ACCESS TO SPACE THROUGH ISRO LAUNCH VEHICLES

Introduction :

Climbing out of the Earth's gravity well and transcending the dense atmospheric shield is the most energy intensive crucial first step in the journey into space and the Launch Vehicles are the primary viable means of accomplishing this task. India acquired the capability to orbit a satellite in 1980, when SLV-3 the indigenously developed all solid launcher deployed the 40 kg Rohini satellite around earth. Tremendous progress has been made in this area in the last three decades and today, India is one among the leading space-faring nations with assured access to space through the work-horse operational launcher PSLV, the Polar Satellite Launch Vehicle.

PSLV which was developed for servicing the Indian Remote Sensing programme has performed an unbroken string of twenty-one successful missions, including Geosynchronous Transfer Orbit (GTO) deployment and the much acclaimed Chandrayaan-1, the mission to Moon. Progressive performance enhancement measures have improved the capability of PSLV, enabling passenger payloads to be carried along with the main satellite, opening up low cost launch opportunities for mini and micro satellites from across the globe. PSLV has so far successfully deployed about thirty auxiliary payloads including experimental satellites built by university students. PSLV is the launcher proposed to carry the Spacecraft for the first Indian Mars Mission.

Sounding Rockets V/S Launch Vehicles :

India's foray into space started in 1963 when the first NIKE APACHE rocket was launched from Thumba Equatorial Rocket Launching Station (TERLS), Trivandrum. Unlike other major space-faring nations where the space launchers were derived from already operational ballistic missiles, Indian Launch Vehicle development had its humble beginning in the form of producing indigenous Rohini sounding rockets. Design and production of these solid propellant motors gave a firm foundation in solid rocket technology based on which the first Satellite Launch Vehicle (SLV-3) was configured. The successful development of all solid four stage SLV-3 not only demonstrated the indigenous strength in solid propulsion which is one of the subsystems of a complex launch vehicle but also the maturity attained in conceiving, designing and realizing other vital elements viz., control, guidance, navigation and staging systems. The nation's capability to plan, integrate and carry out a satellite launch mission which is truly a multi-disciplinary technological challenge was proved on July 18, 1980 when India successfully orbited Rohini-1 satellite on SLV-3 E02 flight.

While the sub-orbital sounding rockets which just carry the payload instruments upto a height of 100 to 200 kilometers have very few sub-systems apart from the propulsive device, a Satellite Launcher which has to import a velocity of around 8 km/sec and precisely deliver the payload into a pre targeted injection vector in space has far more complex systems all of which have to function flawlessly for a successful orbital mission.

PSLV – The Operational Work-Horse :

While SLV-3 and follow on ASLV were the technology development launchers, PSLV – the Polar Satellite Launch Vehicle (Fig. 1) is the first operational launch vehicle which has currently matured as a reliable workhorse launcher providing India an assured access to space. The PSLV project was initiated in 1982 for establishing indigenous capability for launching the Indian Remote Sensing Satellite (IRS) of 1000 Kg class in Polar Sun synchronous Orbits. The sub-systems development took place over the course of next ten years. Some of the major technologies developed and employed for PSLV are large solid booster of 100 ton class, liquid propellant stages, light alloy structures, composite motor cases, closed loop control and guidance systems, redundant strap-down inertial navigation systems, etc. New facilities were set up for processing, handling and testing of various vehicle sub-systems. The 2.8 m diameter, 44 m tall four stage vehicle has a gross lift-off mass of about 300 tons.

The liquid propellant second stage based on the Viking engine technology was to meet the performance requirements, whereas the indigenous liquid upper stage was a functional necessity to carry out three-axis stabilized injection of operational IRS satellites. The induction of liquid stages and the quantum jump in the vehicle size demanded systematic approach to vehicle engineering aspects, structural characterization as well as launch pad interface management.

Today, PSLV has an enviable record of having performed an unbroken string of twenty-one successful missions in a row starting from PSLV-D2 in 1994 to the latest PSLV-C21/SPOT-6 mission in September 2012. The operational PSLV configuration has basically three options viz the Standard PSLV, the PSLV-XL version and the PSLV-Core Alone version with different performance capabilities to fit the specific mission requirements.

