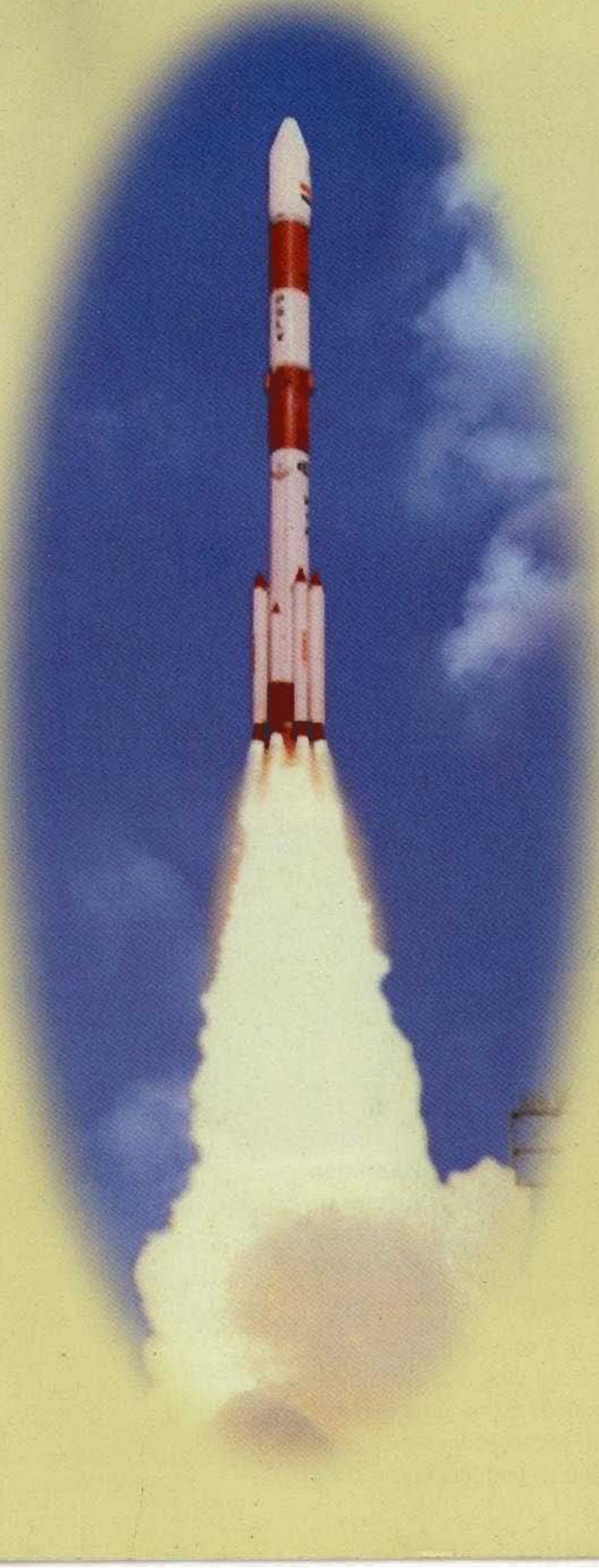
PSLV-C3 MISSION



PSLV-C3 the second commercial launch of ANTRIX/ISRO carries ISRO's Technology Experiment Satellite (TES) and two auxiliary satellites viz. PROBA (Project for On Board Autonomy) from Belgium and BIRD (Bispectral and Infrared Remote Detection) from Germany. The PSLV-C3 is on SSPO (Sun Synchronous Polar Orbit) mission similar to PSLV-C2, however it deploys TES and BIRD in a 568km circular orbit and PROBA in the 568 x 638 km elliptical orbit. After separation of the TES and BIRD the PS4 stage along with the PROBA spacecraft will be raised to the 568 x 638 km orbit by firing the RCS thrusters of PS4. Two axial thrusters will be fired for a duration of about 460 s in order to impart the necessary incremental velocity to put PROBA in the raised orbit.

