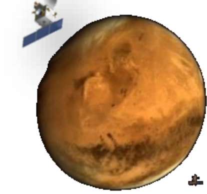


MARS ORBITER MISSION

CHALLENGES & SUCCESS STORY

Dr. S V Sharma

Deputy Director, ISRO Satellite Centre

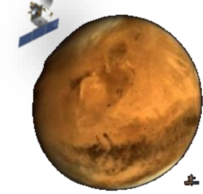
March 1, 2015

SONA COLLEGE OF TECHNOLOGY, SALEM

PRESENTATION OVERVIEW

1. INDIAN SPACE PROGRAMME
2. QUICK FACTS - MARS PLANET
3. CONFIGURATION OF MOM
4. MARS ORBITER MISSION CHALLENGES
5. MAKING OF MOM
6. MOM REACHING MARS
7. LESSONS LEARNT
8. CONCLUSIONS

INDIAN SPACE PROGRAMME



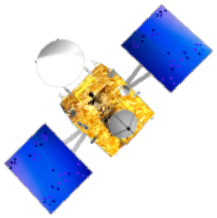
Launch vehicles (PSLV, GSLV)

Satellites (GSAT, IRS,IRNSS & SPACE SCIENCE)

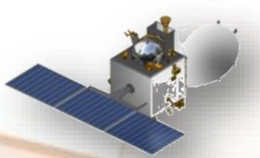
Indian Remote Sensing (IRS) Satellites

Indian Communication & Meteorological Satellites

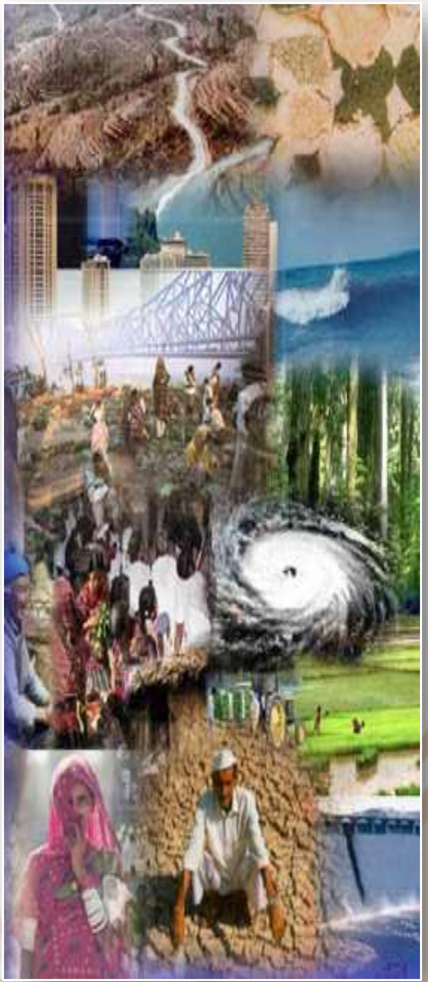
Indian Navigation Satellites

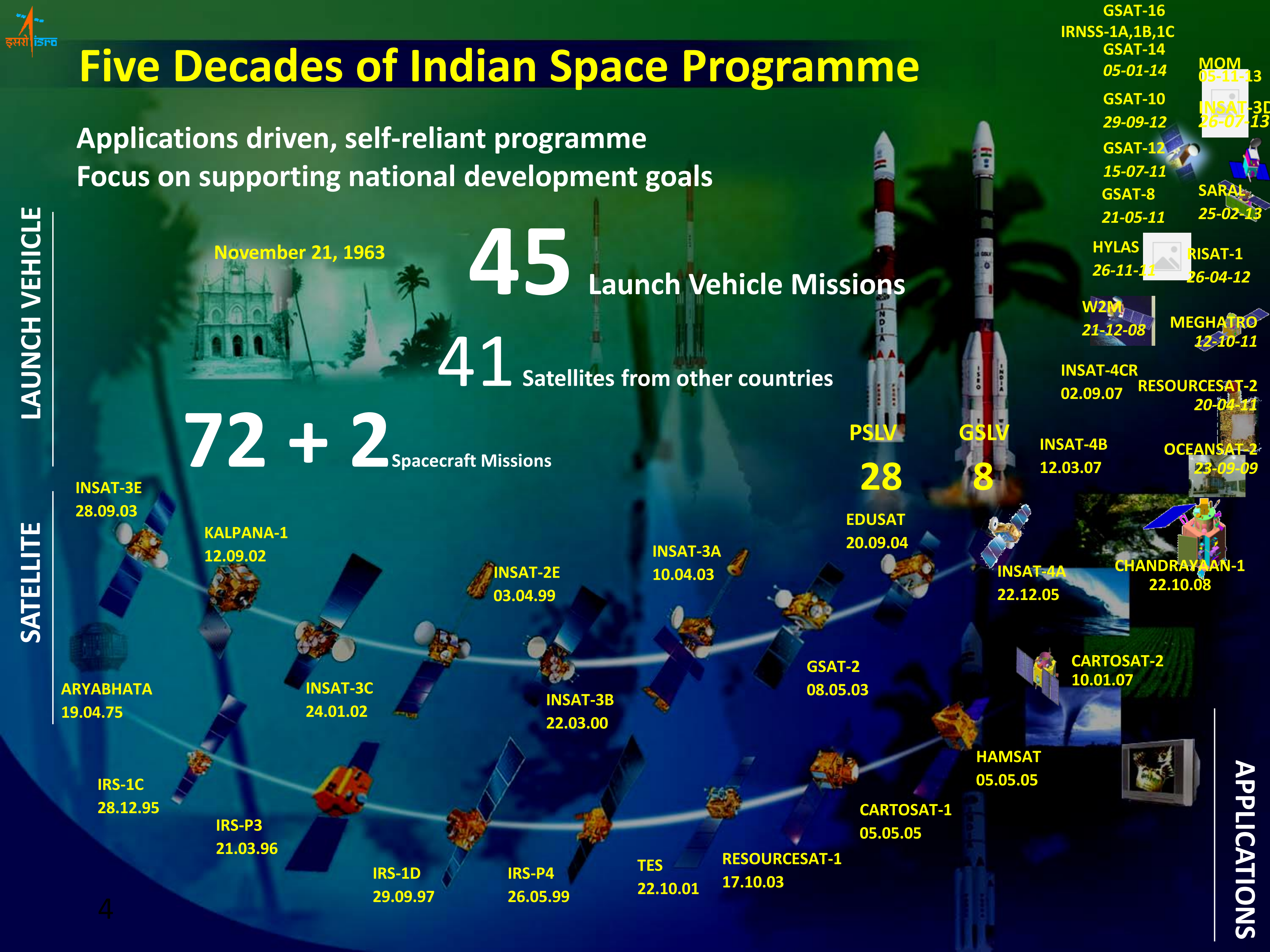


Space Science & Planetary Exploration Satellites



Societal Applications




Five Decades of Indian Space Programme
Applications driven, self-reliant programme
Focus on supporting national development goals
LAUNCH VEHICLE
November 21, 1963
45 Launch Vehicle Missions
41 Satellites from other countries
72 + 2 Spacecraft Missions
PSLV 28
GSLV 8
SATELLITE
INSAT-3E 28.09.03
KALPANA-1 12.09.02
INSAT-2E 03.04.99
INSAT-3A 10.04.03
EDUSAT 20.09.04
ARYABHATA 19.04.75
INSAT-3C 24.01.02
INSAT-3B 22.03.00
GSAT-2 08.05.03
INSAT-4A 22.12.05
