Sequence of events

Commencement of Satellite Integration, 25th June 2012

Launched onboard PSLV-C25 on November 5, 2013



Six orbit raising manoeuvers to raise the apogee



Trans Mars Injection on December 01, 2013

Main Liquid Engine Successfully restarted on September 22, 2014

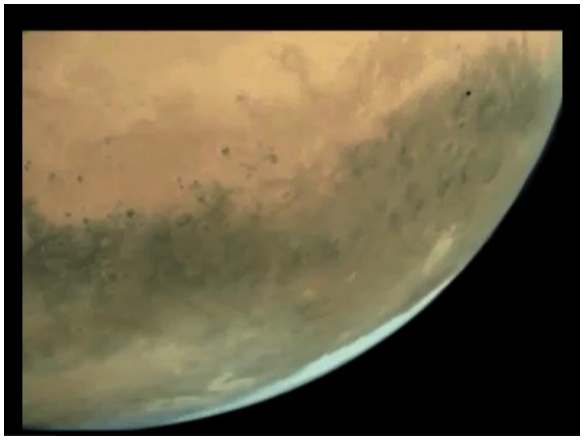
Inserted into Mars Orbit Honourable Prime Minister of India, Mr Narendra Modi September 24, 2014

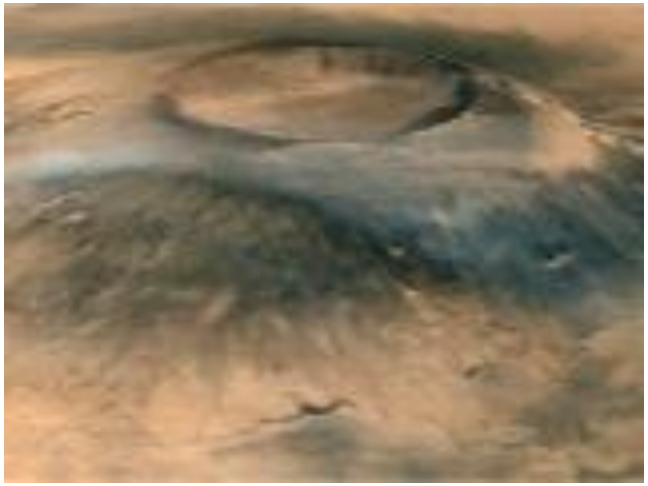
Mars Orbiter Mission Orbiting Mars Planet

Mars Orbiter Mission – Data Products

Full disc image of Mars, taken by the Mars Color Camera, from an altitude of 66,543 km.

Image of Phobos, the larger of the two Martian moons taken by the MOM





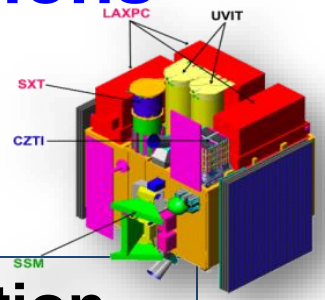
Spectacular 3D View of Arsia Mons a huge Volcano on Mars

View of a Portion of the gigantic Valles Marineris Canyon of Mars

Space Science Missions – On the Anvil

Space Science & Planetary Exploratory Missions

FUTURE MISSIONS…

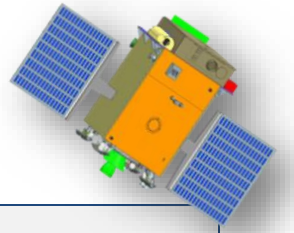


ASTROSAT

Multi-wavelength Astronomy Satellite for observation of galactic objects

CHANDRAYAAN-2

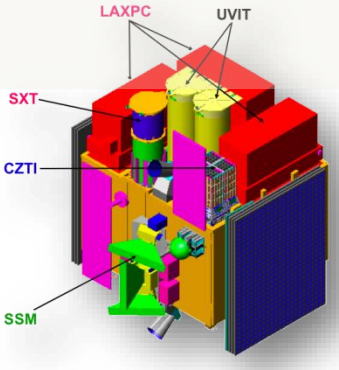
Landing in a high latitude region First Rover-based in-situ studies of lunar chemistry & volatiles



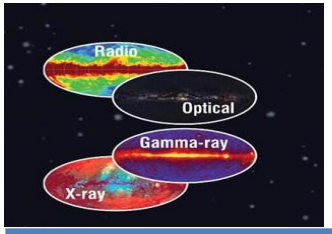
ADITYA

A Space based Advanced Solar Coronagraph to Study solar corona

ASTROSAT



India's first satellite dedicated for multiwavelength astronomy for observation of galactic objects in outer space.



