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Theoretical Overview on Polar Satellite Launch Vehicle (PSLV)

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ABSTRACT

By successfully launching satellites into a range of earth orbits, both Indian and foreign, the Polar Satellite Launch Vehicle (PSLV), India's first operational launch vehicle, has proven to be a remarkably dependable and adaptable vehicle. The Indian Space Research Organization (ISRO) is the developer and operator of the Polar Satellite Launch Vehicle (PSLV), an expendable launch vehicle. It is regarded as one of the most effective and dependable launch vehicles globally and is reasonably priced. The primary purposes of the PSLV are to launch spacecraft into geostationary transfer orbits, polar orbits, and sun-synchronous orbits.In addition to these numerous accomplishments, PSLV is also credited with the launch of satellites into low-Earth orbit with moderate and extremely low inclinations, polar Sun Synchronous, Geosynchronous Transfer, and sub-Geosynchronous Transfer Orbit. This paper examines various significant facets of PSLV, such as its origins, evolution, arrangement, and enhancements, in addition to its legacy, historical significance, and future outlook, in light of its recent accomplishment of launching 31 satellites from India and eight other nations into two distinct orbits on November 29, 2018.

Keywords: PSLV, Satellite, Stages, Features, Characteristics, Specifications

INTRODUCTION

The Indian Space Research Organization's (ISRO) expendable launch system, known as the Polar Satellite Launch Vehicle (PSLV), was developed in-house. It belongs to the class of medium-lift launchers that may reach many orbits, such as the Polar Sun Synchronous Orbit, Lower Earth Orbit, and Geo Synchronous Transfer Orbit. Operating from the Satish Dhawan Space Centre in Sriharikota on India's east coast, all PSLV operations are managed. The Indian Space Research Organisation (ISRO) is responsible for the design, production, and operation of the third-generation rocket launcher known as the Polar Satellite Launch Vehicle (PSLV). It is a disposable launch vehicle that can deliver 1,050 kg of small spacecraft into geostationary transfer orbit (GTO) and 1,600 kg of remote sensing satellites into sun-synchronous orbit (SSO).The PSLV is intended to launch spacecraft into polar, sun-synchronous, and geostationary transfer orbits, among other orbits. It has a four-stage structure with both liquid and solid propulsion systems. Solid rocket boosters are used in the first stage, liquid engines power the second stage, solid rocket motors power the third stage, and liquid engines power the fourth stage. The PSLV's payload capacity, which can transport payloads up to 1,750 kg to sun-synchronous polar orbits, is one of its standout characteristics. The launch vehicle is an appealing choice for economical and successful satellite deployment because of its versatility, which is demonstrated by its capacity to carry numerous payloads in a single mission [1].The PSLV's long history, which includes vital missions for scientific research, remote sensing, navigation, and Earth observation, attests to its operational success. Two notable accomplishments are the launch of India's Mars Orbiter Mission, Mangalyaan, in 2013 and the world record-breaking PSLV-C37 mission in 2017, which launched 104 satellites in a single launch.

The most energy-intensive but necessary initial step on the journey into space is climbing out of the Earth's gravity well and overcoming the thick air shield, and Launch Vehicles are the most practical way to do this. When India's 40 kg Rohini satellite was launched into orbit in 1980 using the homegrown SLV-3 all-solid rocket, the country achieved satellite orbital capability. Significant advancements have been made in this field over the past three decades, and India is now among the top space-faring countries with guaranteed access to space thanks to the Polar Satellite Launch Vehicle (PSLV), a reliable operational launch vehicle. Originally designed to support the Indian Remote Sensing programme, PSLV has completed twenty-one consecutive successful missions, including the highly regarded Chandrayaan-1 mission to the moon and the deployment of Geosynchronous Transfer Orbit (GTO). With the help of progressive performance enhancement efforts, PSLV's capacity has increased, making it possible to carry passenger payloads in addition to the main satellite. This has allowed small and tiny spacecraft from all over the world to launch at affordable prices. About thirty supplementary payloads, including experimental satellites constructed by university students, have been successfully launched by PSLV thus far. The launcher designated to transport the spacecraft for the inaugural Indian Mars mission is called PSLV.

