ISRO's Mars Mission

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The Indian Space Research Organisation's Mangalyaan mission is a remarkable success story. Over the last five decades of its existence, ISRO has notched up many successes and has played a key role in indigenous development of various technologies. Its various programmes are also outstanding examples of its ability to successfully perform complex technological and organisational feats. However, one has yet to see any specific spin-offs in the civilian domain of these fairly advanced technologies. Further, the gap between running a dedicated, focused technological mission and improving the general level of manufacturing competence and quality is huge. ISRO was earlier closely involved in the development of dual-use technologies, that involvement continues though the organisation has tended to downplay its role in military applications as it seeks to obtain a larger share of the global civilian space market.

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"MOM never disappoints" was how Prime Minister Narendra Modi congratulated the scientists of Indian Space Research Organisation (ISRO) at the successful insertion of the maiden Mars Orbiter Mission (MOM) into the Martian orbit. At 07.47 IST, the spacecraft Mangalyaan started orbiting the Red Planet and 12 minutes later, the signal was received at the ISRO's Mission Control Centre.

It is a remarkable achievement by any standard. With this success, India joins the elite club of three (Russia, the United States and the European Space Agency) that has put a spacecraft into Martian orbit. What is noteworthy is that India has been able to do so in its first attempt and at a fraction of the cost of earlier missions by other nations. The total cost of the mission is about Rs 450 crore ($75 million). To put this in perspective, the Mars Atmosphere and Volatile Evolution mission of US's NASA which beat Mangalyaan by three days to reach Mars cost around $700 million.

The project was approved by the central government in 2012 and it is to the credit of ISRO to have managed to assemble the spacecraft and launch it in a relatively short span of 15 months, something which is highly unusual for a space mission of this complexity. In fact, the haste had led an ex-chairman of ISRO, G Madhavan Nair, to comment that "it was a half-baked, half-cooked mission being attempted in undue haste with misplaced objectives" – a pretty strong condemnation coming from a career space administrator.

The haste was understandable. Ideally, the more powerful Geosynchronous Satellite Launch Vehicle (GSLV) which would have put the spacecraft into a much higher orbit should have been used. However, given that our indigenous GSLV is still not considered reliable (more on this later), the workhorse of the Indian space programme, the much less powerful Polar Satellite Launch Vehicle (PSLV) was used to launch the spacecraft into a lower orbit around the earth. The spacecraft orbited the earth for almost a month, during which time six manoeuvres to increase its orbit were performed. The way to do this involves a transfer orbit called the Hohmann transfer orbit. It turns out that for fuel efficiency, the opportunities to do this occur every 26 months. So if the 2013 launch date was missed, the launch could only have taken place in 2016.

Subsequent to the raising of the orbit to the required level, the spacecraft left for its 780 million km journey to Mars, reaching its sphere of influence on 22 September 2014. The most difficult part of the mission was to successfully get the spacecraft to go into orbit around Mars. This required extremely precise control of the equipment and engine on board, all of which were programmed to function in an autonomous mode since the distance precluded any direct control from the earth. At 07.47 hours IST on 24 September this was achieved.

The spacecraft will now orbit Mars using its payload of scientific instruments to record various observations about the Martian atmosphere as well as the Martian soil. These observations, specifically about the presence of methane in the atmosphere, will lead to a better understanding of the chemistry of Mars. The scientific objectives of the mission are modest and not much new insight is expected to be gained about the Red Planet. However, the fact that the instruments are indigenously developed is significant.

The Long Road

India's space programme has come a long way from the setting up of the Indian National Committee for Space Research (INCOSPAR) in 1962 under the chairmanship of Vikram Sarabhai. Just as India's atomic energy programme got to be identified with Homi Bhabha, Sarabhai's name was synonymous with space research in India. In 1969, ISRO was founded and INCOSPAR disbanded.

The rationale for spending precious resources on space research was questioned by many. These were after all the times when we were living from "ship to mouth". However, Sarabhai was in no doubt about the importance of the programme in nation building. As he said in 1969,

> There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the Moon or the planets or manned spaceflight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society.

From modest beginnings of launching sounding rockets from Thumba, near Thiruvananthapuram, to the massive infrastructure that exists today, ISRO has come a long way. With a budget of about Rs 7,500 crore and employing about 18,000 people directly, ISRO has fabricated satellites, developed launch vehicles and even launched Chandrayaan, a successful unmanned mission to the Moon. It is developing the expertise for a landing on the Moon as well as a human spaceflight programme though that is still sometime in the future.

The successful fabrication of the first Indian satellite Aryabhata in 1975 launched India into a select club of nations with indigenous satellites. India now has one of the largest satellite networks for a variety of purposes. Communications, remote sensing, television broadcast and meteorology are some of the civilian applications of the vast network. In addition, the vast satellite-based network is also being used for military purposes. The latest GSAT-7, for instance, has a dedicated platform for naval communications.

Satellites need launch vehicles and it is here that ISRO's report card is mixed. Though the first satellite launch vehicle (SLV) was successfully launched in 1979, it was with the development and deployment of the PSLV in 1993 that the programme really took off. The PSLV remains the most successful launch vehicle developed by ISRO with more than 25 successful launches which have taken 65 spacecrafts or satellites into orbit. This includes the Chandrayaan and Mangalyaan.

