Indian launchers aim at commercial market

India's space program has passed important milestones with the recent launch of INSAT-2E, a new generation of telecommunications satellites, and PSLV, the indigenous polar satellite launch vehicle.

The PSLV launch of Oceansat-1 plus German and South Korean minisats was the fifth for this vehicle and the first launch of a foreign payload by an Indian rocket. It is spearheading India's efforts to get into the commercial launcher business. The next steps will be the lofting of INSAT-3B and the geostationary satellite launch vehicle (GSLV). If successful, GSLV will enable the Indians to launch 2.5-tonne payloads to GEO and will also inaugurate India's use of cryogenic technologies.

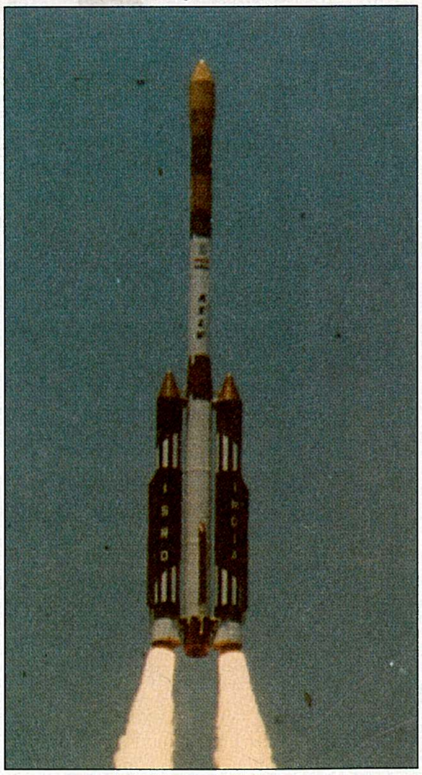
First steps

India's space effort began in 1962 with the establishment of INCOSPAR (Indian Committee for Space Research), under the auspices of the Dept. of Atomic Energy. This led a year later to the creation of the Thumba Equatorial Rocket Launching Station, used to launch French, U.S., and Soviet sounding rockets. In 1965, Vikram Sarabhai, considered the father of the Indian space program, created the Space Science and Technology Center. Next came the establishment of the Indian Space Research Organization (ISRO) in 1969, with Sarabhai as its head.

From the outset, the objectives of the national program were to develop and master space technologies and thus achieve independence in this strategic sector. The Indian program has always focused on three main sectors: telecommunications, remote sensing, and launch vehicle development. Mirroring these priorities are ISRO's main programs: INSAT, for telecommunications and meteorology, the Indian remote sensing (IRS) satellite, and the PSLV and GSLV launchers.

ISRO implemented these objectives under heavy technological and financial constraints. As far as possible, developmental efforts sought to integrate home-grown and foreign technologies. A step-by-step approach was used for satellite and launcher development. This was especially true for development of the SLV-3 and augmented SLV (ASLV), which were essentially technology demonstrators for the PSLV and GSLV launchers.

The 39-tonne ASLV served as a demonstrator for various technologies.



Building a base: SLV-3 and ASLV

Indian launcher development efforts go back to the creation of the TERLS in 1963. Local production of the Centaur sounding rockets and indigenous development and production of Rohini, a family of such rockets, provided experience that was used for the launcher program.

Development of the SLV-3 began in the early 1970s. This four-stage solid propergol launcher, which is very similar to the U.S. Scout and weighs 17 tonnes, can put a 40-kg payload in LEO. In August 1979, the first attempt to launch a satellite with the SLV-3 failed. In the second attempt, on July 18, 1980, the SLV-3 successfully orbited the Rohini RS-1.

After this first success, the SLV-3 was used two more times, launching the Rohini-D1 in May 1981 and the Rohini-D2 in April 1983. The latter flight was only a partial success, because the satellite was put into the wrong orbit and burned up in the atmosphere after only eight days. Following the third successful flight of the SLV-3 in 1983, emphasis shifted to the ASLV.

Fundamentally an SLV-3 with two solid rocket boosters (SRBs), the ASLV was capable of putting 100-150 kg in LEO. The 39-tonne launcher served as a technology demonstrator for stage separation and vehicle guidance technologies. It validated an indigenous closed-loop guidance system as well as Indian-manufactured HTPB (hydroxyl terminated polybutadiene) propergol. The latter replaced the PBAN (polybutadiene-acrylic-acid-acrylonitrile) used by the SLV-3.

ASLV's development was far from trouble free, however. The launch sequence called for the SRBs to ignite on the ground, and for first-stage ignition 44 sec into flight. The first ASLV was lost when the initial stage failed to ignite. A year later, in 1988, the second flight failed because the control system was unable to handle instabilities caused by the transition between the strap-on and the first stage.

