Emirates Mars Mission

Mars Orbital Insertion Factsheet

January 2021

The EMM Hope probe will attain Mars Orbit at 19:57, 9 February 2021

Mars Orbital Insertion (MOI)

- Following the launch of Hope Probe in July 2020 from Tanegashima, Japan, the spacecraft travelled on a seven-month, 493,500,000-kilometre journey to reach Mars orbit.
- This will make the Emirates the fifth player to reach Mars (after the USA, Soviet Union, China, the European Space Agency and India).
- MOI – Mars Orbit Insertion - is a complex manoeuvre, where Hope rapidly decelerates to enter a stable orbit with Mars.
- MOI is the most critical part of the mission. The stresses on the spacecraft of all engines firing at once are far beyond those at launch and the entire operation has to be completed despite the 22-minute two-way radio delay from Earth. This requires the spacecraft to be highly autonomous. Although the operation will commence at approximately 7.30pm GST, we won't know it has until eleven minutes later, just after 7.42pm.
- A number of 'go/nogo' polls and status reviews take place in the days immediately prior to scheduled MOI. The last of these takes place on 'MOI day' itself.
- The spacecraft is rotated to position it for a deceleration 'burn' of 27 minutes' duration, firing all six of its Delta-V thrusters, slowing the spacecraft from its cruising speed of 121,000 km/h to something nearer to 18,000 km/h to achieve MOI.
- Hope is a 1,350 kg mass spacecraft - about the size of a SUV. Of this, some 800 kg of the overall mass is hydrazine fuel - the MOI operation will consume fully 50% of that fuel. The four trajectory correction manoeuvres (TCMs) the probe performed during its cruise towards Mars used just 10kg of the fuel.
- Hope's six thrusters will deliver some 650 Newtons of thrust during the burn.
- The spacecraft system is both robust and has a high level of redundancy. Should a thruster fail, the burn duration will increase to compensate. The MOI operation can still be completed even if two thrusters should fail.
- In addition to the six Delta-V thrusters, the probe also has a set of RCS (Reaction Control System) thrusters, which will maintain the spacecraft's orientation.
- The accuracy of Hope's arrival trajectory is critical: the spacecraft is aiming for a 'corridor' some 600km wide. The MOI burn will commence when the spacecraft is 2,363 km from the planetary surface and will see Hope reaching a proximity of 1,062 km from Mars (the periapse of its planned capture orbit) before the burn ends at 1,441 km away from the planet.
- The burn, slightly shorter than originally planned because of the exceptional accuracy of Hope's trajectory, will commence at 19:30GST and end at 19:57 GST.

- Some five minutes following the MOI burn, the Hope probe flies into the dark side of Mars, 'occultation'. Radio signals will be lost for some 15 minutes until the probe can be contacted again.
- With its command and control centre based at MBRSC in Dubai, EMM depends on the Deep Space Network (DSN) of antennas for its communication. Antennas based in Goldstone, California, Canberra and Madrid. During the MOI operation, Hope's signals will be routed through the Madrid antenna.
- Hope's capture orbit takes the spacecraft from a distance of 1,000 (periapse) to 49,380 (apoapse) km from Mars' planetary surface. In this phase, Hope's instrumentation will be tested and the spacecraft will, over the coming two months, transition to its science orbit.
- Three transition to science (TTS) manoeuvres are currently planned to move the probe from its capture to its science orbit. The final number of such manoeuvres will be defined by the accuracy/success of MOI.
- The transition to Hope's science orbit will be completed by April 2021.
- Hope has a planned 20,000 – 43,000 km elliptical science orbit, with an inclination to Mars of 25 degrees.
- The probe completes one orbit of the planet every 55 hours and will capture a full planetary sample every nine days.
- While the probe will be in daily contact with Earth during the capture orbit phase, in its science orbit, contacts will take place 2-3 times a week with each pass being some 6-8 hours in order to download data and upload updates and instructions.