As illustrated in Fig. 1, the Indian Space Research Organization (ISRO) is the designer and operator of the Polar Satellite Launch Vehicle (PSLV), an expendable medium-lift launch vehicle. In order to enable India to place its Indian Remote Sensing (IRS) satellites in sun-synchronous orbits, it was designed. Because of its multiple multi-satellite deployment missions, where supplementary payloads typically ride share alongside an Indian primary payload, PSLV has established credibility as a small satellite launcher. Using a Dual Launch Adapter, payloads can be integrated in tandem form. Additionally, smaller payloads are mounted on specially designed payload adapters and equipment decks. The vehicle usually comprises multiple rocket stages that are released one at a time as the vehicle accelerates and reaches higher altitudes. In India, imagery from the main satellite Cartosat-2D is used for a variety of geographical information systems and land information system applications [2].The four-stage PSLV system consists of a mix of liquid- and solid-fueled rocket stages. Six strap-on solid rocket boosters surround the first, solid-fueled stage at the very bottom. The rocket motor on the third stage is solid-fueled, while the second stage uses liquid fuel. During the fourth stage, the launcher boosts its performance in space using a liquid propellant.

The launch vehicle weighs 229,000, 296,000, or 320,000 kg and can be configured to fly in three different configurations based on the needs of the mission. The flagship rocket can carry up to 1,600 kg in payload for the Polar Sun Synchronous Orbit and 1,050 kg for the Geo Synchronous Transfer Orbit. In addition to the standard version, PSLV is utilized in an XL Version and its Core Alone configuration. In missions with limited payloads, the Core Alone version is launched with fewer propellant in its upper stage and without six strap-on boosters. To increase the payload capacity, the XL version is launched with more propellant in the strap-on solid rocket boosters.

Fig. 1 Representation of PSLVconfiguration

PSLV Launch History

A total of sixty-two satellites—thirty-seven Indian and thirty-five foreign—were launched by PSLV, including six nanosatellites, Risat-2, Anusat, Cartosat-2A, IMS-1, DLR-Tubsat, Space capsule Recovery Experiment (SRE-1), KALPANA-1, and numerous other satellites. Additionally, it served as the launch vehicle for India's Chandrayaan-1 lunar probe mission.

Features

1. It is a launch vehicle of the third generation. The "Workhorse of the Indian Space Research Organisation (ISRO)" is how people refer to it.
2. This is India's first launch vehicle with liquid stages. This launch vehicle consists of 4 stages in total.
3. The first successful launch of PSLV was in October 1994.

4. These are its variations:
    - PSLV-G: The motors are strap-on.
    - PSLV – CA: The motors are not strap-on.
    - PSLV-XL: Strap-on motors are present.
5. Payload capacity:
    - Up to 1750 kg can be transported to sun-synchronous polar orbits (SSPO) at an altitude of 600 km.
    - It is capable of transporting a 1425 kg payload to geostationary and geosynchronous orbits (GTO).
6. Indian Remote Sensing (IRS) Satellites have been launched.

Polar Satellite Launch Vehicle Variations

Based on payload capacities ranging from 600 kg in low earth orbit (LEO) to 1,900 kg in sun-synchronous orbit (SSO), ISRO constructed five different PSLV variants. As of February 2013, PSLV had conducted 23 launches, and in October 2013, further missions were scheduled. A typical type, the PSLV, has a launch capability of 1,678 kg payload to 622 km into SSO. Three sub-variants are included in it: PSLV (1), PSLV (2), and PSLV (3).

An enhanced version of the PSLV is called PSLV-CA (PSLV-core alone). It has a payload capacity of 1,100 kg and requires 400 kg less propellant than the normal variant to reach SSO. On April 23, 2007, the PSLV-CA made its first flight.

The PSLV-XL is a modified version of the PSLV that weighs 320,000 kg when it takes off. Compared to the normal PSLV, it can carry 4,000 kg extra propellant because of the integration of six strap-on motors. The first launch of PSLV-XL carrying Chandrayaan-1 occurred on October 22, 2008.

