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October 2010

AEROSPACE AMERICA

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Critical times for India's space program

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

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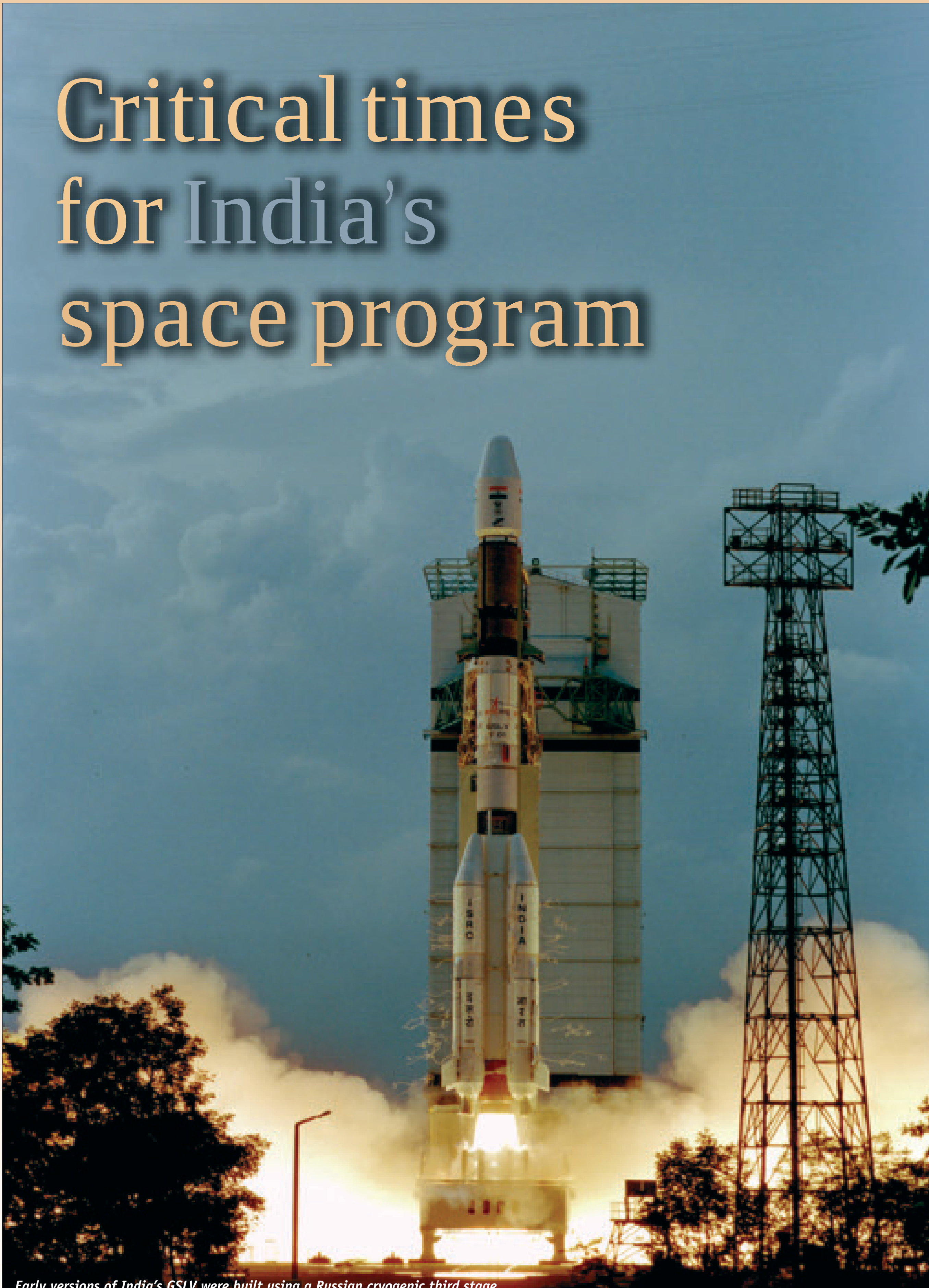


Early versions of India's GSLV were built using a Russian cryogenic third stage.

Although a recent launch failure has dealt India's space program a setback, the country is determined to move beyond its success in the small satellite launch arena and become a serious player in the global heavy-lift market as well. Its ambitious plans include perfecting its cryogenic technology and developing its own manned spaceflight capability.

On April 15, the Indian Space Research Organization's (ISRO) launch of a rocket with a cryogenic third stage designed and built in India ended in failure.