CHANDRAYAAN-1 22.10.08
CARTOSAT-2 10.01.07
HAMSAT 05.05.05
IRS-1C 28.12.95
IRS-P3 21.03.96
IRS-1D 29.09.97
IRS-P4 26.05.99
TES 22.10.01
RESOURCESAT-1 17.10.03
CARTOSAT-1 05.05.05
GSAT-16
IRNSS-1A,1B,1C
GSAT-14 05-01-14
MOM 05-11-13
GSAT-10 29-09-12
INSAT-3D 26-07-13
GSAT-12 15-07-11
GSAT-8 21-05-11
SARAL 25-02-13
HYLAS 26-11-10
RISAT-1 26-04-12
W2M 21-12-08
MEGHATRO 12-10-11
INSAT-4CR 02.09.07
RESOURCESAT-2 20-04-11
INSAT-4B 12.03.07
OCEANSAT-2 23-09-09
APPLICATIONS

QUICK FACTS - MARS PLANET

‘Mars’ known as Mangalyaan beckons the human imaginations .The conditions in Mars are believed to be hospitable as it is similar to earth in many features

MARS PLANET – WHAT DO YOU KNOW	
ATMOSPHERE (Pressure)	7.5 MILLIBARS (Average)
DISTANCE FROM SUN (Average)	227,936,637 KILOMETERS
EQUATORIAL RADIUS	3,397 KILOMETERS
GRAVITY	3.678 M/S^2
LENGTH OF THE DAY(Martian Day)	24 hours,37 minutes
LENGTH OF YEAR (Martian Year)	687 EARTH DAYS
SURFACE TEMPERATURE (Average)	-63 DEGRESS C
TILT OF AXIS	25 DEGREES
NUMBER OF SATELLITES	2 (PHOBOS AND DEIMOS)

MOM - CONFIGURATION

- India’s first interplanetary mission

MARS ORBITER MISSION (MOM)

MOM is configured with an orbiter craft designed to orbit around Mars in an elliptical orbit with the primary objective to develop the technologies required for design, planning, management and operations of an interplanetary mission.