However, the PSLV does not have the capability to launch heavier satellites thereby severely restricting the scope of its use. For launching heavy payloads into space (like, for instance, the INSAT series satellites which weigh around 2,000-2,500 kg), a much more powerful vehicle is required and this was what led to the start of the GSLV programme. Started in 1990, the purpose of the programme was to develop a launch vehicle to deploy geosynchronous satellites, the ones which are most useful for communications and broadcasting. For this purpose, the crucial piece of technology was the cryogenic engine which is added as a third stage to the existing components from the PSLV.

The cryogenic engine and its related technological infrastructure were to be initially supplied by the Russians and thereafter developed indigenously with the transfer of technology. In 1992, the US threatened to impose sanctions on both the Russian agency Glavkosmos and ISRO for violating the Missile Technology Control Regime (MTCR) if the technology was sold to India. Though ostensibly the reason for the sanctions was the dual-use nature of the technology (in satellite launch vehicles as well as missiles), there was undoubtedly a commercial angle to the threat. The satellite launch business is very lucrative and the US did not want another competitor.

The threat resulted in the Russians reneging on the transfer of technology but agreeing to sell seven engines instead. These were used by ISRO in a series of tests while simultaneously attempting to develop in-house capabilities to design and manufacture the crucial cryogenic engine. After a series of failures, it was only in January 2014 that the first indigenously produced GSLV was successfully launched.

Military Use

The dual-use nature of rocket technology is certainly an important aspect to the whole space programme, despite all the public rhetoric about peaceful use of space technology. There never was any doubt about this in the mind of the planners or administrators. Throughout the decade of the 1970s and the 1980s, the synergy between the civilian and military applications was encouraged. In fact, the doyen of Indian space research, Satish Dhawan admitted as much when he said, "Like nuclear energy, we could cross the divide whenever we wanted." The Defence Research and Development Organisation (DRDO) and ISRO had very close links as was evident from the movement of personnel between these organisations, the most notable being A P J Abdul Kalam who started with the DRDO before going to ISRO and then returning to the DRDO.

The use of rocket technology for defence became important once India crossed the nuclear rubicon since nuclear weapons without delivery vehicles are not of much use. The development of ballistic missiles like Prithvi and Agni, capable of carrying nuclear warheads, was deemed to be essential for deterrence which formed an integral part of the defence doctrine. The close links between the missile and the space programme proved to be essential not just for engine development but also for guidance and tracking systems. This indigenous development of all the systems was especially crucial since the MTCR regime prohibited the import of certain critical components.

GSLV development too had a very definite military objective. An essential component of the strategic defence doctrine was inclusion of intercontinental ballistic missiles (ICBMs), which is the Agni series with an enhanced range. The capability to hit targets in the 5,000-km range with nuclear missiles was deemed to be important especially to deter China. The requirements of enhanced range and increased payload meant that the programme could not succeed without cryogenic technology. The indigenous development of the cryogenic engine for the GSLV fit neatly into this requirement.

The synergetic and open relationship between the military and civilian applications continued till the late 1990s. However, over this time, ISRO wanted a larger share of the commercial pie of the satellite launch business as well as felt the need for enhanced international collaboration. Neither of these was possible as long as it was seen as an adjunct of the Indian defence sector. ISRO had to become "respectable" to take what it thought was its legitimate place at the high table. The US-India civil nuclear deal, which ended sanctions, also required a complete separation of the civilian rocket and military missile programmes. All this does not mean that the links have been completely severed – indeed DRDO remains a key subcontractor for ISRO programmes and ISRO continues to provide key technologies to DRDO. However, ISRO downplays this and likes to cultivate a pristine image.

Success and Slogans

Over the last five decades of its existence, ISRO has certainly played a key role in indigenous development (either from the ground up or by reverse engineering) of various technologies. The impressive satellite network that we possess is amongst the largest in the world. Weather forecasting, broadcasting, telecommunications, remote sensing and even telemedicine are some of the applications which would have been unthinkable without an indigenous space programme.

It is also true that ISRO's various programmes, including the Mangalyaan, are outstanding examples of the organisation's capabilities to successfully perform complex technological and organisational feats. Space programmes need an integration of a variety of technologies like electronic fabrication, metallurgy, engine design and fabrication, tracking technology, data processing, etc. Thus the development of these scientific and industrial capabilities is required for the success of the programmes. It is to ISRO's credit that it has managed to perform this mammoth task successfully and relatively cheaply. However, one has yet to see any specific spin-offs in the civilian domain of these fairly advanced technologies.

ISRO's not-so-stellar record in the widespread dissemination of technology has not stopped the drum beaters to use it as an example of Indian ingenuity and "frugal engineering" to attract foreign capital to Indian manufacturing. Sending a successful mission to Mars is obviously something to be proud of. However, it is not clear whether it can be used as an example of manufacturing prowess required for the "Make in India" slogan to work. The gap between running a dedicated, focused technological mission and improving the general level of manufacturing competence and quality is huge. Slogans alone will do little to bridge this gap.

"*Jab kaam mangal hota hai, irade mangal hote hain, to yaatra bhi mangal hoti hai*" is how the prime minister summed up MOM's success to the ISRO scientists. One can of course understand the need for a politician to use a religious metaphor to commend what is indeed a stupendous technological achievement. But, then, it is possibly par for the course since the ISRO chairman, just before the launch of MOM is reported to have performed a pooja at Tirupati using a steel replica of the launch vehicle. We are like that only!