It was only in May 1992 that the ASLV flew successfully. The vehicle was modified with the addition of two passive fins in the pitch plane to improve stability. The digital autopilot also was redesigned for enhanced control margin. Structural strengthening led to a reduced payload of 113 kg for the fourth and last flight in 1994.

PSLV

All of these developmental efforts were directed toward realization of the PSLV, which was capable of putting 1-1.2 tonnes in a 900-km heliosynchronous polar orbit. The PSLV represented a total change of scale for an Indian launcher; it also marked ISRO's first use of liquid propulsion.

Built around what ISRO claims is the world's third largest solid propellant booster, the PSLV stands 44 m tall and weighs 294 tonnes at liftoff. A four-stage rocket, it uses a unique combination of solid and liquid propellant stages. The first is a 20-m-tall solid propergol stage carrying 138 tonnes of HTPB. Flanking it are six SRBs, each providing 66 tonnes of thrust. The SRBs are derived from the ASLV's first stage.

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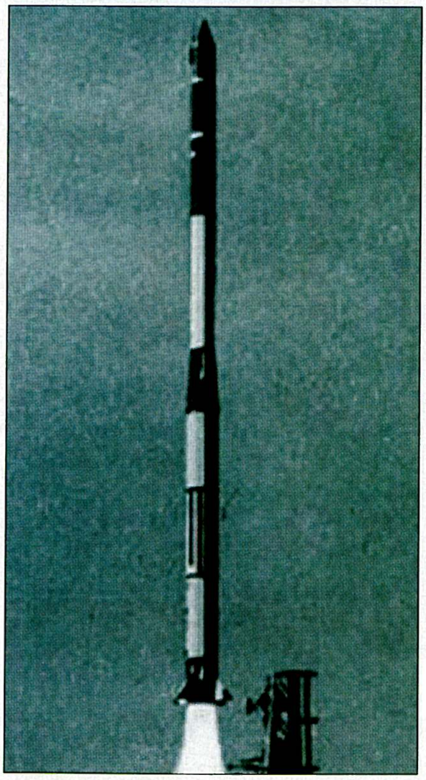
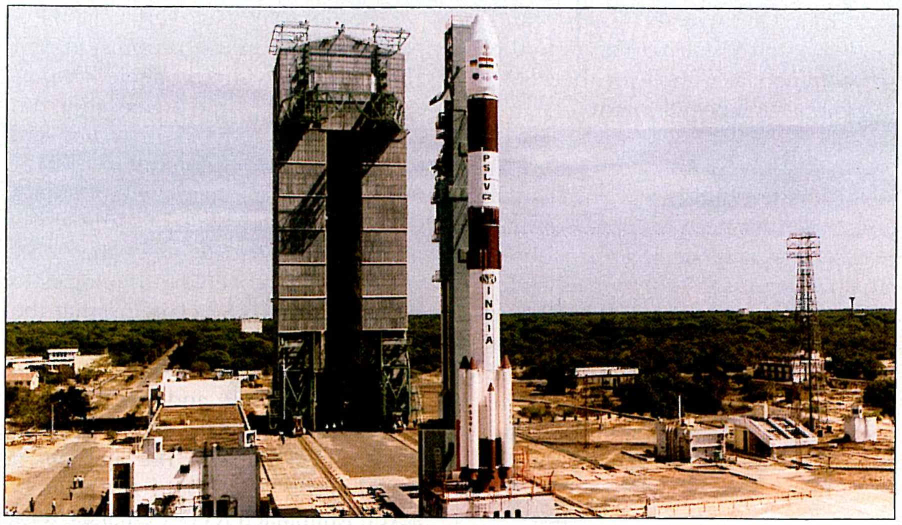




The PSLV sparked development of a ground segment and infrastructure, including a 3,000-tonne mobile service tower for vertical integration of the launcher and payload.

The PSLV's central stage provides 460 tonnes of thrust. The second stage is a liquid propulsion unit burning hydrazine (UDMH) and nitrogen tetroxide. It uses an engine called Vikas, a locally built variant of France's Viking. India bought the license for local production from SEP (Société Européenne de Propulsion) in the early 1980s. The third stage uses solid propergols, and the fourth reverts to liquid propulsion with ISRO-designed engines.

The PSLV also sparked development of a ground segment and infrastructure. A 3,000-tonne mobile service tower allows for vertical integration of the launcher and payload before moving 180 m away prior to launch. A network of radars and ground stations in Sriharikota, Thrivanathapuram, Bangalore, Lucknow, the Andaman islands, and Mauritius follow the vehicle during its flight.