SALIENT FEATURES

Orbital Location	:	370 X 80,000 Kms elliptical orbit
Voyage from Earth's orbit	:	300 Days
Mass	:	1350 Kg
Power	:	750 W
Mission Life	:	~ 6 Months
Launcher	:	PSLV C 25
Payload	:	Lyman Alpha Photometer, Methane Sensor for MARS, Martian Exospheric Composition Explorer, MARS Color Camera and TIR Imaging Spectrometer
Launch Date	:	5^{th} November , 2013
MOI	:	24^{th} September, 2014

MARS ORBITER MISSION- MISSION OBJECTIVE

Technological objectives:

- Design and realisation of a Mars orbiter spacecraft with a capability to survive and perform Earth bound manoeuvres, cruise phase, Mars orbit insertion and capture, and on-orbit phase around Mars.
- Deep space communication, navigation, mission planning and management.
- Incorporate autonomous features to handle contingency situations

Scientific objectives:

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

MARS ORBITER MISSION – SCIENTIFIC PAYLOADS

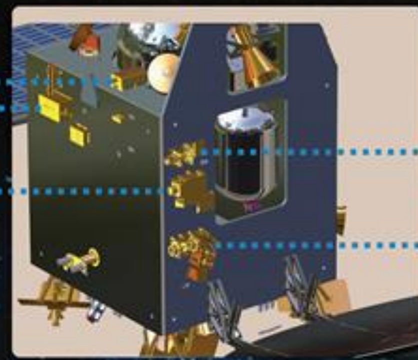
Lyman Alpha Photometer (LAP)

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.

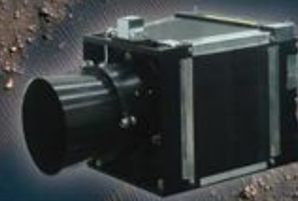
Atmospheric studies



Mars Exospheric Neutral Composition Analyser (MENCA)

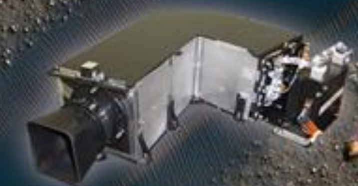
quadruple mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 amu with unit mass resolution.

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.



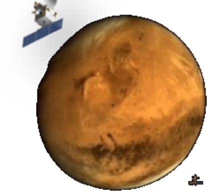
Thermal Infrared Imaging Spectrometer (TIS)

