India’s Mars Orbiter Mission in Orbit

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Outline

• MOM – Mission Objectives
• Spacecraft
• Science Payloads
• Launch & Journey
• Mars Orbit Insertion
• Mars colour images
• Implications
Objectives

- Design & develop an MARS orbiter with a capability to perform earth bound maneuvers, Martian Transfer and MARS Orbit Insertion after nearly 300 days of travel
- Incorporation of autonomous features in spacecraft
- Design, Plan and Operate Deep Space Communication with orbiter (.ca 400 Million km)
- Exploration of MARS surface features morphology, topography, mineralogy.
- Study of constituents of Martian atmosphere , dynamics of upper atmosphere.
- To detect emanation of gaseous constituents from surface/subsurface looking for clues on geologic or biogenic activities
# Systems and the Challenges

<table>
<thead>
<tr>
<th>System</th>
<th>Mission specific changes</th>
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</table>
| Structure| • Heritage: modified 1K bus to suit Launcher.  
            • Incorporation of Communication system elements.  
            • Maximal use of composite elements. |
| Mechanisms| • Deployment of solar panel array at low temperature of – 60 deg C |
| Propulsion| • Incorporation of redundancy flow path lines.  
            • Restart of 440N engine after 300 days of dormancy.  
            • Execution of blow down mode operation during real time mission management. |
| Thermal  | • Use of passive thermal control elements.  
            • Thermal Management of mission at various stages by imparting proper attitude changes. |
## Systems and the Challenges

<table>
<thead>
<tr>
<th>System</th>
<th>Mission specific changes</th>
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<tbody>
<tr>
<td><strong>Power</strong></td>
<td>• Optimised Power generation both at near earth and Martian conditions.</td>
</tr>
<tr>
<td></td>
<td>• Direct Power transfer. (No slip ring assembly)</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>• Higher ranging tone for tracking accuracy improvements and improved receiver sensitivity.</td>
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<td></td>
<td>• Delta DOR for plane of sky measurements.</td>
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<tr>
<td><strong>Autonomy</strong></td>
<td>• Full scale on-board autonomy thro Fault Detection and Isolation Logic.</td>
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<td></td>
<td>• Development of 22 new software modules, modification of 42 modules and usage of 19 existing modules.</td>
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<tr>
<td><strong>Flight Dynamics</strong></td>
<td>• Trajectory generation for all phases of Mission incorporating gravity, atmosphere, solar radiation pressure, angular momentum desaturation models and relativistic effect due to Sun and atmospheric drag.</td>
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<td></td>
<td>• Orbit determination software improvements.</td>
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Mars Orbiter Spacecraft

Primary structure in clean room – ready for integration

Spacecraft integration
HGA 2.2m CFRP Reflector deployment tests
Mars Orbiter Spacecraft

- Propellant Tank
- Reaction Wheel
- Solar Panels (1400 x 1800 mm, 3 Nos)
- +ROLL
- Medium Gain Antenna
- LAP Payload
- High Gain Antenna
- MENCA Payload
- TTC Antenna
- View from +Yaw/+Pitch

View from +Pitch/+Yaw axis
<table>
<thead>
<tr>
<th>Payload</th>
<th>Primary Objective</th>
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<tbody>
<tr>
<td>Lyman Alpha Photometer (LAP)</td>
<td>Study of Escape processes of Mars upper atmosphere through Deuterium/Hydrogen</td>
</tr>
<tr>
<td>Methane Sensor for MARS (MSM)</td>
<td>Detection of Methane presence</td>
</tr>
<tr>
<td>Martian Exospheric Composition Explorer (MENCA)</td>
<td>Study of the neutral composition of Martian upper atmosphere</td>
</tr>
<tr>
<td>Mars Colour Camera (MCC)</td>
<td>Optical imaging</td>
</tr>
<tr>
<td>TIR Imaging Spectrometer (TIS)</td>
<td>Map surface composition and mineralogy</td>
</tr>
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</table>
Integration of MOM with PSLV C25

MOM Spacecraft getting integrated on PSLV-C25
LAUNCH – PSLV C25 XL

• Technical Challenges

• Requirement of larger Argument of Perigee (AOP) ranging from $276.4^\circ$ to $288.6^\circ$

• Launch vehicle flight regime was extended to 2560 s (against 1200s for regular PSLV missions) with a long coasting (1580-1800s) before the ignition of the PS4 stage