Although the cryogenic stage of the geosynchronous satellite launch vehicle GSLV-D3 appeared to have ignited, according to ISRO Chairman K. Radhakrishnan the rocket began to lose altitude seconds after the third-stage ignition, having reached a height of 87 mi. and a speed of around 11,000 mph.

This was a major blow to ISRO's plans to compete in the global satellite launch business and to develop a manned spaceflight capability. The Mark-3 version of the GSLV is intended to make ISRO self-reliant in launching heavy satellite payloads in the 4,500-5,000-kg weight class—the April 15 launch was carrying a 2,224-kg GSAT-4 experimental communications and navigation satellite, which was destroyed during the launch failure.

Earlier versions of the GSLV have been built using a Russian cryogenic third stage. India acquired seven of these stages during the 1990s; it launched five on board earlier GSLV flights, with varying degrees of success, and now has two in storage.

The ISRO has a very challenging set of programs, including the GAGAN (GPS-aided geoaugmented navigation) satellite constellation, two further Moon observation missions, and a manned spaceflight project. This makes it increasingly important for India to develop its own cryogenic propulsive technology. Following the GSLV-D3 failure, ISRO will be targeting a second flight of the indigenous cryogenic upper stage as soon as possible.

According to an ISRO release issued shortly after the failure, "Detailed analysis of the flight data is being carried out to find out the exact reasons for the failure and take corrective measures to realize the next flight test of the indigenous cryogenic engine and stage within the next one year."

Small beginnings

So far the ISRO has developed its programs on a relatively small budget, especially compared to its nearest competitor, China. But as the payload sizes increase and the scientific programs become more complex, the government will need to find increasing amounts of money to fund the country's space ambitions. India is competing in the small-satellite launch market, having won contracts with Germany, Israel, Italy, and Singapore, among others, for Polar Satellite Launch Vehicle (PSLV) flights, and this has provided some modest but useful revenue streams.

"For the launch of small satellites into LEO, India offers a low-cost and reliable solution with PSLV, on par with Russian converted missiles," says one space industry market expert. "However, to become a player in the much larger commercial GTO [geosyn-

by
Philip Butterworth-Hayes
Contributing writer

The INSAT constellation provides telecommunications, broadcasting, search and rescue, and meteorological services.

chronous transfer orbit] marketplace, India will need a more capable launch vehicle than GSLV-Mark 2."

India has been relatively late entering the space race. From the start, its space program has been driven overtly by supporting domestic infrastructure programs such as remote sensing, communications, distance learning, telemedicine—using satellites to set up video conference communications for medical staff in remote locations—and security.

"In India, the space program has not been a geopolitical tool; it supports the social and economic development requirements of the country," according to Rachel Villain, director of space and communications at Paris-based space consultancy Euroconsult. "Indigenous capability is sought in launch vehicle and applications satellites (communications, Earth observation and navigation). However, as experienced in other countries, a capability gap still exists between GSLV and Insat that makes Insat 4 satellites too large to be launched by the domestic launch vehicle."

The Indian National Satellite System (INSAT) constellation is a network of communications satellites providing telecommunications, broadcasting, search and rescue, and meteorological services throughout India. The first in the constellation, INSAT-1A, was flown in April 1982, and launches are continuing, with the INSAT-4F, a 2,330-kg multiband satellite carrying payloads in UHF, S-band, C-band and Ku-band, to be launched next year onboard the GSLV.

Growing ambitions

In recent years, India's ISRO has started to play a wider role in the global space market. The first ISRO Moon probe, Chandrayaan-1, launched on a modified version of the PSLV in October 2008, was the first truly scientific mission ISRO has undertaken. The unmanned lunar exploration mission comprises a lunar orbiter and an impact probe. The orbiter carries five ISRO payloads and other payloads from NASA, ESA, and the Bulgarian Aerospace Agency, underlining India's new commitment to international cooperation in its space programs. It is also equipped with a NASA mini-SAR (synthetic aperture radar), and Chandrayaan-1 has been transmitting images from the Moon for more than two years—the most recent and spectacular reveal ice deposits near the Moon's north pole.

A follow-on Chandrayaan-2—with a lander/rover mission ISRO is developing with assistance from Russia—is planned for 2012, with Chandrayaan-3 coming later, although these missions are now subject to delays following the failure of the April 15 launch.