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
MAJOR CHALLENGES

MARS ORBITER MISSION- MAJOR CHALLENGES



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

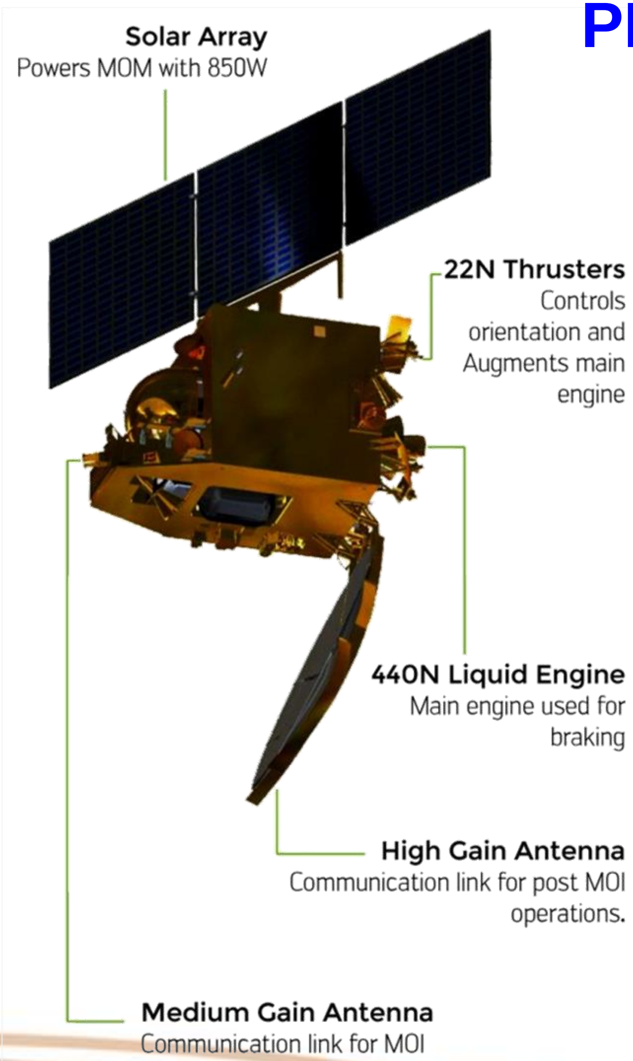
Schedule & Budget Constraint

Optimum Launch Opportunities

JPL /NASA Navigation Support

Ground Segment & Ship-borne Transportable Terminal readiness

MARS ORBITER MISSION- CRITICAL SYSTEMS



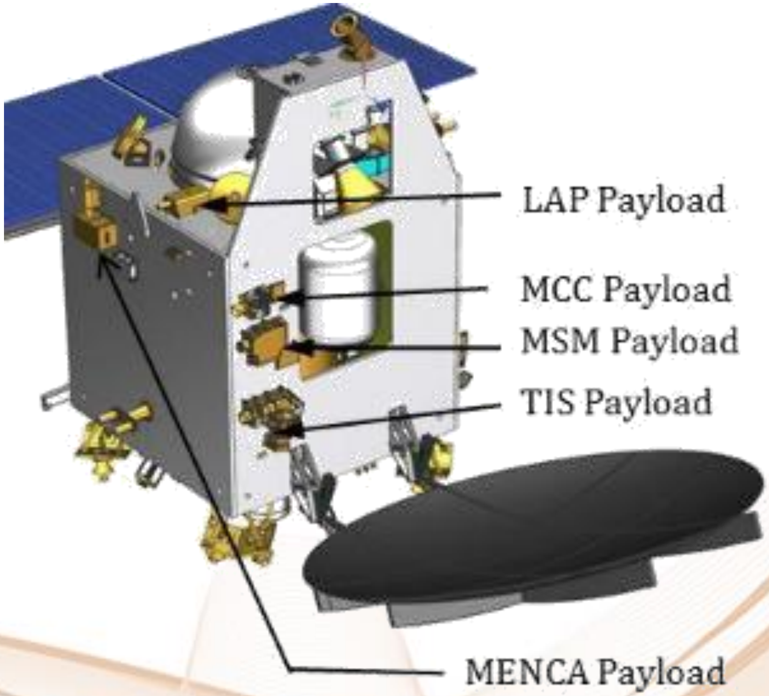
PROPULSION SYSTEM

POWER SYSTEM

COMMUNICATION SYSTEM

SPACECRAFT AUTONOMY

THERMAL SYSTEM



MARS ORBITER MISSION- CRITICAL SYSTEMS

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. Very low temperature of solar panels during eclipse periods (-185 Deg C).	The ground battery identical to the one used in MOM was characterized . 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- CRITICAL SYSTEMS

SPACECRAFT AUTONOMY

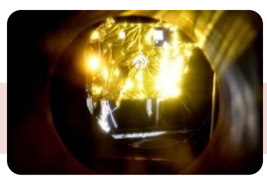
Challenges:

- 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- 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 and 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- PROJECT MANAGEMENT

Challenges

- To realize a satellite in quick turn around time
- Launch opportunity : Once in 26 months.

  If September 2013 target was missed, next opportunity was in January 2016.

Best Practices

- **Use of flight proven Mainframe subsystem**: The spacecraft was configured with the right mix of design from flight proven IRS/INSAT/Chandrayaan-1 bus. Improvisation required for MOM were in the area of propulsion system, power system, communication system, onboard autonomy and thermal control system.
- **Micro Level Scheduling:** Project schedules were continuously monitored and assessed, to effective accomplish each of project milestone as per planned schedule. An online information system was developed to monitor, assess, and evaluate project realization at micro level of detail.
- **Project Priority:** In view of constraint of launch opportunity, the project was given highest, project priority and all the resources were pooled to accomplish the mission
- **Stringent Review Mechanism:** Stringent review mechanism and extensive review by 5 specialized HLRC, ADCOS, PSG, SSTRC, Internal Review played a vital role in Mars orbiter mission project management.

MARS ORBITER MISSION- PROJECT MANAGEMENT

Special Review Process

1. High level review committee (HLRC) for closely monitoring the progress of the project and effective decision making.

2. Advisory committee on space sciences (ADCOS) for identifying the scientific payloads

3. Payload Steering Group (PSG) for ensuring the timely realization of scientific payloads.

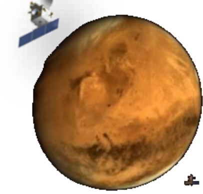
4. Standing Scientific & Technical Review committee (SSTRC) for implementation of MOM including orbiter spacecraft, interface with LV, ground segment including network support and post launch operations

5. Management of International Co-operation & Interfaces.

Mandatory Review Cycle

1. Preliminary Design Review
2. Critical Design Review
3. Mission Readiness Review
4. Standing Review Committee
5. Preshipment Review.