MISSION DEFINITION

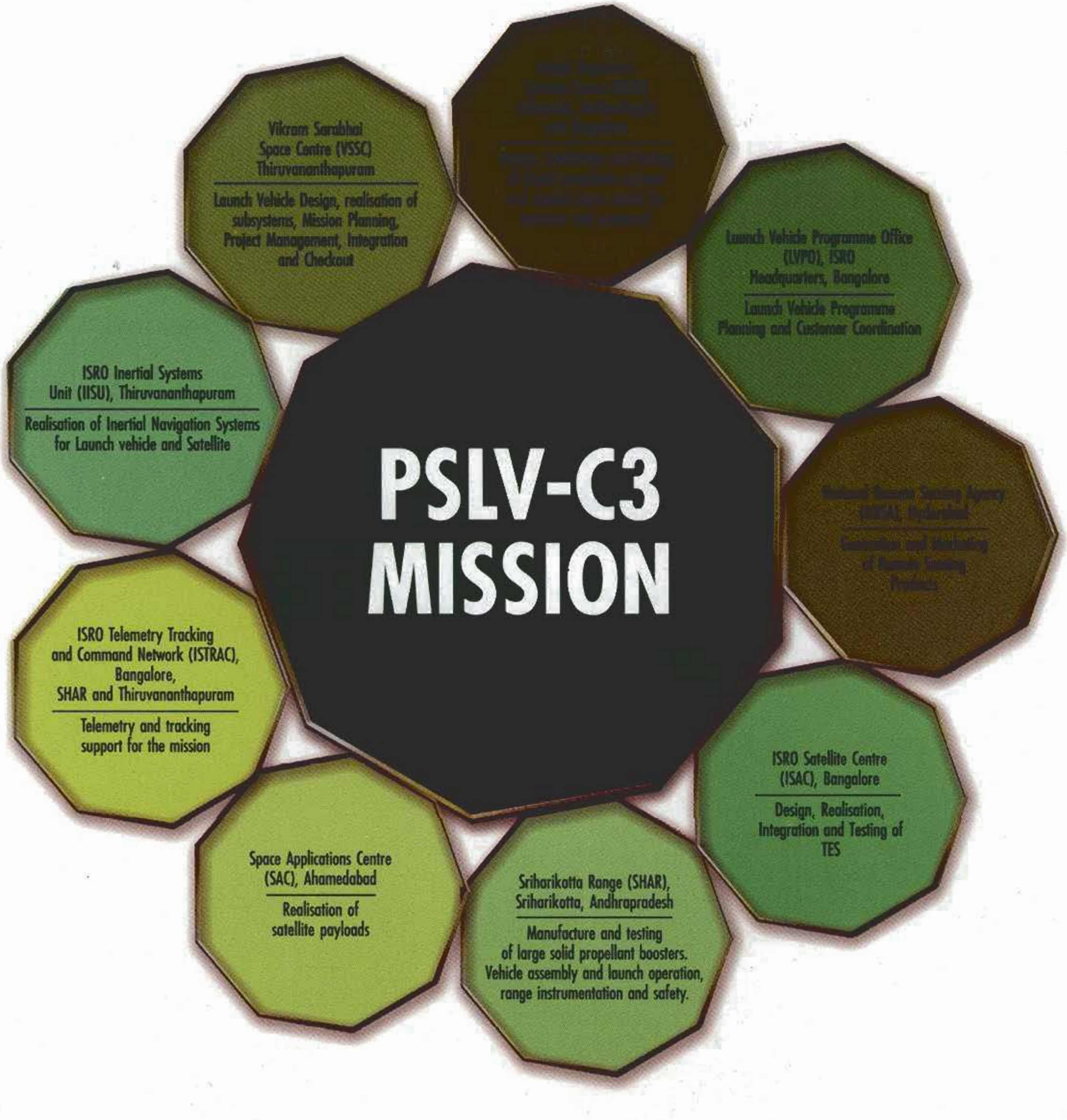
TES & BIRD

Orbit	: Sun Synchronous Polar
Altitude	: 568 km circular
Inclination	: 97.67 deg
Orbital Period	: 5857s
Launch time	: Between 10.15 and 10.45 hrs, IST
Launch azimuth	: 140 deg

PROBA

Orbit	: Elliptical (568 x 638 km)
Inclination	: 97.79 deg.