The first PSLV launch took place in September 1993 with the IRS-1E satellite as the payload. A software error in the guidance system during second- and third-stage separation led to the failure of the mission. The second launch successfully orbited the IRS-P2 experimental remote sensing satellite. However, at 804 kg, the payload was 20% lower than the original 1-tonne planned capability. By the fourth flight, the payload had been increased to 1.2 tonnes. This resulted from increasing the propellant load of the first and second stages and from a weight reduction program.

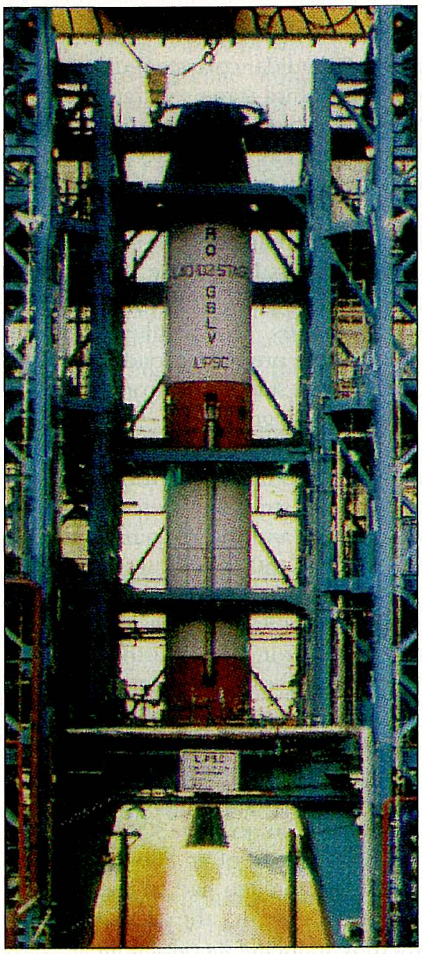
The firing sequence of the SRBs also was modified: For the first three flights, two strap-ons were ignited on the ground and the remaining four in the air at T+30 sec; from the fourth flight on, this was changed to four strap-ons ignited on the ground and two in the air. The fourth flight, although successful in placing the IRS-1D remote sensing satellite in orbit, suffered from a leak of the helium used to pressure-feed the last stage's engines. This meant that the satellite was placed in an 800×300-km elliptical orbit instead of an 800-km circular orbit. The satellite had to use its own engine to get to the desired orbit, thereby reducing its orbital life.

The PSLV's last flight—the second for the upgraded version—took place on May 26 and carried the IRS-P4 (Oceansat-1) as its primary payload. Also on board were two microsatellites from Germany (Tubsat-C) and South Korea (Kitsat-3). This was the first commercial launch for the PSLV; ISRO hopes many will follow.

GSLV

Having achieved independence in the launch of 1-tonne-class payloads, the next step is to attain a geostationary capability for a 2.5-tonne-class telecommunications payload. This is to be done through the GSLV, which builds on the technologies and experience gained from the PSLV program. The GSLV uses the same first and second stages as the PSLV. Replacing the six SRBs are four liquid propergol boosters powered by the same Vikas engine used for the second stage. The third and fourth PSLV stages are replaced by a single cryogenic stage.

The GSLV uses the same first and second stages as the PSLV, followed by a single cryogenic stage.



Because ISRO has very limited experience with liquid propulsion and almost none with cryogenic propulsion technologies, the organization decided to buy the cryogenic engine and technologies from abroad. In 1991 it reached an agreement with Russia's Glavkosmos, which was to supply engines for the first flights of the GSLV and transfer cryogenic technologies to ISRO. But the U.S., claiming that the deal violated MTCR (Missile Technology Control Regime) rules, imposed sanctions on ISRO and threatened to do the same to Glavkosmos if the deal went ahead. Finally, the agreement was limited in 1993 to the sale of seven KhimMach KVD-1 engines, for a value of $250 million-$300 million, without any transfer of technology. The KVD-1 engine produces 7.5 tonnes of thrust; the first flight unit was delivered in September 1998.

India is now obliged to develop a cryogenic engine alone. ISRO's effort to develop cryogenic technologies began with the launching of a study project in 1986. This led to the July 1989 test firing of a 1-tonne-thrust subscale pressure-fed engine using liquid oxygen (LO_x) and gaseous hydrogen.

The project's aim was to acquire a basic understanding of cryogenics and of the developmental problems related to making an engine. To respect the GSLV timetable, ISRO decided it could obtain the technology faster from abroad.

ISRO only acquired the capability for making liquid hydrogen (LH_2) in 1992. In 1993, development efforts suffered a setback when a subscale pressure-fed engine exploded after ISRO tried using LO_x and LH_2. Begun in 1993, the design for a 7.5-tonne-thrust engine was completed in 1996, and design work started on a 12-16-tonne engine for a growth version of the GSLV. It was only in February 1998 that an engine was successfully test fired using LO_x and LH_2. This was still a pressure-fed version, although the flight version of the engine is to use turbopumps that seem to be still some way off.