India's manned space program offers a further definitive break from the past focus on domestic infrastructure programs, though one more in line with its growing importance as a regional and global economic power. Among its neighbors, China and Japan have sent missions to the Moon, and South Korea has embarked on its own space program.

Manned space program takes shape

In February 2009, the Indian government approved the $3-billion budget for ISRO's manned space mission. ISRO wants to launch

LAUNCH VEHICLES

Launcher	Description
Satellite launch vehicle	The four-stage, solid-propellant SLV launched India's first satellite, the 40-kg Rohini-1B, in 1980.
Advanced satellite launch vehicle	After four SLV-3 launches India developed the Advanced SLV, which launched four times between 1987 and 1994 but with two failures.
Polar satellite launch vehicle	ISRO's first fully operational launcher, the four-stage PSLV can take 1,600-kg satellites to 620-km Sun-synchronous polar orbit (SSPO) or 1,050-kg satellites to GTO. With Chandrayaan-1 a PSLV with strap-on motors enhanced the payload capability to 1,750 kg in 620-km SSPO. The PSLV has been India's entrée into the global satellite launch market, with 16 foreign and 14 Indian satellite payloads launched up to the end of 2009.
Geosynchronous satellite launch vehicle	The GSLV was designed to place a payload of up to 5,000 kg in LEO and 2,200 kg into GTO. Five flights have taken place using the Russian cryogenic stage. The first, developmental, flight took place in April 2001, launching a 1,540-kg GSAT-1. The flight was partially successful, but an upper-stage early shutdown left the satellite 4,000 km short of the planned GTO apogee. Flights two and three were fully successful but flight four—the launch of a 2,168-kg INSAT-4C satellite—failed. Flight five, carrying the replacement INSAT-4C, was fully successful.

ISRO SATELLITE PROGRAMS

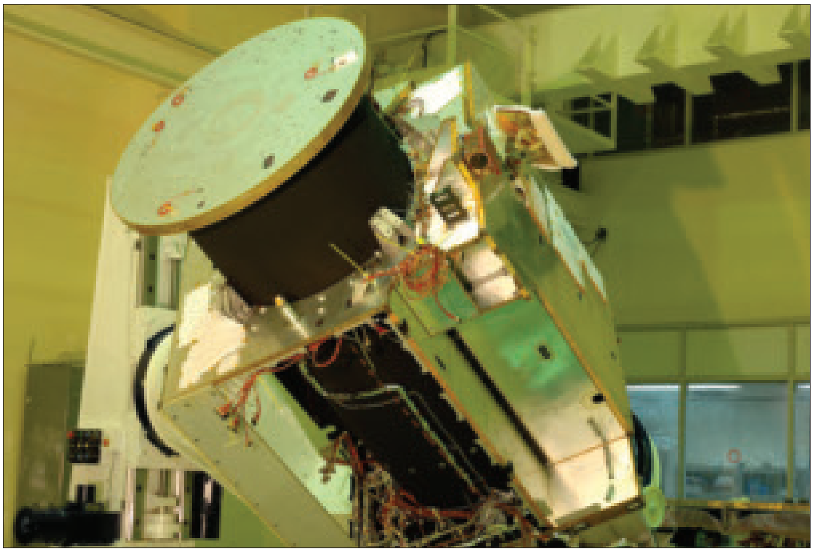
Satellite type	Program	Applications
Earth observation	Cartosat-2B	Enhanced cartographic and other civil applications.
	RISAT 1 and 2	A microwave remote sensing satellite carrying an Israeli-supplied SAR for border control and other security applications.
	Resourcesat-2	Agricultural crop distribution and production, forest mapping, water resources.
	SARAL	Oceanic and climate conditions.
Scientific	ASTROSAT	Multiwavelength observations of the celestial bodies and cosmic sources in X-ray and UV spectral bands simultaneously.
	Chandrayaan-2	Orbiter/lander/rover capabilities to improve our understanding of the origin and evolution of the Moon.
	Megha-Tropiques	An ISRO/French National Space Centre joint venture to improve understanding of the life cycle of convective systems and their role in the associated energy and moisture budget of the atmosphere in tropical regions.
	Corona	Study of the solar corona in visible and near IR bands.
	YOUTHSAT	A joint Russian-Indian microsatellite carrying scientific payloads with participation from universities at graduate, postgraduate, and research scholar levels.
Navigation	GAGAN	Indigenous satellite-based regional GPS augmentation system as part of India's program of Satellite-Based Communications, Navigation and Surveillance/Air Traffic Management plan for civil aviation. First GAGAN navigation payload is due to be launched this year.
Communications	INSAT	A constellation of 199 transponders to support wide-ranging communications applications throughout India. INSAT-3D is due to be launched 2010-2011 for meteorological applications in 2010-2011. INSAT-2 satellites provide telephone links to remote areas and communications for transport operators and television broadcast signals.
	GSAT	Supporting a wide range of broadcast satellites. GSAT-5/INSAT-4D will carry 12 normal C-band transponders and six extended C-band transponders with wider coverage in uplink and downlink over Asia, Africa, and Eastern Europe. GSAT-6/INSAT-4E is a multimedia broadcast satellite.