CONTRIBUTING ISRO ENTITIES



PSLV - C3 MISSION

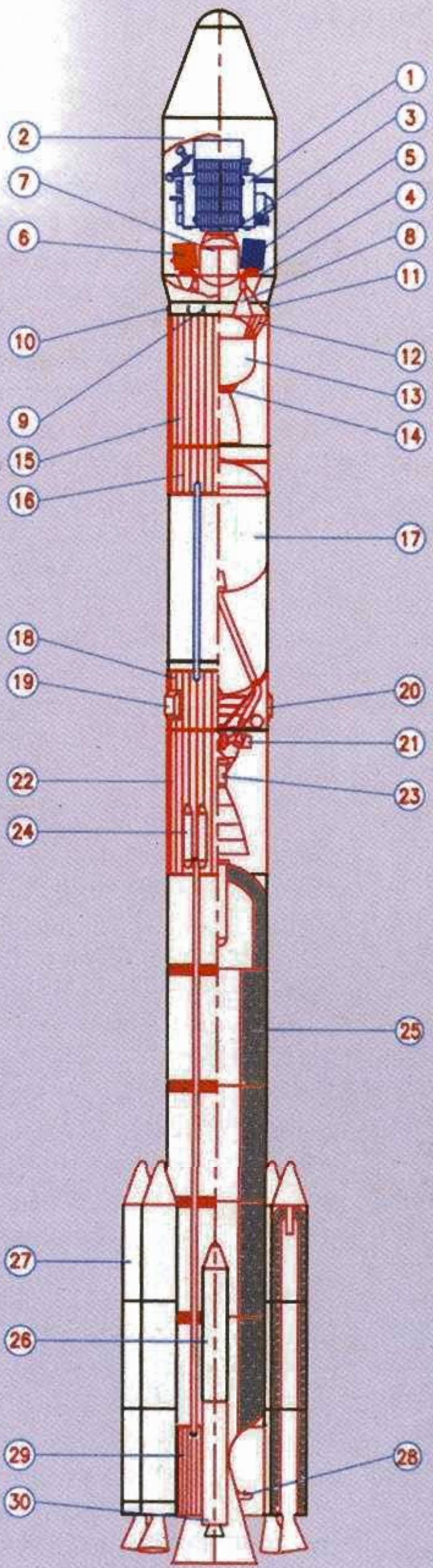
THE VEHICLE

The vehicle Configuration of PSLV-C3 is same as that of PSLV-C2 except for a few changes and additions. The induction of light weight PS4 stage tank is one of the improvements in PSLV-C3 compared to PSLV-C2. This has resulted in an increase in payload of around 25kg. A new ball lock separation system with an interface diameter of 298mm is being used for the first time for auxiliary satellite separation as per standard interface requirements. A Data Storage Unit (DSU), which stores the telemetry parameters and transmits in delayed mode is introduced in this mission. This takes care of breaks in visibility between Trivandrum and Mauritius ground stations as well as recording of PROBA separation. The PROBA separation related parameters will be transmitted when the stage passes over the Lucknow ground station. This package stores data during visibility loss for a duration of about 30s between Trivandrum and Mauritius and during PROBA separation, which is beyond the visibility range. An S-Band Range and Range Rate Transponder (SRRT) is incorporated in Equipment Bay(EB). This will provide an additional source for Preliminary Orbit Determination. An Experimental Video Imaging System is introduced in EB for capturing imageries on Heatshield separation. A mini sequencer is added to switch ON/OFF the telemetry system for the long waiting period from PROBA separation to data downloading.

Polar Satellite Launch Vehicle is developed primarily for deploying remote sensing satellite of 1000kg class in Polar sun synchronous orbits. It is powered by solid propellant first and third stages and liquid propellant second and fourth stages. The first stage consists of a 2.8m diameter solid propellant core motor with six strapon solid motors of 1m diameter. Four of the strapons are ignited on ground while the remaining two are ignited in flight. The core motor case is made of high strength steel and carries 138t of solid propellant. The second stage carries 40t of liquid propellants in an aluminium tank in a common bulk head and powered by the 'Vikas' engine. The third stage has a composite case motor with 7.3t of solid propellant. It has a contoured and submerged nozzle. The fourth stage carries 2t of propellants and has two high performance pressure fed engines.

An Inertial Navigation and Guidance System (IGS) in the EB guides the vehicle from lift- off to spacecraft injection. The Digital Autopilot (DAP) and Closed Loop Guidance (CLG) scheme resident in the onboard computer ensure the required attitude manoeuvre and guided injection of the spacecraft into the specified orbit. The CLG is initiated during the second stage thrusting phase after *Heatshield separation. The three axis* attitude stabilization of the vehicle is achieved by the autonomous control system provided in each stage. The first stage is with Secondary Injection Thrust Vector Control (SITVC) for pitch and yaw control and two swivellable Roll Control Thrusters (RCT) along with SITVC system in two PSOMs for roll control. After the first stage burnout (during auxiliary control phase), RCT engines are used for yaw and roll control and a set of four Reaction Control Thrusters (RCS) are used for pitch control. Second stage has Engine Gimbal Control System (EGC) for pitch and yaw and Hot gas

