ISRO's Mars Orbiter Mission: An Unparalleled Scientific Achievement

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Dr. K.N. Ninan
Former Outstanding Scientist & Dy. Director, VSSC
Emeritus Professor, Indian Institute of Space Science & Technology
Trivandrum
Email: knn403@gmail.com

Abstract

India is the only country in the world to reach a Martian orbit in the very first attempt and thus, its maiden Mars Orbiter Mission (MOM) is an unparalleled accomplishment in the history of modern science & technology. The Indian orbiter, Mangalyaan with 5 in-house realized instruments on-board was launched by ISRO's reliable satellite launch vehicle, PSLV. The major challenges in the mission were the enormous distance to Mars that is moving at a great speed, cruising to it with minimum energy utilization in a trajectory being attempted for the first time and finally getting captured into a pre-determined Martian orbit. The success of MOM has demonstrated that India can do major scientific tasks in a quick, innovative and cost effective manner.

Introduction

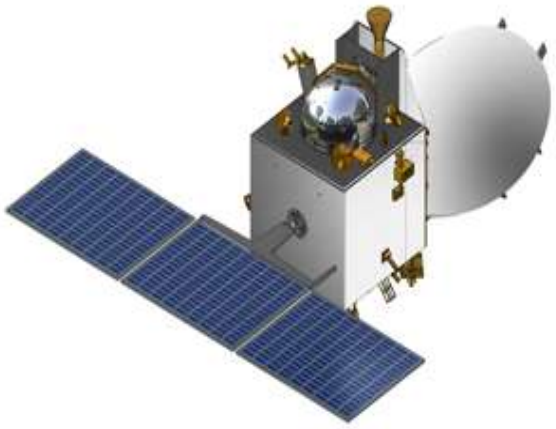
The red planet Mars, our neighbour in the solar system, is still an enigma to humankind. Ancient Romans named it after their god of war. In some parts of India, the horoscopic term *'chovva dosham'* – meaning problem with the position of Mars – is considered bad luck for marriages. Even a century back, there were speculations about rivers, habitats and a civilization on Mars. Now we have a better understanding of the planet, about its red colour being due to iron oxide as a major mineral of Mars or its thin atmosphere with 96% CO_2 as the major constituent. We also know that Mars is practically dry with no liquid water on its surface, though there is about 21 million km^3 of ice and solid carbon dioxide at the polar region. There is a hypothesis that three billion years ago, Mars had liquid water and microbial life on its surface. About 90% of methane on Earth is produced by microbes and therefore, methane can indicate the presence of life on Mars.

A flyby mission by the USSR launched on 10 October 1960 was the maiden attempt to Mars and it was a failure. In fact, no country except India was able to reach the Martian orbit in the very first attempt and the success rate of all the Mars missions put together has been less than 50%, due to the technological complexities involved. Almost all the Mars missions attempted to confirm the presence of methane and thereby life, present or past, on Mars. Some missions of NASA and ESA have shown ppb ranges of methane in Martian atmosphere; however, concordant results are eluding the search. The other major global interest of Mars are as a future habitat or intermediate station to distant planets, verification of the location and amount of water present in Mars and exploration for rare minerals

Mangalyaan, the Indian Mars Orbiter

ISRO's successful maiden Mars Orbiter Mission (MOM) is an unparalleled accomplishment in the history of modern science & technology. No other country has been successful in its first attempt to reach Mars. The main objective of the ISRO mission was to lay the foundations for indigenous capability for interplanetary missions and to develop the technologies required for it. The scientific objective of the mission was exploration of Mars surface features and Martian atmosphere using in-house realised scientific instruments.

The spacecraft named Mangalyaan, meaning *"Mars-craft"* had autonomous features because of the enormous distance to Mars, needing up to 24 minutes for 2-way communications.

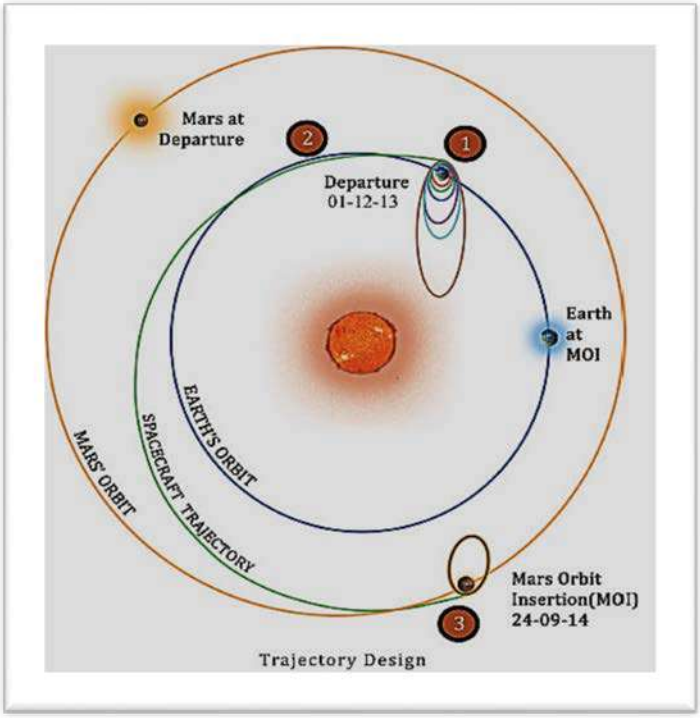


The mass of the spacecraft was 1340 kg that included 850 kg of propellant, comprising MON -3 (3 % NO + 97 % N_2O_4) as the oxidizer and MMH (monomethyl hydrazine) as the fuel. The scientific instruments on-board were (i) Methane Sensor (a short wave IR radiometer) (ii) Lyman

Alpha Photometer (LAP) (iii) Mars Exospheric Neutral Composition Analyser (MENCA), a quadrupole mass spectrometer (iv) Thermal Infrared Imaging Spectrometer (TIS) & (v) Mars Colour Camera. All the five instruments were indigenously developed and their total mass was 14 kg.