MARS ORBITER MISSION REALIZATION: A GLANCE



Milestone	Actual Schedule	Planned Schedule
Configuration finalization	July 2012	Jan 2012
Structure Delivery	Jun 2012	April 2012
Preliminary Design Review	21 September 2012	April 2012
Budget Approval	20 October 2012	Dec 2011
Pre- Shipment Review	21 September 2013	Aug 2013
Launch	5 November 2013	October 2013
Mars Orbit Insertion	24 September 2014	September 2014

MOM was realized in a record time of 15 months

MARS ORBITER MISSION-TRACKING NETWORK

ISTRAC Stations

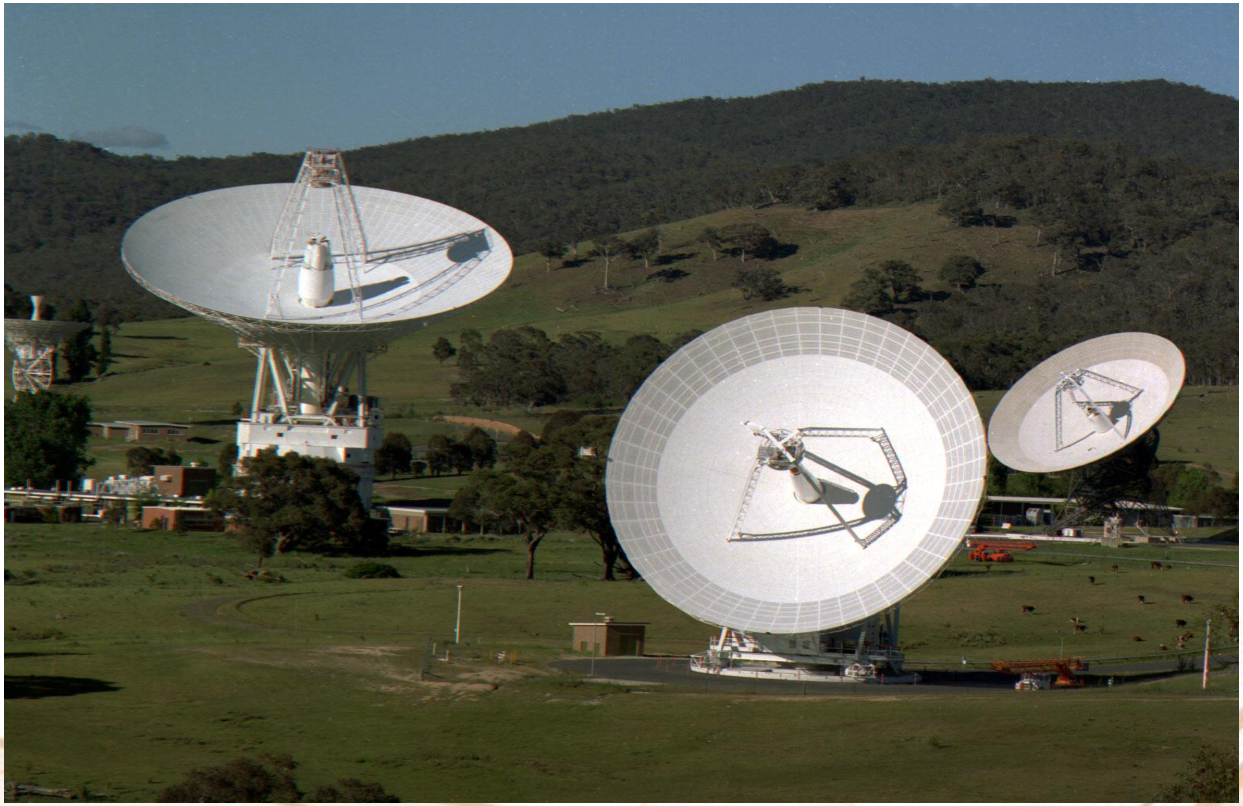
Bangalore
Bangalore (IDSN)
Biak (BI1)
Brunei (BRU)
Lucknow (LK1)
Mauritus(MAU)
Trivandrum (TRV)
Port Blair