VEHICLE CONFIGURATION



1. TECHNOLOGY EXPERIMENT SATELLITE (TES)
2. HEATSHIELD
3. PAYLOAD ADAPTOR
4. EQUIPMENT BAY
5. PROBA
6. BIRD
7. FOURTH STAGE PROPELLANT TANK
8. FOURTH STAGE ENGINE (2)
9. ANTENNAE
10. REACTION CONTROL THRUSTER (6)
11. INTERSTAGE 3/4
12. THIRD STAGE ADAPTOR
13 THIRD STAGE MOTOR
14. FLEX NOZZLE CONTROL SYSTEM
15. INTERSTAGE 2/3U
16. INTERSTAGE 2/3L
17. SECOND STAGE PROPELLANT TANK
18. INTERSTAGE 1/2U
19. SECOND STAGE RETRO ROCKET (4)
20. ULLAGE ROCKET (4)
21. GIMBAL CONTROL SYSTEM
22. INTERSTAGE 1/2L
23. SECOND STAGE ENGINE
24. FIRST STAGE RETRO ROCKET (8)
25. FIRST STAGE MOTOR
26. SITVC INJECTANT TANK (2)
27. STRAP-ON MOTOR (6)
28. SITVC SYSTEM
29. CORE BASE SHROUD
30. ROLL CONTROL ENGINE (2)

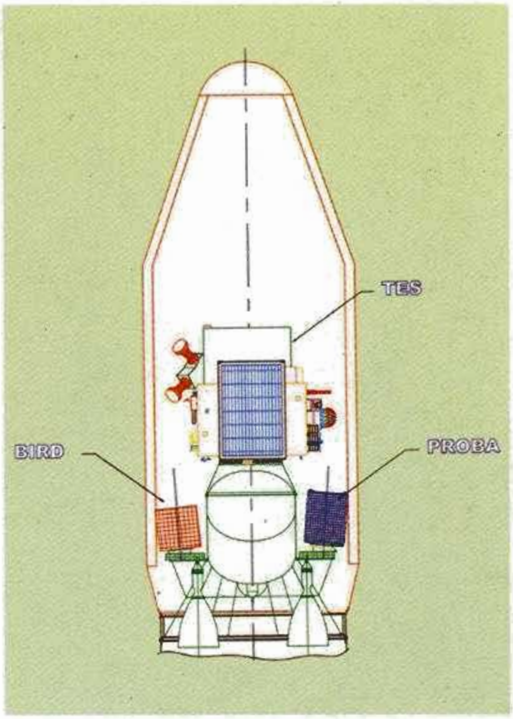
OVERALL HEIGHT - 44.4 m
LIFT OFF WEIGHT - 294 t

Reaction Control Module (HRCM) for roll control. The third stage has Flex Nozzle Control (FNC) for pitch and yaw. Fourth stage is controlled by gimballing its two engines for pitch, yaw and roll. Reaction Control System (RCS) provided in the fourth stage is used for control of pitch, yaw and roll during coast phase. These thrusters are also used for roll control during third stage and post cut-off manoeuvres of the fourth stage.

A bulbous Aluminium alloy Heat shield of 3.2 m diameter protects the spacecraft against hostile flight environment during ascent phase and is jettisoned at a minimum altitude of 105km using a pyrotechnic based zip cord mechanism. Vehicle is provided with various separation systems to discard the spent stages at the appropriate times.

The strapon motors are configured with ball and socket joints clamped using frangible nuts while spring thrusters provide the jettisoning energy. The first stage uses Flexible Linear Shaped Cord (FLSC) to severe the interstage structure and the jettisoning is achieved by 8 retro rockets. Ullage rockets ensure positive acceleration of the vehicle during stage separation to enable start up of the liquid engine of the second stage (PS2). The second stage separation is based on Merman band and jettisoning is by a set of 4 Retro rockets. The third stage separation is through ball lock mechanism and springs while fourth stage uses Merman band and helical compressed springs for imparting separation velocity.

The vehicle is also provided with instrumentation to monitor vehicle performance during flight. S-band PCM telemetry systems and C-band transponders cater to these requirements. The tracking systems provide real time information for flight safety and preliminary orbit determination. Telecommand system together with destruct system onboard, enable flight termination in case of an errant flight.