• The long coasting necessitated the following
  • Specific modification and validation of the coast phase guidance algorithm
  • On-board battery capacity augmentation
The ground segment systems form an integrated system supporting both launch phase, and orbital phase of the mission.
Ground Segment

• *IDSN- 32 is the prime Indian deep space station  for MOM in addition to JPL DSN stations. The ground segment  support continues.*

• *Validation of IDSN-32 for range, range rate and Delta DOR jointly by ISTRAC and JPL/NASA carried out successfully and a cross support agreement is on the anvil. TIM planned on April 2015.*

• *International ground stations including JPL DSN stations supported the mission in the non-visible zones. The contingency requirements met by JPL ground segment need a special mention.*

• *The data processing and archival of science data is being carried out flawlessly by ISSDC.*
TRANS MARS INJECTION
Mars Color Camera: 1st Image

19th November 2013, 0820 UT 13:50 hrs

Indian Subcontinent imaged at an altitude of 70,000 km above earth with a spatial resolution of about 3.5 km
Trans Mars Injection (TMI): Executed on December 1, 2013 at 00:49 hrs. IST

Mid Course Corrections
i. Dec 11, 2013
ii. Apr 2014 (Jun 11, 2014)
iii. Aug 2014 (Not required)
iv. Sep 14, 2014 (Sep 22, 2014)

Mars orbit Insertion (MOI)
September 24, 2014 at 07:30 hrs. (IST)
Mars Orbit Insertion

Re-orienting the Spacecraft
MOM is reoriented to align the thrust vector before firing the engines to reduce the velocity.

In the Shadow of Mars
Because of the Mars-Sun-Earth geometry, the orbit insertion is destined to happen while MOM is in eclipse. MOM enters eclipse 5 minutes before Burn Start.

Engine Firing
The Main liquid Engine and eight smaller thrusters fire, imparting braking velocity of 1098.7 m/s.

The communication blackout
The radio link between MOM and Ground station gets blocked by Mars and MOM executes all operations autonomously.

Resuming Communication
The burn is terminated when the required braking velocity is achieved and MOM is in Martian Orbit. The spacecraft is reoriented to point its Antenna towards Earth to resume communication.

Orbit Around Mars
- Penapsis: 423 km
- Apoaipsis: 80,000 km
- Period: 76.8 Earth Hours

Escape trajectory
# Mars Orbit

## Major events before MOI

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date</th>
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<tbody>
<tr>
<td>Uploading of commands</td>
<td>14-09-14</td>
</tr>
<tr>
<td>Verification of uploaded commands</td>
<td>14-09-14</td>
</tr>
<tr>
<td></td>
<td>15-09-14</td>
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<tr>
<td>Entry into Sphere of Influence of Mars</td>
<td>22-09-14</td>
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<tr>
<td>Fourth Trajectory correction manoeuvre and test-firing of Main Liquid Engine</td>
<td></td>
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<tr>
<td>• Duration : 3.968 seconds</td>
<td></td>
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<td>• Fuel consumption: 0.567 kg</td>
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<tr>
<td>• ΔV : 2.142 m/s</td>
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<tr>
<td>Health Monitoring &amp; checks</td>
<td>Ongoing</td>
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</tbody>
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- **MOI Epoch**: 24-09-2014, 07:18 hrs (IST)
- **Periapsis**: 423 km
- **Apo-apsis**: 80000 km
- **Inclination**: 150.0°
- **Period**: 76.8 hr
Mars Orbiter Spacecraft captures its first image of Mars. Taken from a height of 7300 km; with 376 m spatial resolution.
The highest volcano in the solar system – the Olympus Mons and the famous Arsia, Pavonis and Ascraeus collinear mons adjacent to Daedalia Planum. Valles Marineris- the longest canyon in the solar system can be seen.

Dark region towards south of the cloud formation is Elysium - the second largest volcanic province on Mars.

Taken using the Mars Color Camera from an altitude of 8449 km, this image has a spatial resolution of 439 m and is centered around Lat: 20.01N, Lon:31.54E.
Mission Objectives- Compliance

Technological objectives met with still 53 days to go and 37 kg usable propellant left.

Scientific payload Operations fully met.

Deep space mission management successfully executed.

Time, quality, cost and scope met
Implications

• Enhancing Interest in science
• Explaining Scientific concepts
• Youngsters participation through Social Media

Large Appreciation
  o 10 Best TIME Magazine Inventions of 2014
  o Space Pioneer Award of US Space Society
  o NATURE lists Chairman ISRO among Top 10 Scientists
  o .... many others
Thank You

http://www.isro.gov.in