SPACECRAFT SPECIFICATIONS	
ALTITUDE	650 KM
INCLINATION	8 DEG
MASS	~ 1500 KG
POWER	940 WATTS
MISSION LIFE	5 YEARS
LAUNCHER	PSLV

PAYLOADS	
UVIT	ULTRA VIOLET IMAGING TELESCOPE (IIA/IUCAA)
LAXPC	LARGE AREA XENON PROPORTIONAL COUNTER (TIFR)
SXT	SOFT X-RAY TELESCOPE (TIFR)
CZT	CADMIUM ZINC TELLURIDE DETECTOR (TIFR)
SSM	SKY SCANNING MONITOR (ISAC-ISRO)

SCIENCE OBJECTIVES

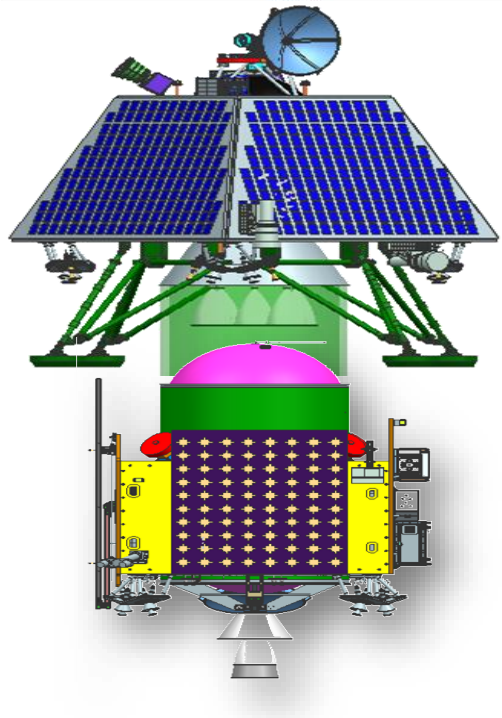
- ***Determination of black hole masses***
- ***Details on nature of transient behaviour, QPO and its evolution, period evolution***
- ***Improved UV morphology, star formation & its evolution, galaxy luminosity function***
- ***Study of Galactic binary systems***
- ***X-ray monitoring of Sky & Deep UV survey of selected regions of sky.***

CHANDRAYAAN-2 : Overview

A follow on mission to the first Indian lunar mission with a capability to soft land at a specified lunar site and to carry out in-situ chemical analysis of the lunar surface and will have Orbiter Craft and Lander craft equipped with rover.