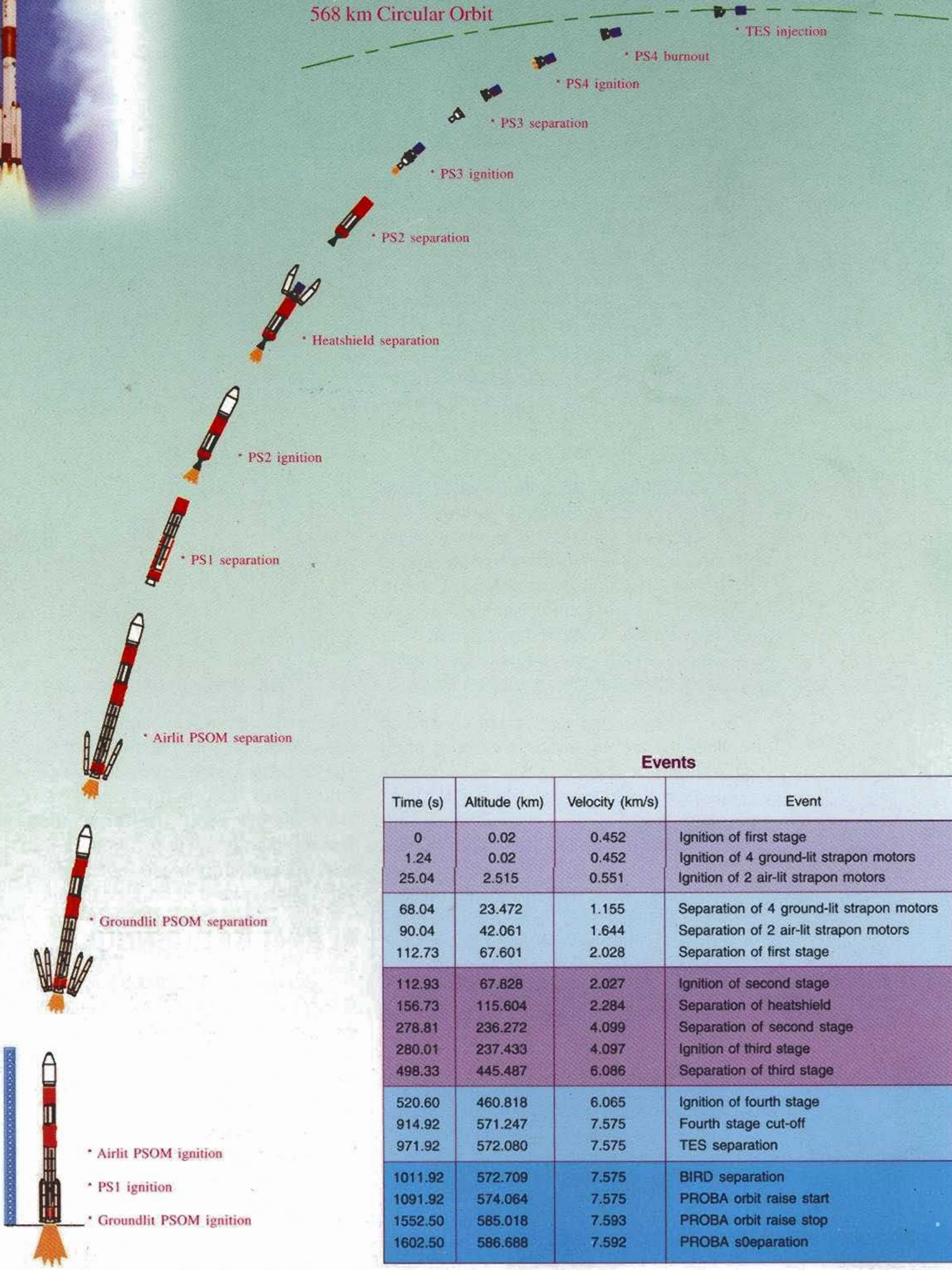


PSLV-C3 Payloads in HS Envelope

FLIGHT SEQUENCE

The overall flight sequence is given highlighting the planned time, altitude and inertial velocity at critical events. TES is separated with a relative velocity of about 1m/s, 57s af terPS4 thrustcut off on reaching desired injection conditions. BIRD is separated 40s later. PROBA is separated after an orbit raise manoeuvre. Both the satellites TES and BIRD are deployed in a 568 km circular orbit and PROBA in 568 X 638km elliptical orbit.

