Research on PSLV-C37 Launcher by ISRO

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Abstract: ***This research is on PSLV-C37 which was the 39th mission of the Indian Polar Satellite Launch Vehicle (PSLV) program and its 16th mission in the XL configuration. PSLV-C37 successfully carried and deployed a record 104 satellites in sun-synchronous orbits. Launched on 15 February 2017 by the Indian Space Research Organization (ISRO) from the Satish Dhawan Space Centre at Sriharikota, Andhra Pradesh, it broke the earlier record of launching 37 satellites by a Russian Dnepr rocket on 19 June 2014. According to ISRO, the 101 international satellites were launched as part of a commercial arrangement between several firms and its commercial arm Antrix Corporation Limited, run under the auspices of the Indian Government's Department of Space.***

Keywords: ISRO, PSLV, Launcher, Satellite, earth-mapping, space record, space technology

1. Introduction

The **Polar Satellite Launch Vehicle** (**PSLV**) is an expendable medium-lift launch vehicle designed and operated by the Indian Space Research Organisation (ISRO) as shown in Fig.1.1. It was developed to allow India to launch its Indian Remote Sensing (IRS) satellites into sun-synchronous orbits.PSLV has gainedcredence as a small satellite launcher due its numerous multi-satellite deployment campaigns with auxiliary payloads usually ride sharing along an Indian primary payload. Payloads can be integrated in tandem configuration employing a Dual Launch Adapter. Smaller payloads are also placed on equipment deck and customized payload adapters. The vehicle typically consists of several rocket stages, discarded one by one as the vehicle gains altitude and speed.Imagery from the primary satellite, Cartosat-2D, is used for various land information system and geographical information system applications in India.[1]

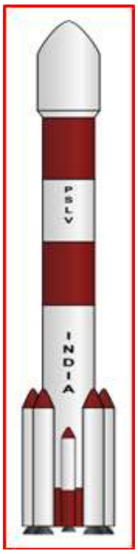

Figure 1.1: PSLV

2. Launch

India creates a history of space exploration with the successful launch of a record 104 satellites by ISRO's Satellite Launch Vehicle in a single mission.

On February 15 2017, PSLV-C37 carrying the 104 satellites lifted off from the first launch pad at Satish Dhawan Space Centre in Sriharikota at 09:28 A.M as shown in Fig-2.1. 17 Minutes later, the rocket started placing the satellites into orbit, one by one with a time-frame of about 11 minutes.

Out of the total 104 satellites placed in orbit, 101 satellites belonged to six foreign countries. They included 96 from the USA and one each from Israel, UAE, Netherlands, Switzerland and Kazakhstan. PSLV first injected its main payload Cartosat- 2 series, India's indigenously built Earth observation satellite. It was followed by two other Nano-Satellites of ISRO (INS-1A and INS-1B).

Then, it took less than 10 minutes for the rocket to spew out 101 passengers, which are all foreign Nano- Satellites, as it travelled up in altitude reaching the polar Sun Synchronous Orbit.[2]

Figure 2.1: Launch of PSLV-C37

2. Launcher Properties

Table 3.1: Properties of the Launcher

Particular	Specification
Spacecraft	Polar Satellite Launch Vehicle
Spacecraft type	Expendable launch vehicle
Model	PSLV-C37
Manufacturer	Indian Space Research Organization
Launch mass	320,000 kilograms
Payload mass	1,378 kilograms
Dimensions	44.4 meters
Altitude	505 kilometers
Mission type	Deployment of 104 satellites
Launch site	Sriharikota Launching Range,India

3. Satellites

When India became the first nation in the world to have launched over a hundred satellites in one mission, the ISRO PSLV rocket carried onboard payloads from six different countries. Here are the details in Table 4.1.[6]

Table 4.1: List of Satellites

S. No	Satellite	Qty.	Country	Weight
1.	Cartosat-2	1	India	714 kg
2.	INS-1A	1		8.4 kg
3.	INS-1B	1		9.7 kg
4.	Flock-3p	88	United States	4.7 kg each
5.	Lemur-2	8		4.6 kg each
6.	Al-Farabi-1	1	Kazakhstan	1.7 kg
7.	BGUSAT	1	Israel	4.3 kg
8.	Nayif-1	1	UAE	1.1 kg
9.	DIDO-2	1	Israel, Switzerland	4.2 kg
10.	PEASS	1	Belgium, Germany, Israel, Netherlands	3 kg

The 104 Satellites are as follows in details with figures.

