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Indian Space Research – Challenge and Response

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Abstract

The world entered into a new space era when Sputnik-I was launched by the erstwhile USSR in 1957. Followed by this, the USA and many other European countries started their space missions. Five years later, India took the initiative along this line. Basically, India faced several challenges on its own. At the same time, the Nehru government was very much interested in encouraging science and technology, in general, and space research in particular. In this connection, the Indian National Committee for Space Research was established in 1962 under the leadership of Vikram Sarabhai. Subsequently, a rocket-launching station was established in Thumba, near Thiruvananthapuram. Moreover, the first sounding rocket was launched from Indian soil in 1963. Several concrete efforts were taken to improve the research. The Indian space programme reached its zenith in 2001 when the GSLV rocket was launched from Sriharikota. Meanwhile, this research met several failures as well. However, these failures paved the way for increasing the responsibilities of the organisations involved in space research and in achieving the target. This article makes an attempt to explain the challenges faced by the Indian space programme.

Keywords: GSLV, Sounding Rocket, INCOSPAR, ISRO, Sputnik-I, Thumba, Vikram Sarabhai

1. Introduction

During the 1950s and 1960s, the world countries expected India to concentrate on various imminent issues that pose threat to the very existence of the vast country, which one can comprehend to be natural because the country has just achieved independence. However, at that time, integrating the country itself was a major task. Then there were issues of providing the people with basic needs such as food, shelter, and clothes, and other necessities such as education, addressing unemployment, and alleviating poverty. Despite all these, a few believed that India should enter into the space programme. They believed that the development of a nation was closely linked to a good understanding of science and its sound application of it in the form of technology. At the same time, the USA and the USSR attained the pioneering stage in space research, and an invisible war was initiated between these two safer powers to conquer outer space. No one ever imagined a developing nation stepping into space research. Nonetheless, India understood the potential of space research and its ability to solve domestic problems, and the most important visionaries were Jawaharlal Nehru, Indira Gandhi, Vikram Sarabhai, and Homi Jahangir.

When the thinkers of the Indian space programme conceived the idea, nobody would have imagined that they had a long-term objective and a roadmap to achieve that. Vikram Sarabhai expressed the basic objectives of the Indian space programme in 1968 when Thumba Equatorial Rocket Launching Station dedicated to UNO in the presence of Late Prime Minister Indira Gandhi.

> *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 explorations of the moon or the planets or manned space flight. 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 problems of man and society which we find in our country*

First, to achieve self-reliance in space technology and its applications, India began to develop the infrastructure necessary for the indigenous development of space launches and satellites. Hence, in the 1960s, the efforts of the Indian space programme were confined to getting familiar with technologies and developing technical and organisational infrastructure for eventual indigenous development and satellites launching vehicles. The efforts became successful when the Indian space programme was institutionalised in 1962 with the setting up of the Indian National Committee for Space Research (INCOSPAR). As a chairman of INCOSPAR, Vikram Sarabhai's foremost step was the establishment of Rocket Launching Station in Thumba, a fishing coastal village near Thiruvananthapuram. Sarabhai selected this place for sounding rockets because of the atmosphere and outer space over low latitudes and, in particular, over the magnetic equator.Thumba also had the benefit of a nearby airport, making it easy to transport the materials. Hence, to establish a launching station, the land is very essential, hence, the district collector of Trivandrum, K. Madhavan Nair, was given the task to acquire the land and hand it over in just a hundred days. But, land acquisition by the government is problematic in most parts of India. Henceforth, along with the collector, the bishop of Trivandrum, the Right Rev. Dr Peter Bernard Pereira, helped with the task of carrying out the land acquisition. Since the fishermen were Christians, the words of the bishop carried much weight. Then, the acquired land was handed over to the Central government. Similarly, St Mary Magdalene's Church, which fell within the area, also agreed to vacate the land. With these efforts, Thumba Equatorial Rocket Launching Station came into existence in 1963.

Following that, on November 21, 1963, the first-sounding rocket, the Nike Apache, provided by NASA with a sodium vapour payload provided by CNES, France, was launched from Thumba. In the initial days, the lack of facilities in Thumba dazed all the scientists. However, the team made a very effective contribution to the development of sounding rocket research in Thumba. In 1969, INCOSPAR was reconstituted under the Indian National Science Academy, and a new organization, the Indian Space Research Organization (ISRO), was formed under the DAE. Then, the national space programme was formally organised in June 1972 with the establishment of the Space Commission and the Department of Space to promote the development and application of space technology and space science for the socioeconomic benefit of the nation.