External Support

Alcantara
Cuiaba
HBK

DSN Stations

Madrid
Canberra
Goldstone

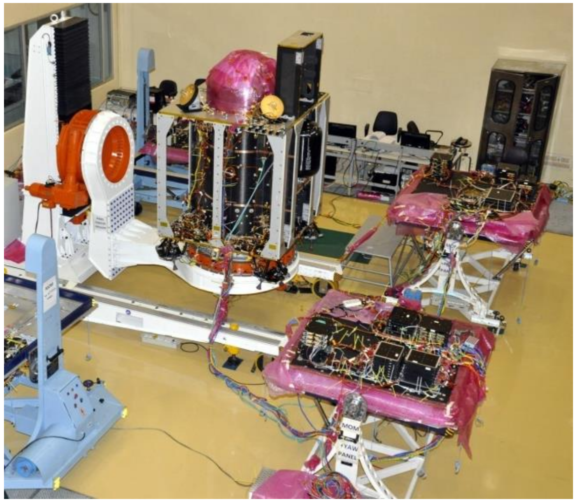


MARS ORBITER MISSION REALIZATION: A GLANCE

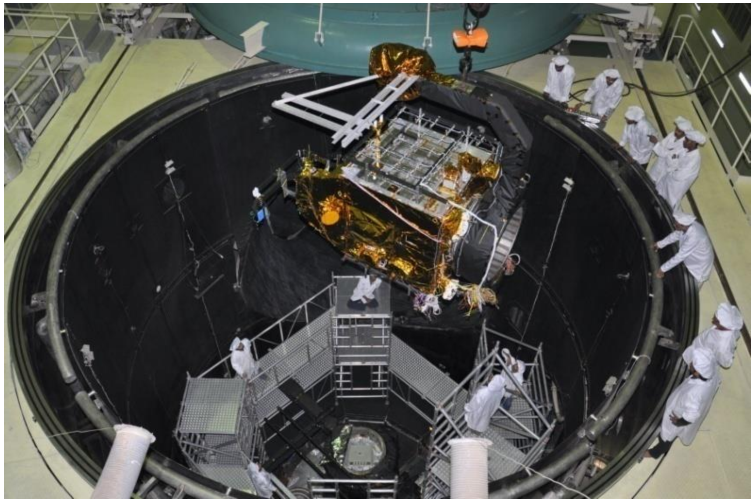
- Technology challenges were taken up on top priority
- Micro level planning and scheduling was the key towards the success
- Multi level review mechanism was the catalyst
- Concurrent and collaborative engineering efforts from all ISRO Centres
- Thoroughly analyzed the lesson learnt from other Mars Missions
- Use of heritage systems
- Dedicated team effort
- Launch window was frozen before the project was conceived.

MAKING OF MARS ORBITER MISSION

Structure Delivery at Clean Room

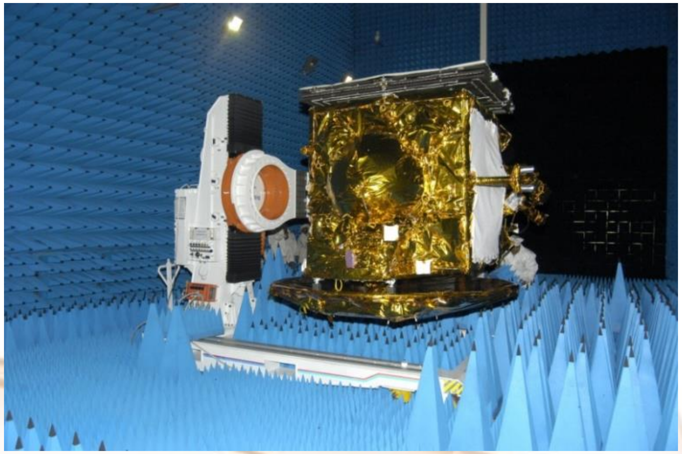


Subsystem Integration activities in Clean Room



Loading to Thermovac Chamber

Antenna Deployment Test



EMI/EMC Test

Vibration Test

MOM REACHING MARS & MAJOR MILESTONES

MOM REACHING MARS

MOM has to travel 65 Crore Kilometer to reach Mars Orbiter. The journey consists of three phases namely Geo Centric Phase, Helio Centric Phase and Martian Phase.

GEO CENTRIC PHASE
21.10.13 to 3.12.13
44 Days

The spacecraft was injected into an Elliptical Parking orbit by the launcher. With 6 Maneuvers using LAM, the spacecraft was put into a departure hyperbolic trajectory with which it escaped from the Earth's Sphere of Influence beyond which the perturbing force on the orbiter is due to the SUN only.