1) *Cartosat -2 Series Satellite*

Figure 4.1: Cartosat -2 Series Satellite

The Cartosat-2 series satellite is the primary satellite carried by PSLV-C37 shown in Fig.4.1. This satellite is similar to the earlier four satellites of the Cartosat-2 series. After its injection into a 505 km polar Sun Synchronous Orbit by PSLV-C37, the satellite was brought to operational configuration following which it began providing regular remote sensing services using its Panchromatic and Multi-spectral cameras.

2) *INS-1A*

ISRO Nano Satellite -1A is shown on Fig.4.2. Surface Bidirectional Reflectance Distribution Function Radiometer (SBR) payload from Space Applications Centre (SAC), Ahmedabad measures the BRDF (Bidirectional Reflectance Distribution Function) of the Earth surface and will take readings of the reflectance of different surface features due to Sun albedo.

Figure 4.2: INS-1A Satellite

Single Event Upset Monitor (SEUM) payload from SAC monitors Single Event Upsets occurring due to high energy radiation in the space environment.

3) *INS-1B*

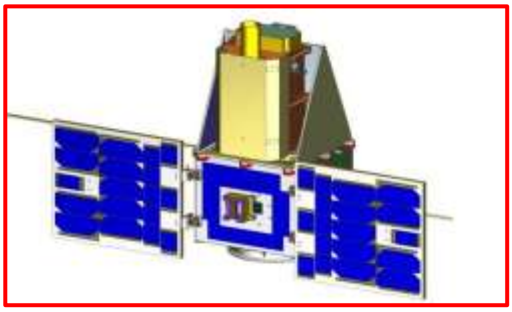

Figure 4.3: INS-1B Satellite

ISRO Nano Satellite -1A is shown on Fig.4.3. Earth Exosphere Lyman Alpha Analyser (EELA) payload from Laboratory for Electro-Optics Systems (LEOS), Bengaluru Registers terrestrial exospheric line-of-sight neutral atomic hydrogen Lyman Alpha flux. Besides, it will estimate the interplanetary hydrogen Lyman-alpha background flux by means of deep space observations. Origami Camera payload from SAC is a Remote Sensing Colour camera with a novel lens assembly for optical realisation in a small package. There is scope for its future scalability and utilisation in regular satellites.

4) *FLOCK-3P*

The Dove spacecraft are based on the three-unit CubeSat specification as shown in Fig.4.4, having a launch mass of about 4.7 Kilograms and being 100mm × 100mm × 340mm in size featuring body mounted solar panels and two deployable solar arrays with three panels each using triangular advanced solar cells.

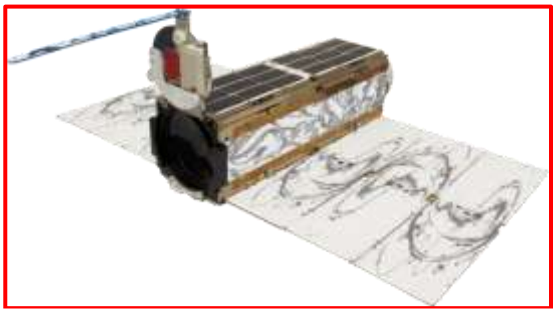

Figure 4.4: Flock-3P Satellite

5) LEMUR-2

The instrument shown in Fig.4.5consists of GPS receivers to be able to track the signals of several MEO satellites and measure the time delay and bend angle of signals that travel through the atmosphere located in the line of sight of the two spacecraft. These phase delay measurements due to refraction by the atmosphere can be made from the satellite altitude to very close to the surface leading to precise information on the properties of the atmosphere at an accurate vertical resolution.[4]

Figure 4.5: Lemur-2 Satellite

6) AL-FARABI -1

Al-Farabi 1 is a 2U CubeSat built by students of the Al-Farabi Kazakh National University shown in Fig. 4.6. The satellite is built as an educational mission with the secondary mission to: work out uplink/downlink and ADCS Mission algorithms and testing of self-made components. The satellite features a 3 Mp CMOS camera.

Figure 4.6: Al-Farabi -1 Satellite

7) BGUSAT

The satellite shown in Fig.4.7 is a basic 3 U CubeSat (30 x 10 x 10 cm) with a mass of about 5 kg. The on board computer is a GR712RC designed by Ramon Chips and CobhamGaisle. The camera payload is a small camera, working in the wavelength of IR and NIR 1.7 - 1.55. The ground station is operated by the researchers and students of Ben Gurion University.

Figure 4.7: BGUSAT Satellite

8) NAYIF-1

Nayif-1 shown in Fig-4.8 is a radio amateur radio from the United Arab Emirates. The 1U-CubeSat includes a complete communication package of the FUNcube series: a transponder for the mode U / V in single sideband modulation (SSB) and telegraphy (CW), as well as a radio beacon with phase shift keying (BPSK) for data transmission. The satellite has one antenna each for the 70 cm and 2 meter bands.