2. The emergence of Indian Satellites

The Indian satellite journey began in 1975 with the launch of India's first satellite, "Aryabhatta," followed by several experimental satellites such as Bhaskara I and II, Rohini, and APPLE.Then, the SLV (Satellite Launching Vehicle) plays a significant role. In the 1970s, Sarabhai selected Sriharikota Island in the Bay of Bengal as a launch pad. In the initial period, Sriharikota was used for launching sounding rockets. As a parallel movement, the SLV project began operations.

Recognizing the immense socio-economic benefits of space technology, Sarabhai decided to go all-in on developing indigenous capability in building and launching India's own satellites (SLV). He had already hand-picked a team to give shape to his dream of an Indian SLV. A.P.J. Abdul Kalam was selected as project director and also given the additional charge of designing the fourth stage. The other three stages were headed by Gowarikar for Design Project Stage-1 (DPS-1), Muthunayagam in charge of DPS-2, and Kurup for DPS-3. When the team was making progress, the sudden demise of Sarabhai shocked the entire Indian space community, and Indian space scientists started to worry about a successful replacement. It was considered as a major setback to the Indian space research. However, the Government of India sharply responded and appointed Satish Dhawan as the chairman of ISRO and secretary of DOS. Like Sarabhai, Dhawan wholeheartedly dedicated his service to the Indian Space Programme in general and the SLV project in particular.

The first SLV-3 lifted off from Sriharikota at 7.58 a.m. on 10 August 1979. The first stage performed perfectly and separated without a hitch. But during the operation of the second stage, the launch vehicle began to deviate from the planned trajectory, and then it went out of control, and thefourth stage with the payload splashed into the sea, 560 kilometres off Sriharikota.

Later, the post-flight analysis committee headed by S.K. Athithan pinpointed the reasons for the malfunction of the vehicle. It was established that the mishap occurred because of the failure of the second-stage control system. Since no control force was available during the second stage of flight, which the vehicle became aerodynamically unstable, resulting in altitude and velocity losses. This caused the vehicle to fall into the sea even before the other stages could ignite. After that, Satish Dhawan gave the green signal to start the work of re-launching the SLV-3.

Little less than a year after the first failure, another SLV-3, designated SLV-3 (E)-02, stood on the launch pad. On 18 July 1980, India’s first satellite launch vehicle, SLV-3, lifted off from SHAR. This time, there were no problems of any sort. The SLV-3 put the 35 kg Rohini Satellite into a 300-kilometre by 900-kilometre elliptical orbit. The satellite had been launched eastwards. After the satellite circled the earth and rose over India’s western horizon; the first radio signals from the satellite were picked up at Thiruvananthapuram, 1 hour and 45 minutes after launch.With this achievement, India became the sixth country to possess launch vehicle technology. Later, two more SLVs were launched successfully in 1981 and 1983.

Then, the ISRO scientists decided to move to an advanced stage, and they preferred that the next step would be to develop the polar satellite launch vehicle (PSLV) to put Indian remote sensing satellites into orbit. The PSLV could then become the basis for developing more powerful launchers needed to carry the INSAT satellites. However, an issue arose as to whether to embark straightaway on the PSLV or have an intermediate launch vehicle between the SLV-3 and the PSLV. Because moving from SLV-3 to PSLV seems like a big technological jump. Similarly, an intermediate vehicle would allow some critical technologies needed for the PSLV to be tested more cheaply. Confronting these issues, an augmented satellite launch vehicle (ASLV) emerged as a new result. The ASLV was particularly appealing to Indian scientists because it appeared to be no more than a straightforward augmentation of the basic SLV-3.