Mission Objective

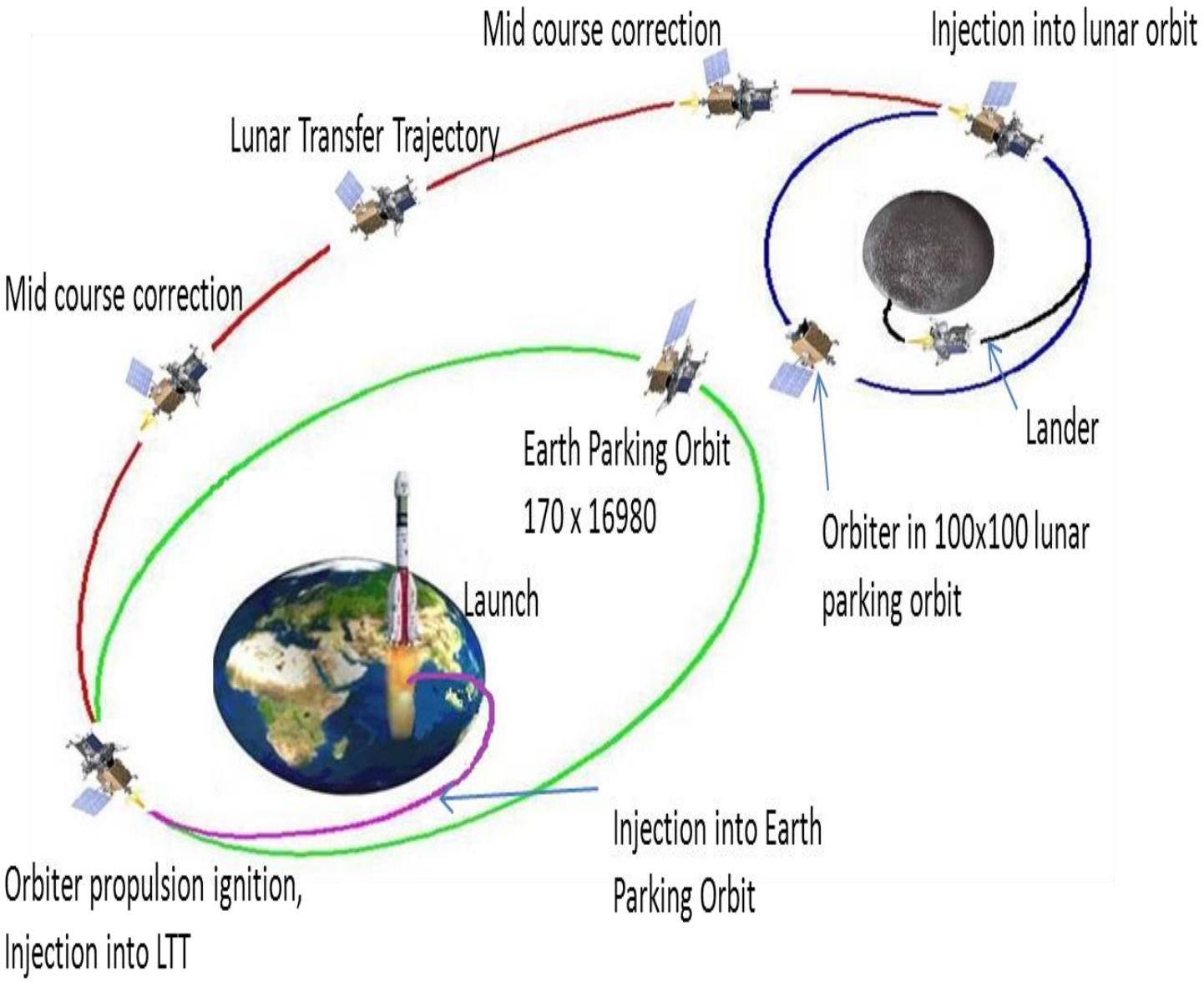
- Expanding the technologies and 'Develop & Demonstrate' newer technologies
- To carry payloads in the Orbiter craft that will enhance the scientific objectives of Chandrayaan-1
- To realize a Lunar Lander - Rover capable of soft landing on a specified lunar site and deploy a Rover to perform mobility and science experiments.



CHANDRAYAAN-2: Mission Specifications

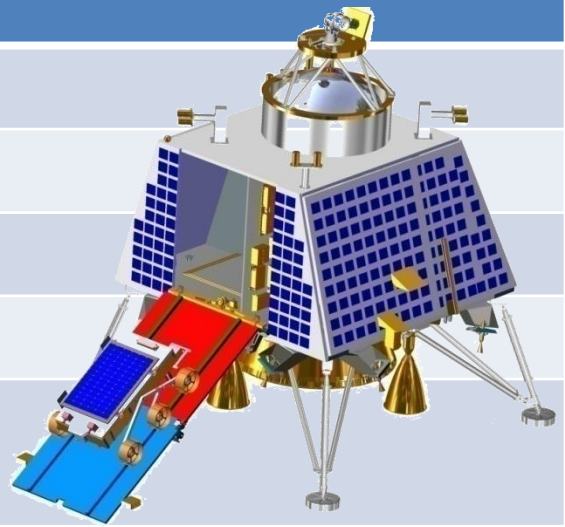
Launch vehicle	GSLV M-II
Lift of Mass	3250kg
GSLV injection orbit	170 X 18500 km
Orbiter	100 km around moon Mission life of one year Orbiter to communicate with Lander & Rover
Lander	100 km (Initial) Soft Landing on Moon Mission life of one lunar day (~14 Earth Days)