Figure 4.8: NAYIF-1 Satellite

9) DIDO-2

This is probably the most intuitive application for DIDO being that vehicles and other machines in space rely heavily on automation or remote controls rather than direct human actions. Out there, a computer that can sense what's happening around it and quickly determine the best response is a valuable asset.DIDO tackled the goal of maneuvering the International Space Station (ISS) 180 degrees within its orbital path without expending any fuel. Typically, the ISS and other vehicles in orbit must use thrusters to maneuver, which require expensive fuel. DIDO creator Ross and other researchers had an idea that a zero-propellant maneuver (ZPM) was possible. The satellite is shown in Fig.4.9.

Figure 4.9: DIDO-2 Satellite

10) PEASS

PEASSS (Piezo Electric Assisted Smart Satellite Structure) shown in Fig.4.10 is a 3U CubeSat built by a multi-national consortium. PEASSS is under development as part of a FP7 European Commission project involving Active Space Technologies GmbH (Germany), TNO and ISIS (Netherlands), SONACA (Belgium), Technion and NSL (Israel).

The main objective of the project is to develop, manufacture, test and qualify "smart structures" which combine composite panels, piezoelectric materials, and next generation sensors, for autonomously improved pointing accuracy and power generation in space. The system components include new nano satellite electronics, a piezo power generation system, a piezo actuated smart structure and a fiber-optic sensor and interrogator system.

Figure 4.10: PEASS Satellite

3. Description

The PSLV has four stages using solid and liquid propulsion systems alternately. The first stage, one of the largest solid rocket boosters in the world, carries 138 t (304,000 lb) tonnes of hydroxyl-terminated polybutadiene-bound (HTPB) propellant and develops a maximum thrust of about 4,800 kilo-newtons (1,100,000 lbf). The 2.8 m (9 ft 2 in) diameter motor case is made of maraging steel and has an empty mass of 30,200 kilograms (66,600 lb).[7] Pitch and yaw control during first stage flight is provided by the Secondary Injection Thrust Vector Control System (SITVC), which injects an aqueous solution of strontium perchlorate into the nozzle to produce asymmetric thrust. The solution is stored in two cylindrical aluminum tanks strapped to the solid rocket motor and pressurized with nitrogen. Roll control is provided by two small liquid engines on opposite sides of the stage, the Roll Control Thrusters (RCT).[6]

On the PSLV and PSLV-XL, first stage thrust is augmented by six strap-on solid boosters. Four boosters are ground-lit and the remaining two ignite 25 seconds after launch. The solid boosters carry 9 t (20,000 lb) or 12 t (26,000 lb) (for PSLV-XL configuration) propellant and produce 510 kN (110,000 lbf) and 719 kN (162,000 lbf) thrust respectively. Two strap-on boosters are equipped with SITVC for additional attitude control. The PSLV-CA uses no strap-on boosters.[6]

The second stage employs the Vikas engine and carries 41.5 t (91,000 lb) of liquid propellant – unsymmetrical dimethyl hydrazine(UDMH) as fuel and nitrogen tetroxide (N2O4) as oxidizer. It generates a maximum thrust of 800 kN (180,000 lbf). The engine is hydraulically gimbaled (±4°) to provide pitch and yaw control, while roll control is provided by two hot gas reaction control motors.[6]

The third stage uses 7 t (15,000 lb) of hydroxyl-terminated polybutadiene-based solid propellant and produces a maximum thrust of 240 kN (54,000 lbf). It has a Kevlar-polyamide fiber case and a submerged nozzle equipped with a flex-bearing-seal gimbaled nozzle (±2°) thrust vector engine for pitch & yaw control. Roll control is provided by the fourth stage reaction control system (RCS).