A high-performance variant called PSLV-HP is presently being developed. It will have improved strap-on boosters and a 2,000 kg payload capacity. Between 2013 and 2015, it plans to deploy seven navigation satellites. A sophisticated rocket that is presently being developed is the PSLV-3S. This version will have three stages for launching small satellites into low-Earth orbit.

Design of PSLV Launch Vehicle

The PSLV was intended to be 2.8 meters in diameter and 450 meters high. To complete missions including navigation, guidance, and attitude control, it is equipped with an inertial guidance system.

By inserting an aqueous solution of strontium perchlorate in the nozzle to create a secondary injection thrust vector control system (SITVC), which regulates the roll augmentation, the vehicle can be controlled in pitch and yaw during the thrust phase of the solid booster.

To store the injected fuel, the vehicle additionally has two cylindrical aluminum tanks mounted to the solid rocket boosters. For roll control during the first stage, roll control thrusters (RCT) were also deployed.

Launch Stages

A satellite can be launched into orbit by PSLV in four stages. Two solid propulsion systems are integrated into the first and third stages, while liquid engines power the second and fourth stages.

Six strap-on boosters in the first stage can burn 139t of propellant connected to hydroxyl-terminated polybutadiene (HTPB) to produce a maximum thrust of 677 kN apiece.

During lift-off, four ground-lit boosters catch fire, and the two airlift boosters that are left burn at 2.4 km altitude.

At 23.7 kilometers and 42.6 kilometers, respectively, the air-lit and ground-lit boosters are discarded. After traveling 68.5 km, the second stage ignites and is powered by a single Vikas liquid engine that produces 800kN of thrust.

The liquid propulsion system, which is attached to a turbopump, burns 41.5 tonnes of dimethyl hydrazine fuel and nitrogen tetroxide oxidizer for 162 seconds. The payload fairings parted about 117 km above the ground.

At 248 km, the third stage is set aflame. With a maximum thrust of 324kN, it is propelled by a solid rocket motor that uses 7.6t of HTPB propellant. A 425 km height is reached when the third stage is destroyed.

The fourth stage uses liquid propellant and is equipped with two engines.

To provide 14kN of thrust, the last stage burns 2.5t of monomethylhydrazine fuel and nitrogen tetroxide oxidizer for 420 seconds. This phase puts the satellite, depending on its purpose, into either low-Earth orbit or geostationary orbit.

Operational Launch Vehicle
Since PSLV was India's first operational launch vehicle, it has consistently launched satellites with accuracy and dependability. Even though India has since developed two more launchers with greater payload capacities and complexity—the GSLV Mark II, which was used for twelve launches between 2001 and 2018, and the GSLV Mark III, which was used for one suborbital and two orbital missions in 2014, 2017 and 2018, respectively—the PSLV has launched more frequently than any other vehicle and has earned the moniker "workhorse launch vehicle of India" thanks to its extensive track record of success [3, 4].

Even though PSLV's first launch failed because of an incredibly unusual circumstance that its guidance and control processor was not designed to handle, the company's 39 following launches were successful in delivering the satellite or satellites carried aboard into orbit [5,6].

However, PSLV experienced a setback on its forty-first flight when its payload fairing (heat shield) failed to separate, leaving the IRNSS-II navigation satellite permanently encased in that fairing. Despite reaching orbit during that flight, PSLV's orbit was not the intended one, as the satellite became permanently lodged within the vehicle's rounded payload fairing. However, PSLV has since achieved three noteworthy victories in a row, and in one of the three launches, it was successful in launching 31 satellites [7-10].

CHARACTERISTICS OF PSLV

Adaptability
PSLV is renowned for its flexibility and multipurpose nature. It can be set up in a variety of ways to meet the needs of different missions, such as transporting numerous payloads on a single flight and launching satellites into distinct orbits.

Payload Capacity
It can transport payloads ranging from a few hundred kilos to over a ton, though the precise payload capacity will depend on the mission profile and PSLV type. For instance, the PSLV-CA version is capable of delivering payloads to sun-synchronous orbit (SSO) weighing about 1,100 kg.

Polar Orbit Capability
The PSLV is an excellent vehicle for putting satellites into polar orbits, as its name implies. For scientific missions requiring worldwide coverage, remote sensing, and Earth observation, this capacity is critical.