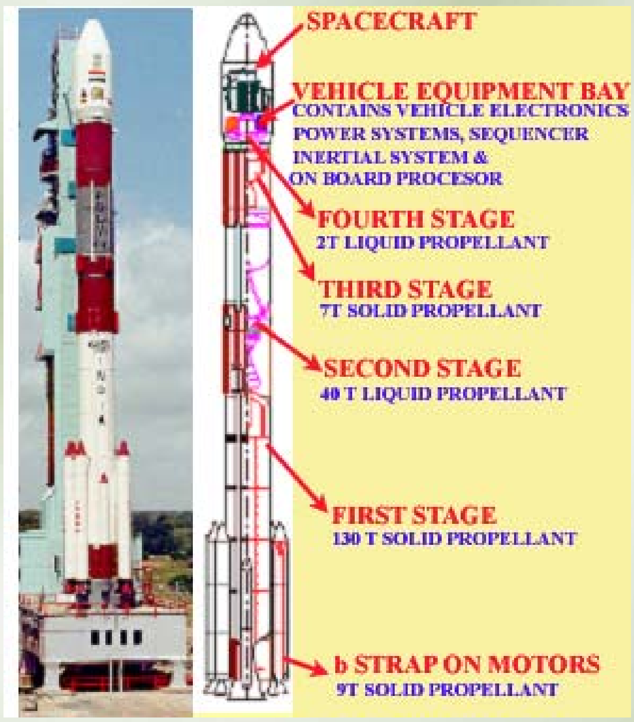

Figure 1: The Polar Satellite Launch Vehicle

Passenger Payloads and Multi-satellite Mission:

The payload capability of PSLV made a quantum jump from 850 kg to 1200 kg in SSPO in the first operational mission PSLV-C1 and subsequently it has been steadily growing through progressive optimization of vehicle and mission design and currently touches around 1500 to 1700 kg (SSPO) and 1300 kg for GTO. To exploit the excess payload capability, specific interfaces were created in the Vehicle Equipment Bay deck to accommodate two auxiliary small satellites of 150 kg class along with primary spacecraft. PSLV-C2 was the first vehicle to carryout multi-satellite mission (Fig. 2) when along with IRS-P4 (Oceansat-I), KITSAT from South Korea and TUBSAT from Germany were deployed on commercial terms.

PSLV-C3 vehicle performed multi-orbit mission when it injected the primary satellite TES and passenger payload BIRD in the nominal 567 km orbit, and subsequently deployed the second auxiliary satellite PROBA of ESA into a higher orbit of 638 x 567 km.

PSLV has also demonstrated its capability to launch two primary payloads in a dual launch mode using a Dual Launch Adaptor (DLA). This configuration was first used to orbit the Space-capsule Recovery Experiment (SRE) module in PSLV-C7 along with the CARTOSAT-2. PSLV created a record when it successfully carried ten independent spacecrafts in a single launch mission (PSLV-C9) and deployed all of them perfectly in their designated orbits.

Multi-satellite deployment missions demand meticulous interface management for each of the payload including the operational aspects at the launch complex. Collision free smooth release of multiple spacecrafts during final injection demands detailed modeling and analysis of multi-body dynamics and specific maneuvers to avoid near term or long term re-contact between the different satellites.

Figure 2: Multiple Spacecraft Mission

PSLV/Payload Interfaces *:* While the main spacecraft interface with vehicle is through a standard 937Ø band clamp system, the passenger payloads have an option of adopting a variety of flight qualified ISRO Ball-lock separation systems viz, IBL 230, IBL 298 and IBL 358 (Fig. 3). Also, specific interfaces can be provided for mini/micro satellites as required. The DLA configuration (e.g. Fig. 4) offers another option for two primary payloads. PSLV offers a cool environment to the spacecrafts in terms of dynamic loads as well as the vibration and acoustic levels and these have been measured and validated through several successful missions.

Figure 3: IBL Separation System for Auxiliary S/C

PSLV to GSLV :

As PSLV was taking shape and maturing into an operational workhorse for the polar orbit launches of remote sensing spacecrafts, a launch vehicle was conceived and developed to attain a capability to launch 2.5 t class of communication satellite into GTO. GSLV was essentially derived from PSLV modules by replacing the six solid strapon motors with four liquid boosters named the L-40 stage which is a variant of PSLV second stage, and replacing the two upper stages of PSLV with a single cryogenic stage (CS) procured from Russia (Fig. 5).