The ASLV would have a more sophisticated onboard guidance system as well as a bulbous heat shield so that satellites would be larger than the vehicle’s diameter. The ASLV and PSLV projects were both cleared in June 1982. The sanctioned project cost of the ASLV at the time was Rs. 19.73 crore, and the first developmental flight was scheduled for 1985. The ASLV was essentially the SLV class, but with the addition of two strap-on boosters in the first stage to provide extra thrust. The weight of an ASLV was almost 40 tonnes, and the height was 23.5 m. The launcher was assembled vertically on the launch pad on a 40-metre-tall mobile service structure with lifts, access platforms and a clean room. The strap-on boosters were first tested in flight in November 1985, when they were attached to a Rohini-300 sounding rocket. The first launch of ASLV occurred at 12:09 pm on 24 March 1987, and the second launch at 2:48 pm on 13 July 1988; unfortunately, both of these did not achieve their target. The first stage motor failed to ignite in 1987, though the computer had given the command. ASLV-D2 was launched in July 1988 after incorporating several improvements suggested in the wake of the failure of the first ASLV. But, the second attempt also failed. However, when compared with the previous attempt, the first stage did ignite, but the strap-on motors burned out a second or too soon, leading to inadequate control for a few seconds.

Hence, ISRO realised that a third failure would have had disastrous consequences for the entire launch vehicle programme. Later, the Failure Analysis Committee, headed by R. Aravamudan after the first failure in 1987 and the second one led by S.C. Gupta in 1988 clearly examined the causes for the failure of ASLV-D1 and ASLV-D2, launched in 1987 and 1988, respectively. Besides this, a national expert review panel under the direction of R. Narasimha also recommended several measures. They indicated in their report that "recognizing the inherent dispersion in the burn out of strap-on boosters, the ignition of the core [first stage], instead of being at a prefixed time, should be preferably linked to the event when the strap-on boosters become ineffective in the tail off region". ISRO's launch vehicle teams took these lessons to heart.

Finally, on 20 May 1992, the ASLV was launched for a third time, from Sriharikota. This time, after an uneventful flight, it put the 106 kg SROSS-C1 satellite into an orbit about 450 kilometres above the Earth. Compared to the wild jubilation that greeted the successful launch of SLV-3, there was heartfelt relief all around. ISRO had successfully crossed an important Rubicon. In May 1994, just four months before the first PSLV launch, ASLV successfully launched the 113 kg SROSS-C2 satellite into an elliptical orbit of 938 km by 437 km , and ISRO also abandoned the ASLV program.

3. The Polar Satellite Launching Vehicle (PSLV) Programme

In November 1972, a study group headed by R. M. Vasgam was set up to examine configurations for launchers that could put an Indian National Satellite (INSAT) into orbit. The committee recommended a cluster of four liquid engines, each producing a thrust of 60 tonnes, for the first stage, and a similar engine would be used for the second stage. The third stage would have two cryogenic engines, each producing 7.5 tonnes of thrust. The launcher had the fourth stage with a pressure-fed liquid engine to take the satellite from transfer orbit to geostationary orbit. On the morning of 20 September 1993, the PSLV lifted off from Sriharikota for the first time. The PSLV-D1 (the 'D1' indicating that it was the first developmental flight) carried the IRS-1E remote sensing satellite. Three seconds before lift-off, the liquid roll control engines of the first stage were ignited. Then, the first stage was fired. In less than a second, its thrust built up, and the vehicle lifted off. About a second later, two of the six strap-on motors were ignited, and the vehicle rose vertically for 5 seconds.

The screen inside the launch control centre showed the course of the launch vehicle superimposed on the planned trajectory. There was a difference between the two, and the flight appeared uneventful. The remaining four strap-ons had ignited. The first stage motors and the strap-ons performed well, and their separation passed off without any hitches. Then, the second stage, with the Vikas engine, worked as planned. Soon after the second stage began operation, the launch vehicle was turned south of the polar orbit. The heat shield was jettisoned, having served to protect the satellite during its travel through the atmosphere. A tail-off of thrust as the second-stage propellants became exhausted and was detected some 261 seconds post-launch and initiated a sequence of events. The separation of the second stage was carried out about 3 seconds later, and the ignition of the third stage took place 12 seconds after that. When the third stage ignited, the vehicle was at an altitude of about 250 kilometres and travelling at a speed of 3.83 kilometres per second. Things went wrong thereafter.