Reliability
The PSLV has an impressive history of dependability. It is a reliable option for satellite deployment because it has effectively launched multiple satellites for both Indian and foreign clients.

Cost-Effectiveness
When compared to other launch vehicles with comparable capability, PSLV is renowned for its affordability. Because of its low cost, it is a desirable choice for many different types of missions.

Sun-Synchronous Orbit (SSO) Capability
Sun-synchronous orbits, which are frequently employed for Earth observation and remote sensing missions, can be reached by satellites launched by PSLV. SSOs offer reliable lighting for data collecting and imaging.

Multi-Orbit and Multi-Payload Capability
If necessary, PSLV may launch numerous satellites into separate orbits during a single flight. When several payloads share a launch, like in rideshare missions, this functionality comes in handy.

International Collaboration
Since PSLV has been used to launch satellites from many different nations, it has become a major player in the commercial launch industry and promoted cooperation between nations in space exploration.

Ease of Integration
The PSLV is renowned for its simplicity of integration and short mission turnaround times, which enhance its dependability and efficiency.

Sustainability
The organization in charge of the PSLV, ISRO, has been attempting to reduce the environmental impact of its launch vehicles by implementing green propulsion technologies and clean fuels.

SPECIFICATIONS OF PSLV

PSLV G (Standard Variant)

- **Height:** Approximately 44 meters (144 feet)
- **Diameter:** Approximately 2.8 meters (9.2 feet)
- **Liftoff Mass:** Approximately 320,000 kilograms (705,000 pounds)
- **Payload Capacity to Sun-Synchronous Orbit (SSO):** Approximately 1,100 kilograms (2,425 pounds)
- **Number of Stages:** Four solid stages (PS1, PS2, PS3, PS4) and one liquid stage (PS4)
- **Propulsion:** Solid rocket motors for the first and second stages, and a liquid bi-propellant engine for the fourth stage (Vikas engine)
- **Guidance and Control:** Inertial Navigation System and onboard computers for precise navigation and guidance

PSLV-XL (Extended Variant)

- **Height:** Approximately 44 meters (144 feet)
- **Diameter:** Approximately 2.8 meters (9.2 feet)
- **Liftoff Mass:** Approximately 320,000 kilograms (705,000 pounds)
- **Payload Capacity to Sun-Synchronous Orbit (SSO):** Approximately 1,600 kilograms (3,530 pounds)
- **Number of Stages:** Four solid stages (PS1, PS2, PS3, PS4) and one liquid stage (PS4)
- **Propulsion:** Solid rocket motors for the first and second stages, and a liquid bi-propellant engine for the fourth stage (Vikas engine)
- **Guidance and Control:** Inertial Navigation System and onboard computers for precise navigation and guidance [11].

Planetary Missions Using ISRO Launch Vehicles

India's first lunar mission on the PSLV-C11 flight (PSLV-XL), Chandrayaan-I was launched, placing the 1380 kg spacecraft in a 250 x 23000 earthbound orbit. Although GSLV is designated to transport the bulkier Chandrayaan-II spacecraft, PSLV is once more selected to carry out the difficult MARS mission, to launch the first Indian spacecraft in the direction of Mars.

The operationalization of GSLV and the LVM3 will significantly improve this capability to deliver heavier spacecraft on orbital/landing missions to planetary bodies. While very modest payloads can be deployed on fly-by missions to planetary bodies like Mars, Venus, and some near-earth asteroids with PSLV, this capability will be greatly enhanced.

CONCLUSION

The PSLV, India's first operational launch vehicle, has shown to be a dependable, adaptable, and sturdy launch vehicle. Its capacity to launch several satellites on a single mission is highly valued worldwide. While the nation's accomplishments in launching Indian satellites have allowed it to become self-sufficient in orbiting its planetary spacecraft, scientific satellites, remote sensing satellites, and navigation satellites, its commercial satellite launches from overseas have further improved its reputation and instilled a sense of pride in the nation.

The Indian Polar Satellite Launch Vehicle (PSLV) has demonstrated its resilience and adaptability through numerous successful launch missions, such as SSPO, GTO, and inclined orbits. The science community is monitoring the PSLV launch rate.

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