CHANDRAYAAN-2: Mission Profile



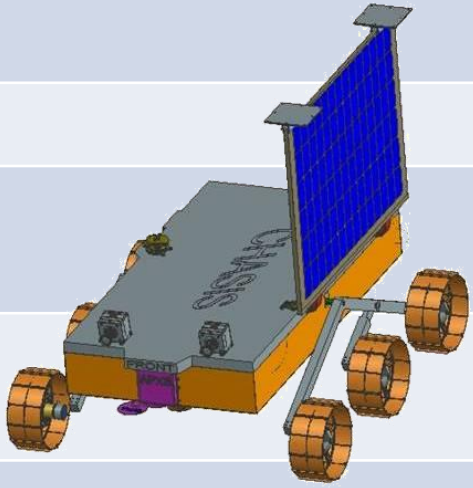
Lander Craft – Salient Features

Parameters	Lander Craft (LC)
Orbit	Soft Landing on the Moon
Mass	940 kg [Propellant :500 kg]
Envelope	Compatible with GSLV MK II
Velocity at touchdown	< 2m/ sec
Power Generation	~ 300 W to 150W (Three Body mounted panels)
Battery	Li Ion (26 Ah)
Communication – Ground – Rover	 S -Band & X-Band S -Band
Propulsion Tanks LAM Thrusters	 2 x 350 L 4 x 800 N (Throttlable) 8 x 50 N
Mission life	1 Lunar Day(~ 14 Earth Days & Related to Landing site)