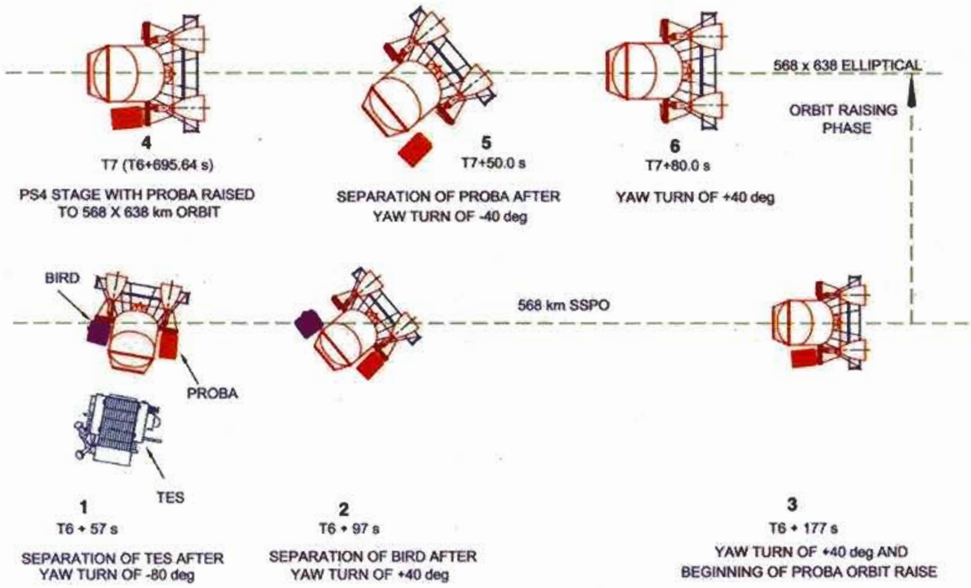
PSLV-C3 FLIGHT PROFILE



Events

Time (s)	Altitude (km)	Velocity (km/s)	Event
0	0.02	0.452	Ignition of first stage
1.24	0.02	0.452	Ignition of 4 ground-lit strapon motors
25.04	2.515	0.551	Ignition of 2 air-lit strapon motors
68.04	23.472	1.155	Separation of 4 ground-lit strapon motors
90.04	42.061	1.644	Separation of 2 air-lit strapon motors
112.73	67.601	2.028	Separation of first stage
112.93	67.828	2.027	Ignition of second stage
156.73	115.604	2.284	Separation of heatshield
278.81	236.272	4.099	Separation of second stage
280.01	237.433	4.097	Ignition of third stage
498.33	445.487	6.086	Separation of third stage
520.60	460.818	6.065	Ignition of fourth stage
914.92	571.247	7.575	Fourth stage cut-off
971.92	572.080	7.575	TES separation
1011.92	572.709	7.575	BIRD separation
1091.92	574.064	7.575	PROBA orbit raise start
1552.50	585.018	7.593	PROBA orbit raise stop
1602.50	586.688	7.592	PROBA s0eparation

PSLV - C3 MISSION



Separation Sequence of Spacecrafts in PSLV-C3

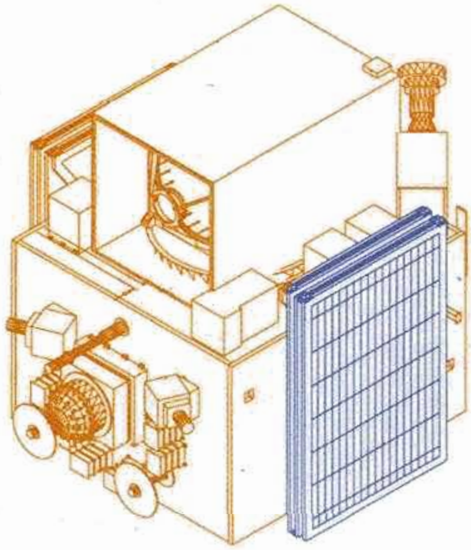
TES

The Technology Experiment Satellite (TES) built by ISRO Satellite Centre, Bangalore, has a bus similar to IRS-1C/1D incorporating a set of critical technologies. The technology improvements are in the areas of

- Attitude and orbit control
- RF systems (Phased Array Antenna)
- Reaction Wheels (with higher torque)
- Reaction Control System (single tank with 1N and 11N thruster configuration)
- Data Handling (indigenous Solid State Recorder)
- Payload (large size optics)

The Spacecraft mission objectives of TES is to provide for

- On-orbit demonstration of the above technologies.
- Validation of these technologies to enable their usage in future enhanced capability missions.
- Hands on experience in complex mission operations



TES in stowed configuration

PHYSICAL CHARACTERISTICS OF TES	
Mass	1110 kg
Shape	Cubical
Dimension in launch Configuration	1935x2650x2060mm (Ht.)
Solar Panel	9.636sq.m
Power	800W
Batteries	2x24 Ah. Ni-Cd Batteries

PROBA

PROBA, acronym for PROject for On Board Autonomy, is an ESA funded program with Verhaert Design and Development, Belgium as the prime contractor and Spacebel Informatique & SAS from Belgium, SSF from Finland, University of Cherbrooke of Canada as its subcontractors. The primary objective of this spacecraft is demonstration of onboard operational autonomy with focus on the following functions

- Scheduling, preparation and execution of scientific observations.
- Scientific data collection, storage and processing
- Data communication, management between PROBA scientific users and ground station
- Management of on-board resources and house-keeping functions
- Failure detection, reconfigurations and software exchange.