Work is continuing on the GSLV itself for a first launch by mid-2000. The launcher's liquid-fueled boosters successfully underwent qualification tests in March 1998 after developmental firings in July 1995 and May 1997. The strap-on boosters are 19.7 m long and have a 2.1-m diameter. Burning a mixture of UDMH and N_2O_4, they produce 60 tonnes of thrust for 160 sec. This means the solid-propellant first stage that burns for 107 sec actually burns out before the strap-ons. This reduces the GSLV's payload, as the launcher will carry the dead weight of the central core before the strap-ons burn out. However, this compromise seems to have been considered acceptable, probably because of reduced development risks and

Rohini sounding rockets laid the foundation for India's launch business.

INDIAN LAUNCH VEHICLES AND LAUNCHES

Launcher	Height× diameter, meters	Mass, tonnes	Launch vehicle	Satellites	Payload, kilograms	Date	Remarks
SLV-3	22.7×1.0	17[1]	SLV-3	Rohini-0	40	8/10/79	Launch vehicle failure
			SLV-3	Rohini-1	40	7/18/80	First successful launch
			SLV-3	Rohini-D1	40	5/31/81	
			SLV-3	Rohini-D2	42	4/17/83	
ASLV	23.8×1.0	41.7[2]	ASLV-D1	SROSS-1	150	3/24/87	Launch vehicle failure
			ASLV-D2	SROSS-2	15	7/13/88	Launch vehicle failure
			ASLV-D3	SROSS-C1	106	5/20/92	
			ASLV-D4	SROSS-C2	113	5/4/94	
PSLV	44.4×2.8	283[3]	PSLV-D1	IRS-1E	870	9/20/93	Launch vehicle failure due to software problems
			PSLV-D2	IRS-P2	804	10/15/94	Successful launch of experimental version of the IRS
			PSLV-D3	IRS-P3	922	3/21/96	
		294[4]	PSLV-C1	IRS-1D	1,200	9/29/97	Fourth stage malfunction left satellite in lower orbit
			PSLV-C2	IRS-P4	1,050	5/26/99	First launch of foreign payloads
				Kitsat-3 (S. Korea)	107		
				Tubsat-C (Germany)	45		
GSLV	49×2.8	402[5]	GSLV-D1	GSAT-1A	2,000	2000	Cryogenic third stage with Russian engine

[1]*Four stages solid propellant.* [2]*Four stages plus two boosters solid propellant.* [3]*Four stages plus six solid boosters mixed liquid and solid propellant.* [4]*Four stages plus six solid boosters mixed liquid and solid propellant.* [5]*Three stages plus four liquid boosters mixed solid plus liquid and cryogenic.*

economies of scale through commonality with the PSLV.

Toward a commercial future?

Over the past 35 years, Indian efforts to achieve an independent launch vehicle capability have been continuous, as has the development of telecommunications and remote sensing satellites. Launcher development accounts for 50% of ISRO's budget, and this is likely to continue, as the GSLV will demand a substantial effort. While ISRO's budget is small compared to those of the major space agencies, it has been growing at an impressive rate: The 1998-1999 budget was up more than 50% over that of the previous year. India is now seeking to capitalize on its investments in the space sector.

In 1992 ISRO created a commercial branch called ANTRIX. Its IRS series of remote sensing spacecraft has enjoyed some success on world markets. This success and the leasing of transponders on INSAT-2E to Intelsat in a $100-million deal have prompted ISRO to try and enter the launcher business. So far the PSLV has won three contracts to launch minisatellites as additional payloads. The first two, Tubsat and Kitsat, were launched by the PSLV-C2 for around $1 million. The third, the Belgian PROBA, is to be launched by a PSLV-C3 in 2000-2001.

To try and get a greater share of the minisatellite market, ISRO and Arianespace signed an agreement in April 1998 that allows for the launch of microsatellites on either Ariane or ISRO vehicles. A common users' manual for auxiliary payload clients has been established and is compatible with both Ariane 5 and the PSLV.

India still has some way to go before becoming a major player in the commercial launcher market, despite lower costs. The PSLV has a rather limited payload capacity compared with other launchers, and a lot depends on the GSLV and the successful development of its associated technologies.

ISRO's launchers have been developed specifically for the home market. With a capability of two launches a year, this means that for the immediate future ISRO can offer to launch only additional payloads. But the approaching maturation of the Indian space program means that in the medium-to-long term, the commercial launcher business will see the emergence of a new and serious contender.

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