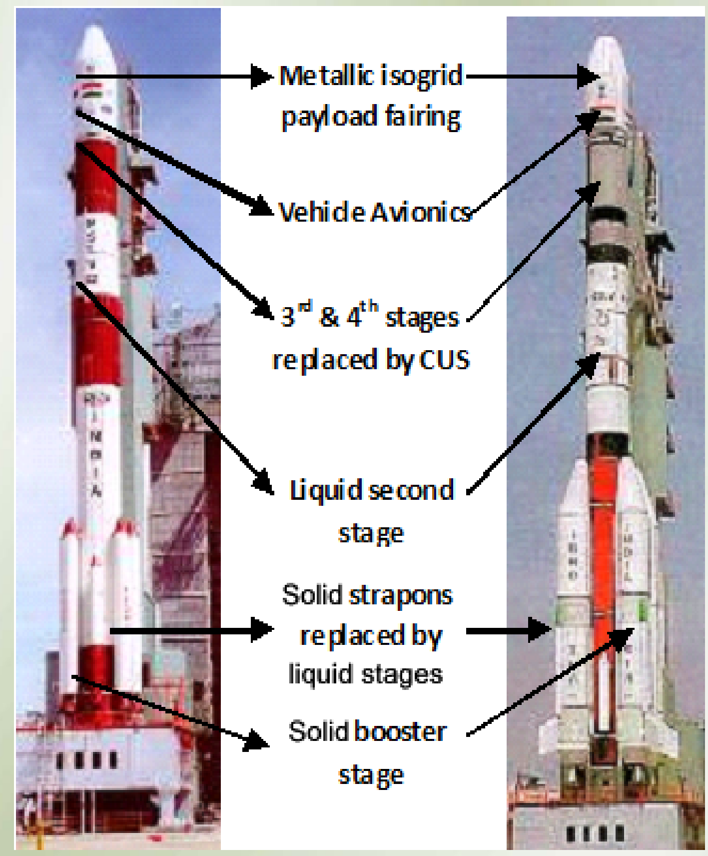

Figure 5: The transition from PSLV to GSLV

GSLV is three stage vehicle, 49 m tall, with a gross lift-off weight of about 415 tons. While most of the vehicle system elements including the navigation, guidance and control and other avionics modules were essentially adopted from PSLV. GSLV is yet to stabilize as an operational launcher. Seven launches have so far taken place out of which four were successful and three mission failures. Replacement of the Russian Cryo Stage with the indigenous Cryo Upper Stage (CUS) is imperative to sustain the GSLV programme. The first flight test of indigenous CUS on GSLV-D3 was not successful and the next attempt is targeted in the forthcoming GSLV-D5 flight.

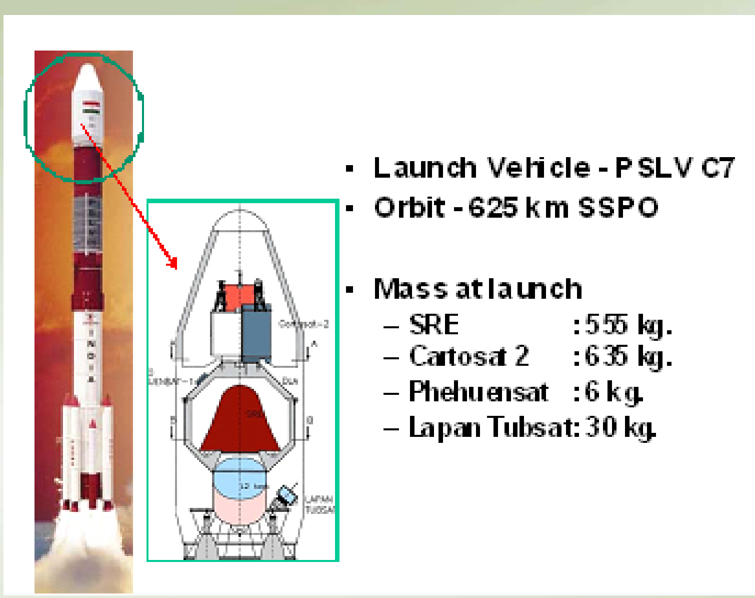

Figure 4: SRE Launch configuration

GSLV has a capability to take upto 2.5 ton into GTO and can accommodate larger spacecrafts with a 4m dia payload fairing.