The Journey to Mars

- EMM launched on 20 July 2020 to reach Mars Orbital Insertion (MOI) in February 2021. It launched from Tanegashima Space Centre in Kagoshima Prefecture, southwestern Japan, on a Mitsubishi MH-IIA rocket. The launch was originally scheduled for 15 July but was delayed because of unstable weather conditions.
- The two-stage launcher travelled at a speed in excess of 34,000 km/h to a short 'parking orbit', of earth before the second stage released the Probe on its launch trajectory at something like 38 times the speed of sound.
- The MH-IIA launch platform used some 300 tonnes of bi-propellant, a mixture of liquid hydrogen and liquid oxygen. The by-product of this combustion is not C02 exhaust, but water vapour – the rocket makes clouds!
- The average speed of the Hope Probe during its 7 months journey to Mars was 121,000 km/h. it performed four course correction manoeuvres (Trajectory Correction Manoeuvres or TCMs) over the course of that journey.
- Star trackers, low resolution cameras linked to a database of stellar positions, helped to position the highly autonomous spacecraft. Later in the cruise, a 'dust tracking' feature of these instruments was enabled, to take measurements of interplanetary dust density.
- A number of additional tests and measurements were taken during Hope's cruise, enabled by the spacecraft's highly accurate trajectory. In one of these, Hope was rotated to align with the European Space Agency's BepiColombo spacecraft, on a seven-year journey to Mercury. The two spacecraft cross-calibrated instruments during the operation.
- While radio signals will take 22 minutes to travel from Hope to Earth and back, this signal delay will increase to up to 26 minutes depending on the spacecraft's orbital phase.

The Emirates Mars Mission

Project Goals:

The main goals set by UAE's federal government for the program are the following:

- Get a probe to Mars by the Emirates' 50th anniversary in 2021.
- Develop the Science and Technology Sector in the UAE.
- Develop Emirati Scientific Capabilities.
- Increase the Emirates' Contribution to the Global Science Community.

Objectives:

The following objectives were derived from the main goals set by the government:

- Train and prepare Emirati scientists to do significant scientific work in the field of space exploration.
- Train and prepare Emirati engineers to develop outer space exploration systems and instruments in the Emirates.
- Build the necessary infrastructure to create a sustainable outer space exploration program in the Emirates.
- Establish partnerships with international entities in the field of outer space exploration.
- Establish, improve and further develop the engineering and scientific programs in the academic sector.
- Transfer knowledge to the different sectors in UAE. (Spin-offs and spill over effects)

Project Requirements:

The following requirements were set to develop the EMM mission conceptualization:

- The mission should be unique and should aim for novel and significant discoveries.
- The mission should have significant contributions to the ongoing work of the global space science community and should be of great value to humanity.
- The mission should help build a sustainable outer space exploration program in the Emirates.
- The mission should include a valuable contribution from Emirati engineers and scientists.
- Some of the system development activities should take place in the Emirates.

EMM Objectives

The Emirates Mars Mission (EMM) and its Hope spacecraft, represent the Emirates' vision for the future. A post-oil future, where the knowledge and capabilities of those in the Emirates are the wealth of the nation, in addition to, being the source of stability and readiness of tomorrow's challenges and opportunities. The mission's ownership lies with the Emirates' cabinet.

Finally, a recurring theme within the mission is that EMM is not about sending a probe to Mars; but represents a greater hope for the region, that in empowering the youth in the fields of science and technology and having overarching goals; nations today, just like our ancestors, can aspire to reach for the stars, contribute on a global scale and creating impactful policies that will influence generations to come.

Science Objective:

- Hope's mission is focused on atmospheric dynamics. It will explore the atmosphere of Mars globally while sampling both diurnal (daily) and seasonal timescales. This has never been done by any previous Mars mission.
- Understanding atmospheres of other planets, allows us to better understand our planet (since there is another sample to compare with) and better understand other planets in the universe.

Science Questions:

- How does the Martian lower atmosphere respond globally, diurnally (daily), and seasonally to solar forcing (radiated energy from the sun)?
- How do conditions throughout the Martian atmosphere affect rates of atmospheric escape (escape of Hydrogen and Oxygen, building blocks of life from the Martian atmosphere)?
- How does the Martian exosphere (Upper atmosphere) behave temporally (At different times during the day) and spatially (At different distances relative to Mars)?