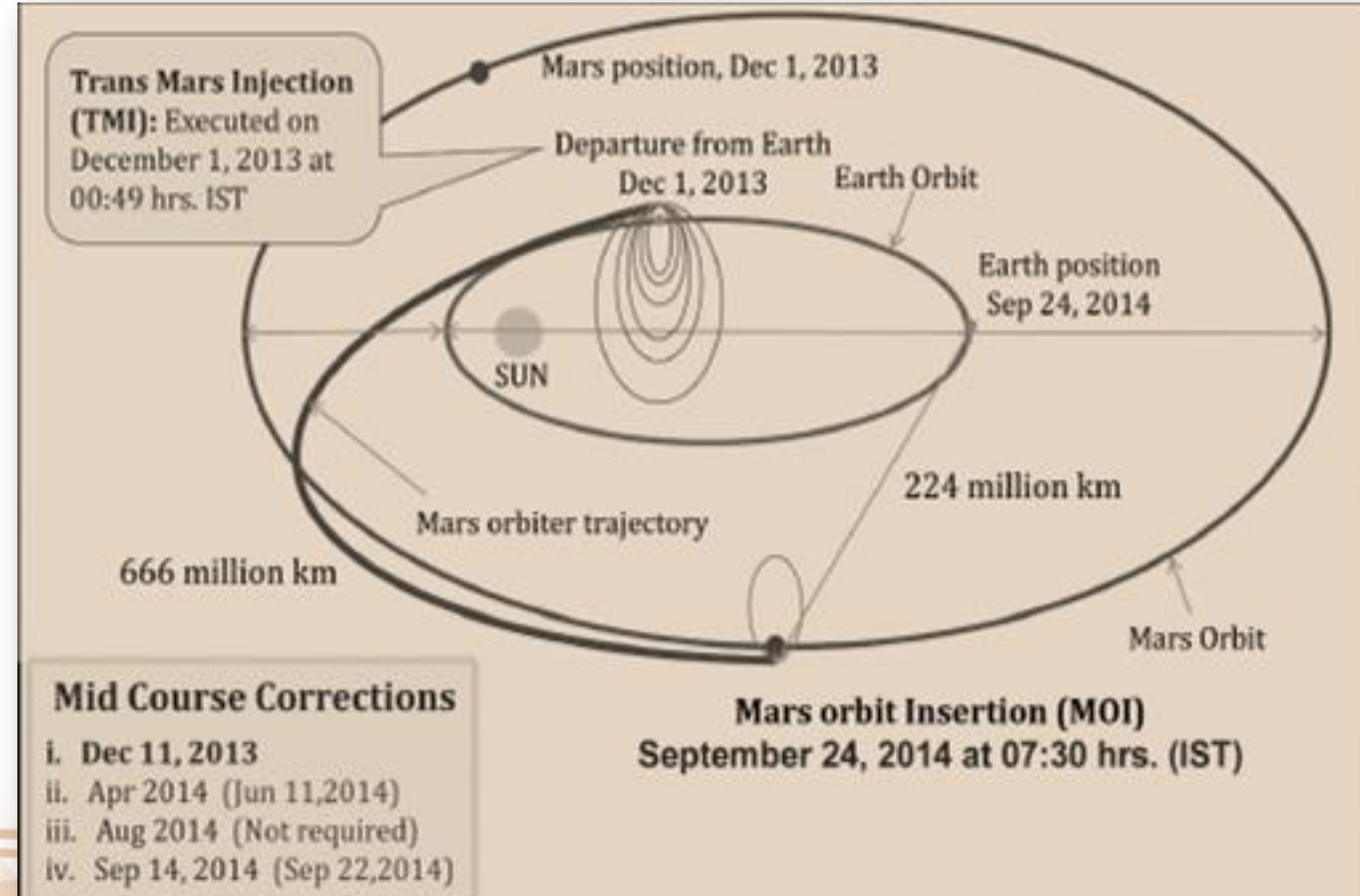
HELIO CENTRIC PHASE
3.12.13 to 22.9.14
298 Days

The spacecraft left 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 the spacecraft intersected the orbit of Mars at time when Mars is there too. 3 Trajectory Corrections maneuvers carried out .

MARTIAN PHASE
22.09.14 Onwards
Till EOL
298 Days

The spacecraft arrived at the Mars Sphere of Influence (around 5,73,473 Km from the surface of Mars) in hyperbolic trajectory. At that time the spacecraft reached the closest approach to Mars and it was captured into planned orbit around Mars by imparting retro trust called Mars orbit Insertion(MOI) maneuver.