GSLV MkIII (LVM3):

While PSLV and GSLV will meet the indigenous launch requirements upto 2.5t in GTO and about 4.5t in LEO. GSLV Mk-III (Fig. 6) is planned as the logical next step in the development of higher capacity launch vehicle, to place 4 tons in GTO at half the launch cost per kg of satellite mass. It also targets to maximally utilize the developed technologies and infrastructure of

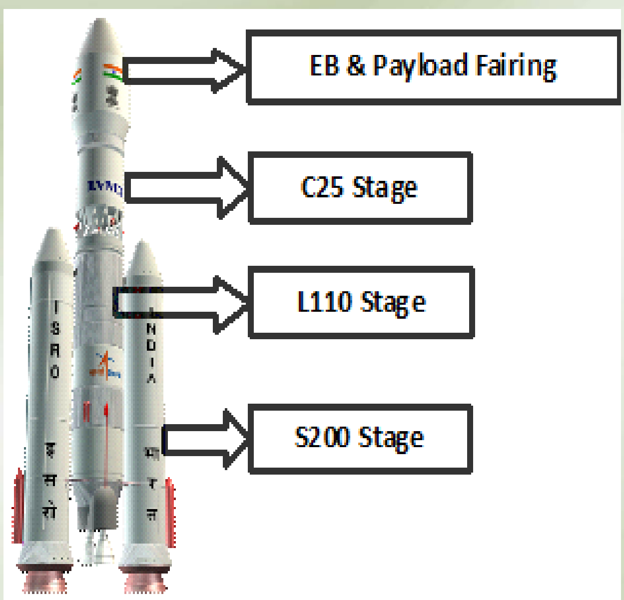

Figure 6: The GSLV MkIII

PSLV/GSLV.

LVM3 is a three stage vehicle of composition:

2S200+L110+C25

The solid strap-on stage (S200) derives its heritage from the PSLV/GSLV boosters. It incorporates flex nozzle control systems which is used in the third stage of PSLV. Each S200 has 200 tons of propellant loading.

The second stage is L110 stage which derives its heritage from the L-40 stage of GSLV. A twin-engine clustered configuration is adopted with similar stage engineering concepts as that of L-40. The third stage is a cryogenic stage with 25 tons of propellant loading and a single engine with 20 ton thrust. The new cryogenic stage draws the technological strengths from the development of the indigenous cryogenic stage (CUS) for GSLV. GSLV MkIII has advanced navigation systems and on-board electronics. It has a payload fairing of 5m diameter and 10m height.

Two out of three propulsive stages of LVM3, the S200 solid booster and the L110 liquid core have been developed and qualification tested. Work on the 25 ton indigenous Cryogenic Stage (C25) is progressing well. The first developmental launch of LVM3 is expected by 2014/15.

ISRO Launch Vehicles For Planetary Missions:

Indian first moon mission Chandrayaan-I was launched on PSLV-C11 flight (PSLV-XL) which deployed the 1380 kg Chandrayaan spacecraft into a 250x23000 earth bound orbit. While GSLV is identified to carry the

Flyby Capabilities (kg)				Orbital Capabilities (kg)		
Mars	Venus	Asteroid		Mars	Venus	Asteroid
720-770	717-766	556-862	PSLV	150-230	107-146	80-186
1220-1390	1260-1346	625-1514	GSLV	350-530	247-328	150-443
2610-2700	2705-2890	1342-3250	LVM3	650-1010	542-719	182-972

Figure 7: Flyby and Orbital capabilities of various Indian launch vehicles for Mission to Mars, Venus and Asteroids

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heavier Chandrayaan-II spacecraft, it is again PSLV that is chosen to perform the challenging MARS mission, to dispatch the first Indian spacecraft towards Mars.

While with PSLV, very modest payloads can be deployed on fly-by missions to planetary bodies like Mars, Venus and some near earth asteroids (Fig. 7), operationalisation of GSLV and subsequently the LVM3 will substantially enhance this capability to deliver heavier spacecrafts on orbital/landing missions to planetary bodies. Indian launch vehicle programme is depicted in Fig. 8.

ramped up to touch five per year with the payloads and missions upto PSLV-C48 listed in the manifest during the time-frame 2012-2020. Commissioning of the Second Launch Pad (SLP) at SDSC/SHAR makes possible to sustain this enhanced launch rate of PSLV alongwith the missions planned on GSLV and the LVM3 launchers.