Science Instruments

Mars Hope carries three instruments:

EXI – The Emirates eXploration Imager is a digital camera that will capture high-resolution images of Mars along with measuring water ice and ozone in the lower atmosphere through the UV bands.

EMIRS – The Emirates Mars InfraRed Spectrometer will measure the global distribution of dust, ice cloud, and water vapor in the Martian lower atmosphere.

EMUS – The Emirates Mars Ultraviolet Spectrometer will measure oxygen and carbon monoxide in the thermosphere and the variability of hydrogen and oxygen in the upper atmosphere.

Partners

- The Hope Probe was designed and developed by the EMM team at MBRSC together with Knowledge Transfer partners at the University of Colorado, Boulder; Arizona State University and the University of California, Berkley.
- The Laboratory for Atmospheric and Space Physics (LASP) at University of Colorado, Boulder is the primary knowledge transfer partner for mission design, spacecraft, and EXI/EMUS instrument development, testing, science team/apprenticeship, and operations
- Arizona State University is the knowledge transfer partner for EMIRS instrument development and science team/apprenticeship
- The University of California, Berkeley Space Sciences Lab (SSL) is the knowledge transfer partner for Science team/apprenticeship & EMUS detectors
- The project team for this mission, the members who worked on the development of spacecraft, instruments, mission operations, and science - consisted of more than 450 team members, 150 from LASP, 200 from MBRSC of whom 75 were dedicated to the mission, with the other contributors from partners. Of these, the integrated team for spacecraft development numbered 45.

EMM in Numbers

- $200 million budget, covering spacecraft development, launch and operations
- 60,000 young people and teachers engaged in outreach programs
- 200 new technical designs
- 100% Emirati, 34% female (science team is 80% female) team
- 66 components made in the Emirates
- 87 scientific presentations published in international conferences
- On time, on budget in a 6-year program as opposed to usual 10-year development time.

Background - MBRSC and satellite development

- The Mohammed bin Rashid Space Centre (MBRSC) in Dubai, UAE, has been working on developing earth-observation satellites since 2006.
- MBRSC embarked on a technology transfer program with Satrec Initiative of South Korea.
- DubaiSat-1, developed with 30% contribution from Emirati engineers, launched successfully in 2009 from Kazakhstan.
- DubaiSat-2 was a joint development project with 50% contribution from Emirati engineers and launched successfully in 2013 from Russia.
- The UAE's first CubeSat and University satellite, Nayif-1, launched from India in February 2017. The CubeSat was developed by MBRSC with students from the American University of Sharjah.
- Khalifasat was the first satellite to be wholly designed and developed in the UAE. It was launched from Tanegashima, Japan, in October 2018.
- Over 200 employees now work at MBRSC, the staff is 100% Emirati.

About the Emirates Mars Mission

The Emirates Mars Mission (EMM) was initiated to disrupt and accelerate the development of the UAE's space, education, science and technology sectors, and was first announced by the United Arab Emirates' President His Highness Sheikh Khalifa Bin Zayed Al Nahyan and UAE's Vice President and Prime Minister His Highness Sheikh Mohammed Bin Rashid Al Maktoum on 16 July 2014.

EMM and the Hope probe are the culmination of a knowledge transfer and development effort started in 2006 by the Mohammed bin Rashid Space Center (MBRSC), which has seen Emirati engineers and experts working with partners around the world to develop the UAE's space mission design and engineering capabilities.

The Mohammed bin Rashid Space Center was assigned by the UAE government to manage, develop, and execute EMM, supervised by the UAE Space Agency.

The UAE Space Agency

- The Emirates Mars Mission was funded by the UAE Space Agency.
- The Agency is focused on the development of policies, strategies and plans related to the space sector. It provides advice and guidance for national space programs, and supports research and studies for theoretical and applied areas within space.