a two-person mission into space, with Indian astronauts staying aloft for seven days in an orbit of 275 km. The original date for this was set for 2015, though this looks likely to slip to 2017 at the earliest.

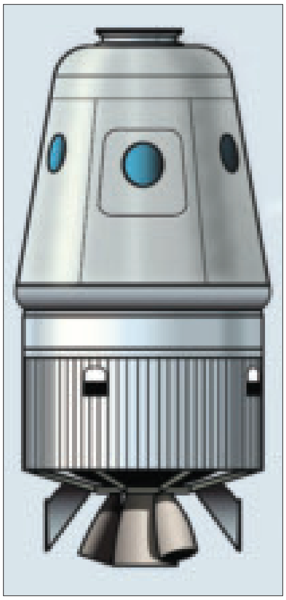
"It depends whether the 2017 deadline is a 'must be,'" says Euroconsult's Villain. "In China it took over 10 years to develop a manned capability, and there was no issue of having to undertake parliamentary approval for budget spending. It's a lengthy process to develop a manned rated capability, and outside help can accelerate it."

The failure of the GSLV-D3 launch may mean ISRO will have to compromise further its policy of autonomy, looking increasingly to support from Russia. India is working closely with that country on the astronaut program, following an agreement signed between the two countries in December 2008. Russia will help develop the astronaut selection program, and ISRO has reserved a Russian Energia Soyuz TMA spacecraft flight in 2013 for two Indian astronauts in a classified "space tourist" deal, to fly with a Russian cosmonaut. India's first astronaut was Sqn. Ldr. Rakesh Sharma, who traveled into space aboard the Russian Soyuz T-11 in April 1984.

Work has been under way on the manned space program in India for some years. In January 2007, ISRO launched its 600-kg Space Capsule Recovery Experiment aboard a PSLV rocket, to test the agency's ability to develop carbon phenolic ablative material and silica tiles, heat-resistant materials needed for reentry. The full manned spaceflight program encompasses the development of an orbital vehicle, a new mission control center, an astronaut training site, and a new launch pad at the ISRO's Satish Dhawan Space Centre in Sriharikota.



Chandrayaan-1 has been transmitting images from the Moon for more than two years.



Preliminary designs of the orbital vehicle have been completed, but much work still remains.

The preliminary designs of the 3-ton orbital vehicle (OV) have been completed. In early 2009 a full-scale mockup of the OV crew capsule was finished, but a great deal of work still needs to be finished before the final design is mature. There are conflicting reports on whether the ISRO OV crew capsule will be a new Indian design or a modification of the Soyuz capsule.

ISRO, meanwhile, is setting up an astronaut training facility in Bangalore, close to Bengaluru International Airport. ISRO is recruiting 200 Indian air force pilots as a first part of the selection process, with the aim of selecting four astronauts—two plus two reserves—at the end of the process.

The manned spaceflight program will require a third launch pad at the Satish Dhawan Space Centre. The preliminary design for the new pad, 1 km south of the spaceport's second pad, is now complete, including the provision of a crew entry and crew escape module system. It should also be capable of handling reusable launch vehicle flights; ISRO has started designing a landing strip for a reusable launch vehicle at the Sriharikota Range.

Cryogenics and cooperation needed

Beyond the first manned spaceflight, ISRO is planning a series of technology demonstrator

In July 2006, GSLV-F02, carrying the INSAT-4C communication satellite, failed seconds after a perfect takeoff as it deviated from its trajectory and plunged into the Bay of Bengal.