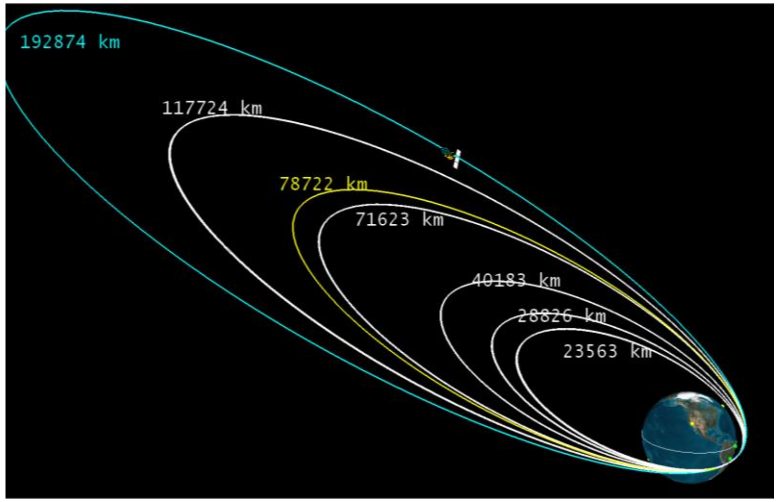
MOM REACHING MARS



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

MARS ORBITER MISSION- SEQUENCE OF EVENT

Launched onboard PSLV-C25 on November 5, 2013

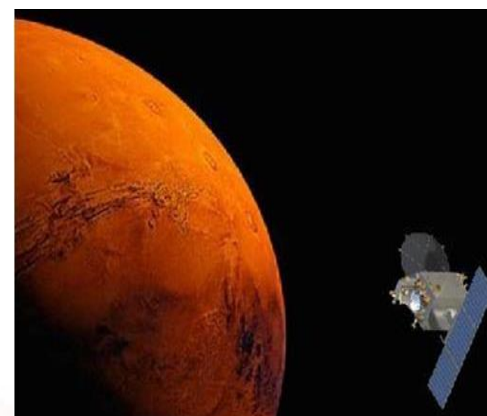


Six orbit raising manoeuvers to raise the apogee

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 Witnessed the event

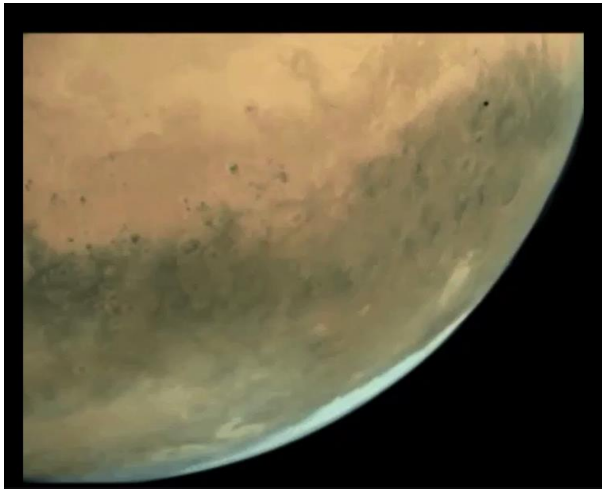


MOM orbiting Mars

MARS ORBITER MISSION- DATA PRODUCTS

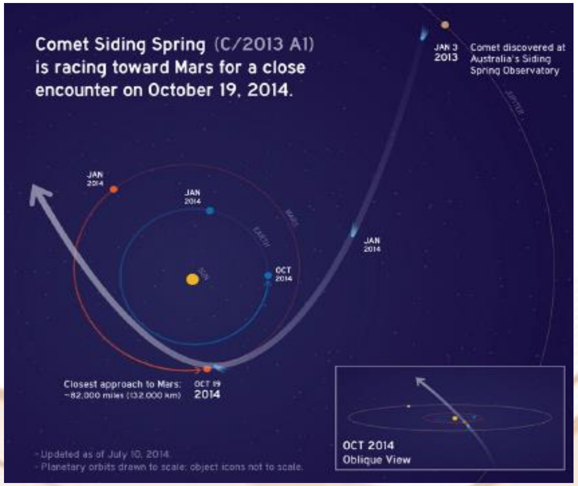
Full disc image of Mars, taken by the Mars Color Camera, from an altitude of 66,543 km.

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

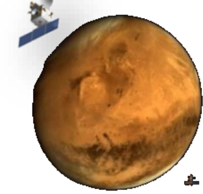


Google doodle- on 1 month completion of Mom

MoM encounter with the comet Siding Spring on October 19, 2014



LESSONS LEARNT FROM OTHER INTERNATIONAL MARS MISSIONS



1. Studied all International Mars Missions including mission approach for Orbiter, Lander, Rover and fly by missions.

2. Of 51 attempts to reach the planet, only 21 succeeded, a success rate of 42%. Eighteen of the missions included attempts to land on the surface, but only eight transmitted data after landing.

3. The majority of the failed missions occurred in the early years of space exploration and were part of the Soviet and later Russian Mars probe program that suffered several technical difficulties.

4. The reasons for the failures were not connected with MARS hostile conditions. Majority of failures are primarily due to Launch related issues followed by propulsion system problems, landing problems, software errors both in ground and on-board, Human errors, insufficient hardware testing and the conceived mission concepts.

CONCLUSIONS

All the Knowledge the world has ever received comes from the mind; the finite library of the universe is in our mind.

-Swami Vivekananda

Make Sure that you make use of all opportunities that come your way with a strong mind. Be entrepreneurial and have the courage to fail. Like they say, Failures are the stepping stones to success.

Develop the inner strength within you. Remember tough time do not last, tough people do. Believe you can and you are halfway there.

If you can’t fly, then run
If you can’t run, then walk,
If you can’t walk, then crawl,
but whatever you do, you have to keep moving ahead.

-Martin Luther King Jr