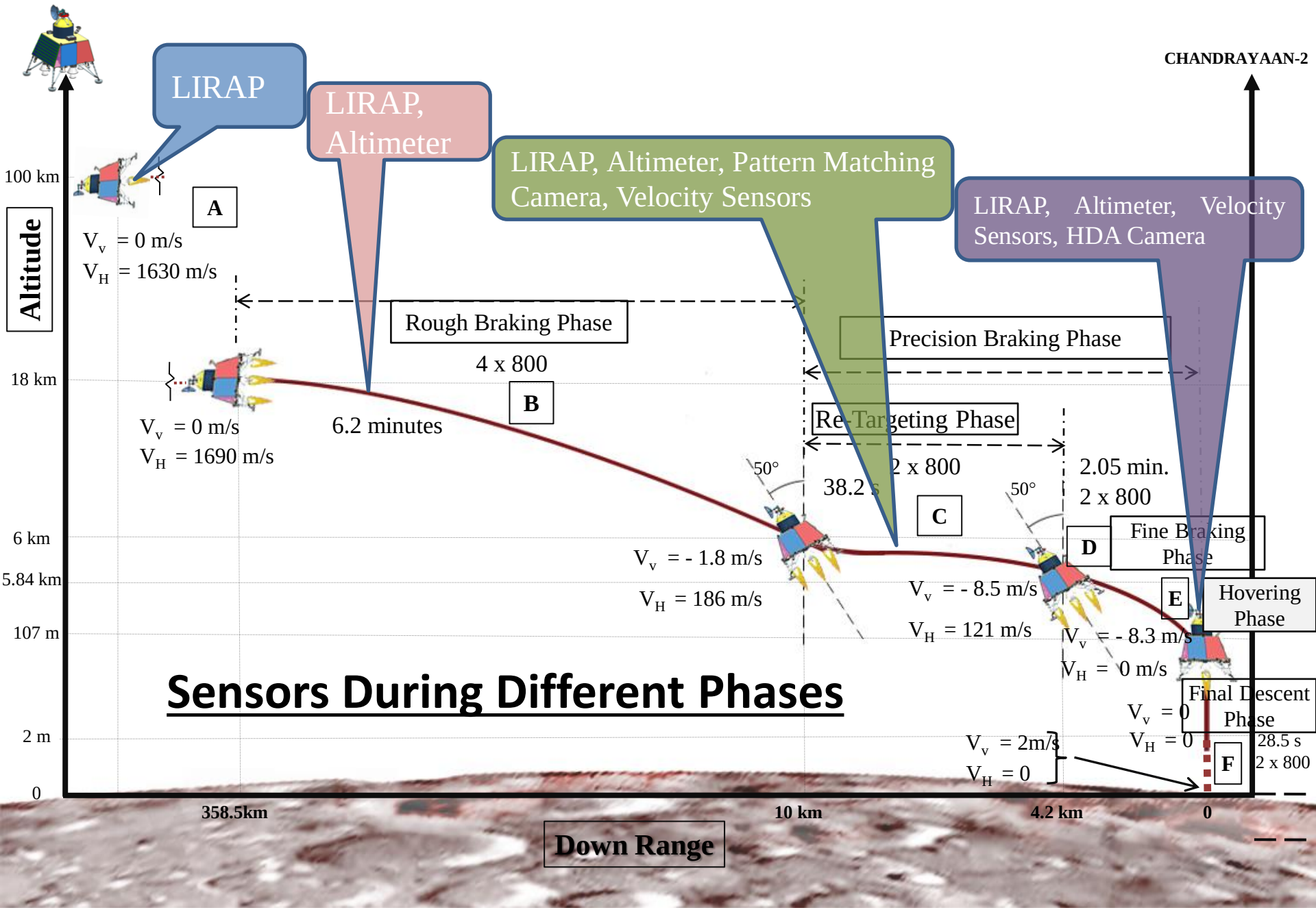


Rover – Salient Features

Parameters	Rover
Chassis WEB size	850 x 450 x 100 mm
Mass	25 kg
Life of the Mission	1 Lunar Day(~ 14 Earth Days & Related to Landing site)
Nominal velocity	1 cm / sec
Obstacle climbing capability	50 mm (max)
Power	Solar Array - 40 Watts Battery- 3Ah
Communication	To Receiver : S-Band 2kbps From Transmitter: S-Band64/10kbps
Sensors	Navigation camera for determining ground topology
Payloads	LIBS(Laser Induced Breakdown Spectroscope) APXS(Alpha particle Induced X-Ray Spectrometer)

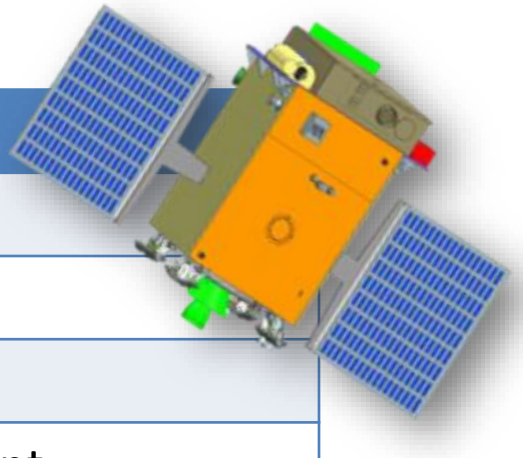


TRAJECTORY PROFILE OF CHANDRAYAAN-2 LANDER



ADITYA

ADITYA - The first Indian space based coronagraph intended to study the solar corona in visible and near IR bands. The main scientific objectives of the mission is to study the Coronal Mass Ejections (CME).



Spacecraft Bus	IRS Bus
Mass	~ 1400 Kg
Power	1500 W
Mission Life	> 5 Years
Orbit	Halo Orbit about Sun- Earth L1 Point
Data Volume & Download Read out Rate	110 Gb, 4 MBPS
Payloads Proposed	1. Enhanced Visible Emission Line Coronograph 2. High Energy L1 Orbiting X-ray Spectrometer 3. Plasma Analyser Package 4. Solar Wind & Thermal Ion Spectrometer 5. Solar Low Energy X-ray Spectrometer 6. Solar Ultraviolet Imaging Telescope

THANK YOU