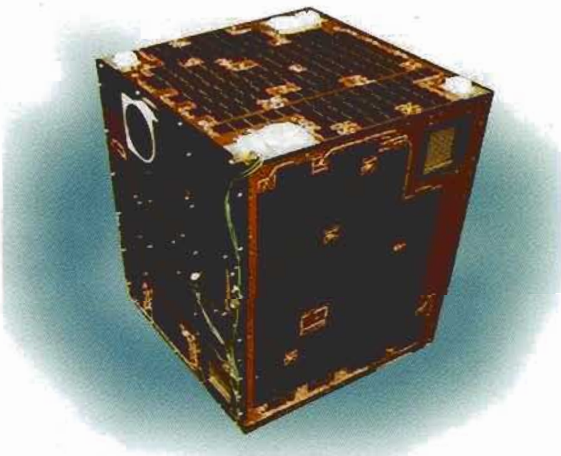
It also incorporates demonstration of new technology viz. Data handling (DHS) based on RISC processors (ERC-32) and Data processing using Temic's DSP (21020).

The onboard autonomy of PROBA is exercised in realistic scenarios through the accommodation of the following payload instruments.

- Main Imager - An earth Observation instrument CHRIS (Compact High Resolution Imaging Spectrometer) from SIRA Electro-Optics, U.K.
- Space Radiation Environment Monitoring (S-REM) from Contraves, Czech Republic to provide measurements of electron and proton influences and total radiation dose received by Spacecraft.
- Debris In-Orbit Evaluator (DEBIE) from Finnavitec, Finland to measure mass, impact speed and penetration power of dust environment around spacecraft.

Other payloads include

- A high resolution Camera from Verhaert D-D & OIP DSS, Belgium to provide 10m resolution images.
- *Star Tracker* from Astrium, U.K.
- A smart instrument bus
- Miniature radiation Monitor


PROBA spacecraft

PHYSICAL CHARACTERISTICS OF PROBA	
Mass	94 kg
Shape	Cuboidal
Dimension in launch Configuration	600x600x805 mm (Ht.)
Solar Panel	Body mounted Gallium Arsenide solar panels on five faces
Power	100W
Batteries	One 9 Ah. Lithium ion battery

The spacecraft structure is made of H-shaped aluminium honeycomb panels consisting of Payload board, BUS board and the AOCS board. Front, back , right and left boards form the outer structure with the top and bottom decks. It consists of a power system capable of delivering 100 W peak in sunlit and 30 W average in eclipse. The telecommunication system consists of 2 receivers and 2 transmitters operating in S-band mode with capacities of 4kbps for telecommanding and 1 Mbps for telemetry. The software used is more reactive and allows uplink of patches of even complete new software. One of the unique characteristics of the ground station system for PROBA is that it allows an authorised end user to transmit payload commands via the Internet server. The spacecraft is mounted on PPL deck along the vehicle P+ axis and will be separated by a ball lock mechanism which has a nominal diameter of 298 mm. The separation velocity imparted to the spacecraft will be of the order of 1m/s.

BIRD

BIRD, acronym for Bispectral and Infrared Remote Detection, is a milestone mission in the small satellite program of DLR, Germany to demonstrate the scientific and technological value and the programmatic feasibility of not yet space-proofed advanced technologies with a small satellite mission conception. The scientific and technological objective of the BIRD mission include

- Test of new generation of Infrared array sensors adapted to Earth remote sensing objectives by means of small satellites,
- Detection and scientific investigation of hot spots (forest fires, volcanoes etc.)
- Thematic on-board data processing
- Test of a neural network classificator in orbit.

It also has payload demonstration modules to obtain precise information about

- Leaf mass and photosynthesis for early diagnosis of vegetation condition & changes
- Real-time discrimination between smoke and water clouds
- Cloud analysis.

BIRD spacecraft

PHYSICAL CHARACTERISTICS OF BIRD

Mass	92 kg
Shape	Cuboidal
Dimension in launch Configuration	550x620x580 mm (Ht.)
Solar Panel	1 solar array (1 body mounted panel, 2 deployed panel)
Batteries	12 Ah. Ni-H2 batteries, 8 Nos.