WORLD GOVERNMENT EXPENDITURES ON CIVIL SPACE PROGRAMS (2009)

Asia and Australia	**$Millions**
Australia	36
China	1,269
India	906
Indonesia	18
Japan	2,340
Malaysia	25
Pakistan	71
South Korea	208
Taiwan	42
Thailand	20
Vietnam	19
Europe	
Austria	81
Belgium	237
Czech Republic	16
Denmark	47
European Union	735
Finland	71
France	2,436
Germany	1,245
Greece	24
Ireland	21
Italy	940
Luxembourg	21
Netherlands	194
Poland	9
Portugal	26
Romania	30
Spain	324
Sweden	117
Switzerland	137
Turkey	71
U.K.	406
Middle East and Africa	
Algeria	5
Egypt	3
Iran	100
Israel	11
Nigeria	43
South Africa	5
UAE	60
Latin America	
Argentina	82
Brazil	85
Chile	15
Peru	1
Venezuela	8
North America	
U.S. (NASA, 18,135; NOAA, 1,158; others, 790)	20,083
Canada (including ESA 33)	298
Russia and the states of the former Soviet Union	
Azerbaijan	67
Kazakhstan	55
Russia	2,719
Ukraine	109
Total	**$35,970**

Source: Euroconsult's Profiles of Government Space Programs.

missions as part of its plan to develop a two-stage-to-orbit fully reusable launch vehicle. The first of these is the Winged Reusable Launch Vehicle Technology Demonstrator, a flying test bed to evaluate various technologies, including hypersonic flight and autonomous landing. The vehicle is reported to incorporate supersonic combustion ramjet technology, which is being tested this year. Meanwhile ISRO has also announced it plans to carry out an unmanned mission to Mars and a manned mission to the Moon by 2020.

But many of these programs ultimately will depend on the successful development of Indian cryogenic engine technology. India has been limited to accessing this via international agreements on the transfer of dual-use technology, which has meant Russia could only provide ready-made third stages for the GSLV series. It has taken nearly 20 years and a reported $76 million for India to develop its own cryogenic rocket stage, so the April failure was a significant setback. The cryogenic stage was built at ISRO's Liquid Propulsion Systems Centre in Tamil Nadu.

To meet its target dates for improved launcher and manned space mission capabilities, India might well have to increase its cooperative efforts with other countries. Its policy of autonomy has not stopped it entirely from such cooperation. The PSLV Vikas engine built by ISRO is based on the Viking 4A engine manufactured by Snecma of France for Ariane. More recently, India has developed closer ties with Israel, using the PSLV to launch the Israeli military surveillance Polaris satellite, for example. In June 2005 India and the European Union signed a bilateral agreement of cooperation in the fields of science and technology, including space science.

In July 2005, then-President George W. Bush and Indian Prime Minister Manmohan Singh reached an agreement on space exploration, satellite navigation, and launch technology. It would give India access to U.S. technology in the commercial market, with India agreeing to adhere to Missile Technology Control Regime guidelines.

Military space efforts

India's civil launch capabilities have developed in parallel with its military launch programs, most notably the Agni missile family, which has evolved from a short-range (500-700-km) ballistic missile, through to an intermediate range (the Agni III, with a range of potentially more than 3,500 km). Reports that India is developing an intercontinental missile capability (over 5,000 km)—via the Agni V or the Surya programs—have been denied by Indian officials, but a test flight of the latest in the Agni range is due before early 2011.

The Agni missile family has evolved from a short-range ballistic missile, through to an intermediate range.

In May 2008 the Indian Institute of Science announced that a team from the Dept. of Aerospace Engineering and Dept. of Inorganic and Physical Chemistry had developed new materials to reduce the drag on a rocket's blunt nose by adding a treated coating of chromium-based material and thereby increasing the range by at least 40%. According to some reports, this new technology would be applied to future versions of the Agni. Early versions of the missiles are understood to have incorporated SLV launcher technologies.

For many reasons the next few months will be critical for India's space program, as ISRO engineers research the reasons for the failure of the April 15 launch. If the failure is due to a relatively minor fault rather than a wider design flaw, then India will be able to accelerate work once again on its manned spaceflight program and other more ambitious missions such as the RLV. But these are increasingly risky areas where, for some projects, outside help is no longer available.

"In terms of the reusable launch vehicle, there will be fewer possibilities of support from other countries as most of the work on reusable space launchers began to slow down in the early 2000s as more effort was put into developing more capable expendable launchers," according to Euroconsult's Villain.

But if the fault can be traced quickly and a fix identified, then the door is open for India to play a much-enhanced role in the global space science and satellite launch markets.