Journey towards the Red Planet

On 5 November 2013, Magalyaan was launched by ISRO's prestigious and most reliable satellite launch vehicle, PSLV into 250 x 23500 km elliptical orbit around Earth. The subsequent six orbit raising maneuvers and injection towards Mars were performed by the spacecraft propulsion module. Thereafter, for cruising to Mars with minimum energy (propellant) utilization, the trajectory of Mangalyaan was arrived at, based on thousands of simulations.



On 30 November 2013, the velocity of spacecraft was increased tangentially at (1) to take it into as elliptical orbit around the sun from (2) to (3), needing no energy to travel around sun. The meeting point of Mars was at (3) on 24 September 2014, 667 million km away, travelled in 300 days. The calculations and the performance of the propulsion system were so precise that only two minor orbit corrections with 0.8 kg propellant utilization were required in the 300 days of travel. Mars also arrived at the same time, at the same point.

Entry to Martian Orbit

On reaching the sphere of influence of Mars, the velocity of Mangalyaan was to be reduced from its sun orbital velocity of 22.1 km/s to 1.1 km/s to get captured into the pre-determined Martian obit. The important question was: will the engine work after its hibernation during the cruise phase of 300 days in deep space environment? A four seconds firing of the engine on T-2 days gave the exactly expected results and great confidence for the Mission. The major events on 24 September 2014 were: (i) at 06:56:32 hrs: the spacecraft was turned by 180 deg to reduce its velocity by 'reverse firing', (ii) between 07:17:32 to 07:41:46 hrs: the thrusters were fired for 24 min 14 s, and the velocity was reduced to 1.099 km/s (within 0.1% of the target, indicating a near perfect performance of the propulsion system), (iii) the spacecraft was turned back to normal position and (iv) at 08:00:00 hrs: confirmation of the orbit was received from Canberra, the first point of visibility. The first-cut analysis showed an orbit of 422 x 76994 km around Mars, against a prediction of 423 x 80000 km, a near prefect mission!

Conclusions:

The total cost of the Mission was approximately Rs. 450 Crore, making it the least-expensive Mars mission to date and it was realized in record time of 15 months. At the time of the lecture, the orbiter has performed for more than 4 years, much beyond the mission objective of 6 months in orbit. The success of MOM has demonstrated that India can do major technical tasks in a quick, innovative and cost effective manner. The vision, vitality and values which have become the hallmarks of ISRO in all areas of work are the basic reasons for this unparalleled accomplishment.

Dr. Ninan: Brief Biosketch

Dr. Ninan is renowned chemical scientist and former deputy director of VSSC. After his 40 years of work tenure at VSSC, Ninan worked as Professor Emeritus at Indian Institute of Space Science and Technology. His research interests are polymer science, rocket propellants, solid state chemistry and kinetics. He has more than 200 publications having more than 5000 citations. His post-retirement interest is in the popularization of science among school children and university students.

NUCLEAR MEDICINE FOR THE DIAGNOSIS AND THERAPY OF CANCER

M.R.A. Pillai Ph.D.; D.Sc

Molecular Cyclotrons, Puthuvype, Ernakulam, Kerala 682 508

Email: pillai.m.r.a@gmail.com

Abstract

Nuclear medicine is a medical faculty used for the diagnosis of a large number of diseases. It also has a niche in the treatment of certain type of cancers. There are two imaging modalities available in nuclear medicine, SPECT and PET. Radiopharmaceuticals made using a gamma emitting isotope called ^{99m}Tc is used for SPECT imaging. PET uses radiopharmaceuticals labelled with radioisotopes decaying by positron emission tomography. Radiopharmaceuticals made of both α and β- emitting radioisotopes are used for targeted therapy. India is one of the early entrant in nuclear medicine and that leadership position continues.

Introduction

The quest to use radioactivity for disease management is as old as the discovery of radium by Marie Curie and Pierre Curie in the year 1898. Radium-226 was tried as a medicine to treat a variety of diseases but miserably failed. The treatment resulted in unwanted radiation exposure without any commensurate benefits and thus abandoned. The use of atomic bombs in Hiroshima and Nagasaki in August 1945 brought the widespread awareness of the damages of radiation making the people scary of the use of radioactivity. However, once the war ended scientists started working towards the beneficial uses of radiation and radioisotopes in medicine which were the bye products of the reactors made for making nuclear weapon materials. The result was the emergence of two important medical fields namely radiotherapy and nuclear medicine.

Nuclear Medicine

Nuclear medicine is a faculty of medicine in which radioactive formulations called ‘radiopharmaceuticals’ are administered to the patients. Radioisotopes decaying by β- or alpha