By the time of the fourth stage ignition, the top of the rocket had reached an altitude of only 340 kilometres. The fourth stage lacked sufficient thrust to get the payload into orbit, and it fell back to Earth. To analyse the reasons behind the failure, the National Failure Analysis Committee was set up and submitted its report in January 1994. The committee concluded that the problem was due to a software error in the pitch and control loop of the onboard guidance and control processor, which occurs only when the control command exceeded the specified maximum limiting value, and an ultimate unintended contact between the second and third stages. It was determined that the rocket's design was fundamentally sound. However, the expensive and valuable IRS payload was lost: the satellite was in fact the refurbished engineering model of IRS-1A. After careful examination of the failure report, ISRO scientists once again learned valuable lessons to avoid such a failure in the future.

Then, a year later, the PSLV-D2 lifted off from Sriharikota on 15 October 1994. ISR-P2, weighing 870 kg, was successfully injected into an 825-kilometer polar orbit after a flawless flight. The Union government wholeheartedly supported the PSLV programme and more funds were allocated for this endeavour. With the help of this, PSLV-C1 was launched on 29 September 1997, carrying the IRS-1D into an 817-kilometre polar orbit.

4. GSLV Programme

After the successful launch of PSLV, ISRO moved on to the next stage. In the 1980s, when ASLV and PSLV projects were in active progress, Indian scientists deeply conceived the idea of launching vehicles to put the satellites into GTO (Geosynchronous Transfer Orbit). Hence, the idea of GSLV emerged, and its development represents the culmination of India's efforts to achieve complete launcher autonomy. However, it was not an easy task. Hence, ISRO depended on other space powers, especially for the cryogenic engine. The simplest option turned out to be for the GSLV was to replace the top two stages of the PSLV with a cryogenic stage.

ISRO needed Cryogenic technology in the 1990s for the GSLV programme, and it became obvious that ISRO might depend on other nations that possess such technology. In 1987, the Missile Technology Control Regime (MTCR) was signed between different space-faring nations. The agreement mainly ensures that no other new country excels in the field of space research. Under the influence of this regime, the United States was able to make Glavkomas (Russian State Space Corporation), an organisation comparable to ISRO in India. The agreement between the Glavkomas and India made possible the import of cryogenic technology to India. However, the successful launch of Agni I in 1989 created a ban. Then, in 1994, Glavkomas agreed to supply cryogenic engines without the underlying technology. With only the engines, Indian scientists were able to understand cryogenic technology. However, while depending on other nations for cryogenic technology, India embarked on indigenously developing the technology. In February 2000, the first test of India's home-grown cryogenic rocket had to be prematurely terminated because of a hydrogen leak. Six years later, on 28 October 2006, India successfully tested the first integrated stage level test of the indigenously developed cryogenic upper stage. This was carried out at the LPSC test complex at Mahendragiri, Tirunelveli District, Tamil Nadu. After this test, the then ISRO Chairman Madhavan Nair delightfully announced, "We had a very successful first cryogenic stage test at Mahendragiri. It is a major milestone in the development of rocket systems in the country".With these initiatives, India partially achieved the cryogenic technology for the GSLV rocket.

Then, on 20 September 2004, India's GSLV successfully launched EDUSAT, the country's first thematic satellite dedicated exclusively to educational services, into a GTO from Sriharikota. This was the first operational flight of a GSLV (GSLV-F01) and the third in the GSLV series. The 49-metre-tall, 414-tonne, three-stage vehicle injected the 1950 kg DUSA into GTO. Two years later, on 10 July 2006, the GSLV-F02 carried the INSAT-4C satellite, from SHAR. This was the second operational flight of a GSLV and the fourth in the GSLV series. Fifty-five seconds after lift-off, the launching vehicle started deviating significantly from its nominal flight path, resulting in the vehicle breaking up at 62 seconds and the debris falling into the Bay of Bengal. The failure of GSLV-F02 seems to be a major setback for the GSLV project.

5. Conclusion

Then, India's first moon mission, Chandrayaan-1, was successfully launched in October 2008 by ISRO, and then, to reach Mars orbit, the spacecraft, Mangalyaan under the Mars Orbiter Mission (MOM), was launched in 2013. Even though, India now occupies a remarkable position in the space research programme, the failures that the ISRO team overcame during their inception play a vital role because, whenever failures occur, they become a source of inspiration to accomplish the goals set.

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