The fourth stage is powered by regenerative cooled twin engines, burning monomethyl hydrazine (MMH) and mixed oxides of nitrogen (MON). Each engine generates 7.4 kN (1,700 lbf) thrust and is gimbaled (±3°) to provide pitch, yaw & roll control during powered flight. Coast phase attitude control is provided by RCS. The stage carries up to 2,500 kg (5,500 lb) of propellant in the PSLV and PSLV-XL and 2,100 kg (4,600 lb) in the PSLV-CA. PSLV is developed with a group of wide-range control units as shown in Table-5.1..[6]

Table 5.1: 4 Stages of PSLV

	Stage 1	Stage 2	Stage 3	Stage 4
Pitch	SITVC	Engine Gimbal	Flex Nozzle	Engine Gimbal
Yaw	SITVC	Engine Gimbal	Flex Nozzle	Engine Gimbal
Roll	RCT and SITVC in 2 PSOMs	HRCM Hot Gas Reaction Control Motor	PS4 RCS	PS4 RCS

4. Applications

Telecommunication

India uses its satellites communication network – one of the largest in the world – for applications such as land management, water resources management, natural disaster forecasting, radio networking, weather forecasting, meteorological imaging and computer communication. Business, administrative services, and schemes such as the National Informatics Centre (NICNET) are direct beneficiaries of applied satellite technology[6]

Resource management

The satellites have found applications with the Indian Natural Resource Management program, with Regional Remote Sensing Service Centres in five Indian cities, and with Remote Sensing Application Centres in twenty Indian states that use IRS images for economic development applications. These include environmental monitoring, analysing soil erosion and the impact of soil conservation measures, forestry management, determining land cover for wildlife sanctuaries, delineating groundwater potential zones, flood inundation mapping, drought monitoring, estimating crop acreage and deriving agricultural production estimates, fisheries monitoring, mining and geological applications such as surveying metal and mineral deposits, and urban planning.[6]

Military

The satellites were primarily intended and used for civilian-economic applications, but they also offered military spin-offs. In 1996 New Delhi's Ministry of Defence temporarily blocked the use of IRS-1C by India's environmental and agricultural ministries to monitor ballistic missiles near India's borders. In 1997 the Indian Air Force's "Airpower Doctrine" aspired to use space assets for surveillance and battle management.[6]

Academic

Institutions like the Indira Gandhi National Open University (IGNOU) and the Indian Institutes of Technology use satellites for scholarly applications. Between 1975 and 1976, India conducted its largest sociological programme using space technology, reaching 2400 villages through video programming in local languages aimed at educational development via ATS-6 technology developed by NASA. This experiment—named Satellite Instructional Television Experiment (SITE)—conducted large scale video broadcasts resulting in significant improvement in rural education. Education could reach far remote rural places with the help of above programs.[6]

Telemedicine

ISRO has applied its technology for telemedicine, directly connecting patients in rural areas to medical professionals in urban locations via satellites. Since high-quality healthcare is not universally available in some of the remote areas of India, the patients in remote areas are diagnosed and analysed by doctors in urban centres in real time via video conferencing. The patient is then advised medicine and treatment.. The patient is then treated by the staff at one of the 'super-specialty hospitals' under instructions from the doctor. Mobile telemedicine vans are also deployed to visit locations in far-flung areas and provide diagnosis and support to patients.[6]

Biodiversity Information System

ISRO has also helped implement India's Biodiversity Information System, completed in October 2002. NirupaSen details the program: "Based on intensive field sampling and mapping using satellite remote sensing and geospatial modeling tools, maps have been made of vegetation cover on a 1: 250,000 scale. This has been put together in a web-enabled database that links gene-level information of plant species with spatial information in a BIOSPEC database of the ecological hot spot regions, namely northeastern India, Western Ghats, Western Himalayas and Andaman and Nicobar Islands. This has been made possible with collaboration between the Department of Biotechnology and ISRO."[6]

Cartography

The Indian IRS-P5 (CARTOSAT-1) was equipped with high-resolution panchromatic equipment to enable it for cartographic purposes. IRS-P5 (CARTOSAT-1) was followed by a more advanced model named IRS-P6 developed also for agricultural applications. The CARTOSAT-2 project, equipped with single panchromatic camera that supported scene-specific on-spot images, succeeded the CARTOSAT-1 project.[6]

5. Conclusions

Ironically, ISRO successfully launched 104 satellites on 15 February 2017, of which 3 satellites are Indian satellites while the remaining are foreign commercial satellites. Ninety-six satellites are from the United States, while the others come from Israel, the UAE, Kazakhstan, the Netherlands, Belgium and Germany. It is the largest number of satellites launched on a single flight by any space agency.

References

[1] "ISRO Launches PSLV-C37 Rocket: Here's the List of 104 Satellites on Board". NDTV Gadgets360.Retrieved 15 February 2017.
[2] "ISRO launches 104 satellites in one go, creates history". The Hindu. 15 February 2017. Retrieved 15 February 2017.
[3] https://space.skyrocket.de/doc_sdat/al-farabi-1.htm
[4] http://spaceflight101.com/pslv-c37/lemur-2/
[5] https://computer.howstuffworks.com/dido2.htm
[6] “Indian Space Research Organisation” ,Wikipedia.com.

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