TELEMETRY, TRACKING AND COMMAND SYSTEM

ONBOARD SYSTEMS

Telemetry

The Telemetry system for PSLV-C3 consists of two telemetry chains (1 chain with format switchover from 1 Mbps to 500 kbps after PS3 separation and 2nd chain with 500 kbps throughout the flight) operating in S-band with decentralized programmable PCM system as base band. 900 parameters telemetered for four stages include stage motor chamber pressure, control system pressures, vibration, temperature, acceleration, health monitoring of various onboard subsystems / components, navigation and guidance control processor health parameters and also navigation information. About 350 parameters are monitored redundantly.

Tracking

Major functional requirements of tracking systems for PSLV mission are :

- To track the vehicle from lift – off to satellite injection to determine instantaneous position and velocity.
- To compute instantaneous impact point accurately for range safety application.
- To give antenna pointing information to the other tracking antennas.
- Vehicle performance analysis and evaluation.
- For preliminary orbit determination (POD).

Keeping in view of all above, PSLV - C3 mission has been provided two C- band transponders (Non-coherent type) and one S- band range and range - rate transponder in the Equipment Bay.

Two C-band transponders operating in 5.4-5.9 GHz band are housed in EB to provide redundancy. Both transponders will respond upto a maximum PRF of 1171 Hz. C-band antenna is of loop type. The S-band Range and Range-Rate Transponder provides Range and Radial Velocity information using coherent system .

Ground stations

Ground stations network track the vehicle and acquire TM data during pre launch, launch and till 200s after PS4 thrust cut- off.

TTC support to PSLV-C3 is provided by a network of ground stations, SHAR-1, SHAR-2, Trivandrum, Mauritius, Bangalore and Lucknow, which acquire the telemetry data during various phases of launch and track the vehicle. Telemetry data to confirm POD of PROBA spacecraft launched in ellipticl orbit is received from onboard DSU at Lucknow during the first pass of spent PS4. POD (Preliminary Orbit Determination) for TES and BIRD spacecraft is determined by Mauritius Down Range Station. Trivandrum ground station provides the required space diversity for ensuring continuous telemetry data link. TTC support for spacecraft is provided by Bangalore, Lucknow and Mauritius. In addition, support from external stations such as Bears Lake , Biak and Weilheim are also taken for the TES operations in the initial phase. Data transmission between ground

stations is carried out through satellite links and partly through terrestrial links. ISRO Telemetry, Tracking and Command Network (ISTRAC) provides co-ordinated operations at the various ground stations.

Ground telecommand system at SHAR is used for sending flight termination command from Range Safety Officer (RSO) console for Range and flight safety in case of deviation of the vehicle from safe trajectory. Ground tracking support is provided by two coherent monopulse C-band radars located at SHAR in conjunction with two onboard C-band transponders as well as through satellite and vehicle Range and Range Rate Transponders (SRRT).

LAUNCH RANGE FACILITIES

The final vehicle and spacecraft preparations, checkout and launching of the vehicle are carried out at Launch base at Sriharikota Range (SHAR). The SHAR complex is ideally located at the east cost of India, 80km north east of Chennai (lat. 13.73 , long 80.24). The main elements of PSLV launch complex are the following.

- Mobile Service Tower (MST), Umbilical Tower (UT) & Launch pedestal.
- Preparation Facilities for solid motor, interstages, liquid propellant stages, heatshield and spacecrafts (SMPF, SSPF).
- Liquid propellant storage and transfer facility.
- Hardware storage facility for interstages
- Launch Control Centre (LCC) & Mission Control Centre (MCC)
- Range Instrumentation and support facility.

The vehicle is vertically integrated over the launch pedestal. The Umbilical Tower (UT) provides interface structure through which all the required fluid servicing lines and electrical checkout lines are attached to the vehicle. The 75m tall Mobile Service Tower (MST) is positioned around the launch pedestal and the UT. This provides access and protective enclosure during the vehicle integration. It also houses handling systems and ensures clean environment for the vehicle and satellite. The tower is moved on a rail system to a safe distance of 100m before vehicle lift - off.

Located 5km away from the launch pad, the LCC has facilities for the remote checkout and launch of the vehicle. The LCC houses all the vehicle control consoles, filling consoles as well as checkout and automatic launch systems. It is connected to the launch pad through fibre optic data links communicating in real time to computers as well as specialist's consoles in the appropriate format.

The MCC located adjacent to LCC has consoles for the mission executives who authorise the launch based on readiness of all the systems. The vehicle performance is graphically depicted in large display boards in real time. The range safety console is manned by the Range Safety Officer who is authorised to terminate the flight in case of vehicle malfunction or gross deviation in trajectory.

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