The availability of Passenger Payload (PPL) opportunities in many of the PSLV launches offer a low cost option for undertaking innovative small satellite missions for planetary exploration as well as earth

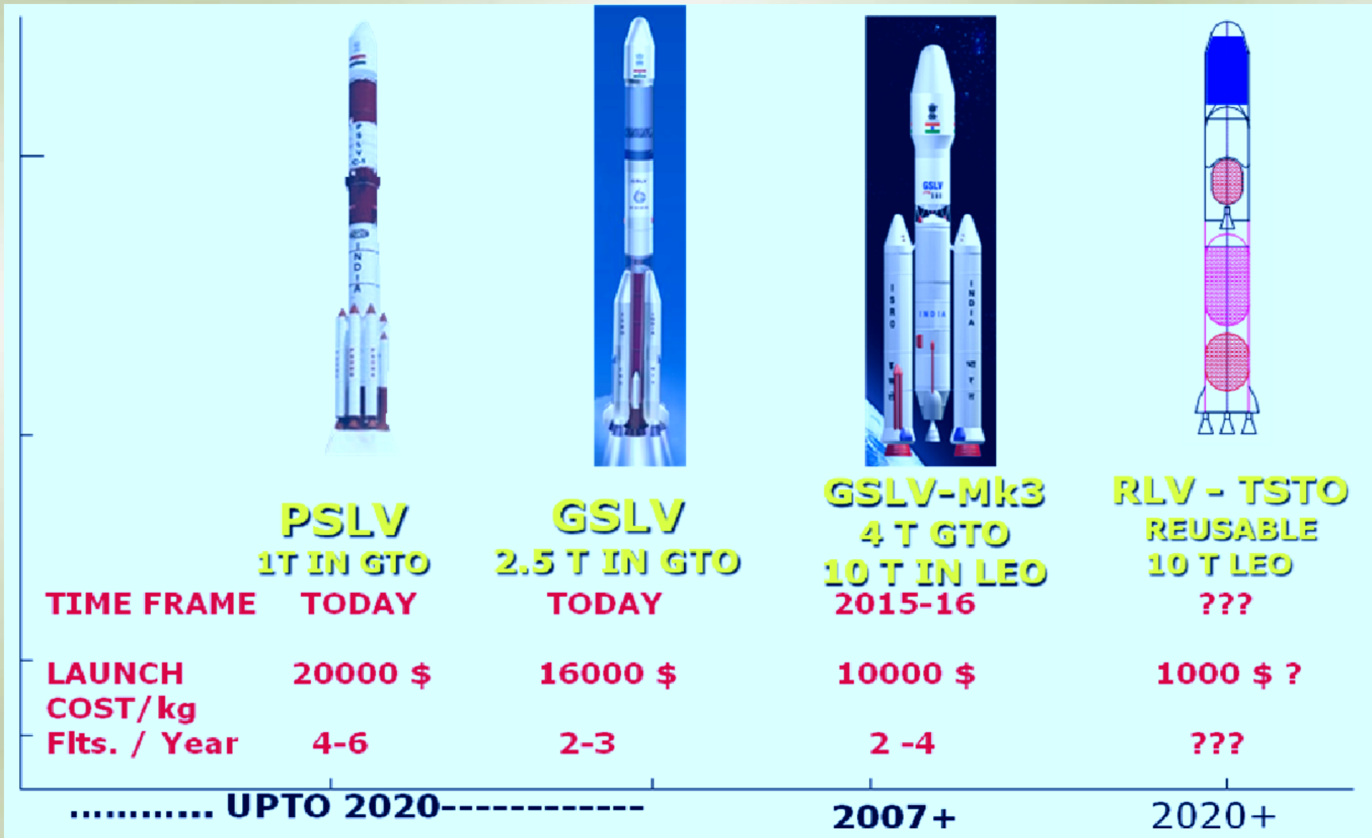

Figure 8: The Indian Launch Vehicle Programme

With the maturing of Electric Propulsion Systems (EPS) technology, it is feasible to embark on planetary reconnaissance missions with smaller spacecrafts such as the SMART mission to Moon by ESA, using modest launch capability.

observation to the science community. The maturing of GSLV and subsequently the much bigger LVM3 will enable India to embark upon more ambitious missions to other celestial bodies in the Solar System.

Conclusion:

The Polar Satellite Launch Vehicle (PSLV), of India has proved its robustness and versatility by performing a variety of successful launch missions including SSPO, GTO, and Inclined orbits. PSLV launch rate is being

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