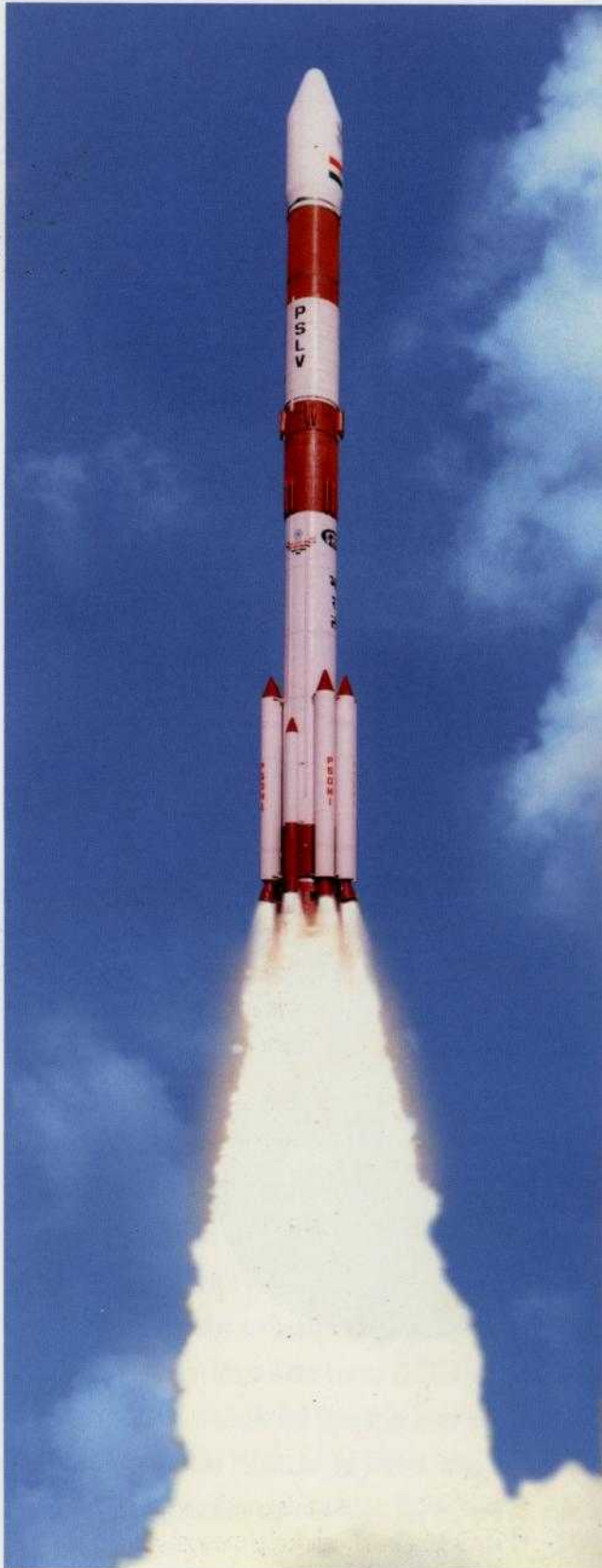




PSLV-C2 MISSION



INTRODUCTION

The C2 mission is the second operational flight of PSLV to deploy the Indian Remote Sensing Satellite IRS-P4 which is dedicated for ocean study. To exploit the spare payload capacity in this flight, two auxiliary satellites are also carried onboard in piggy back mode. These are injected into the same orbit as the primary satellite soon after the primary satellite separation. Special interface provisions are created on the vehicle to mount these satellites and separate them at the appropriate time.

MISSION OBJECTIVES

- Launch the Indian Remote Sensing Satellite-OCEANSAT-1 (IRS-P4) weighing 1050 kg into sunsynchronous polar orbit.
- Deliver the two auxiliary experimental satellites 110kg KITSAT-3 from South Korea and 45kg DLR-TUBSAT from Germany into the same orbit.

MISSION SPECIFICATIONS

The mission specifications are tailored to meet IRS-P4 requirements

Orbit	- Sun synchronous Polar orbit (SSPO)
Altitude	- 727 ± 35 km
Inclination	- 98.286 ± 0.2 deg.
Orbital Period	- 99.310 min
Launch time	- Between 11-40 and 11-50 Hrs. IST
Launch Azimuth	- 140 deg.

CONTRIBUTING ISRO ENTITIES

Vikram Sarabhai Space
Centre (VSSC),
Thiruvananthapuram

Launch vehicle design, realisation of
subsystems, mission planning,
Project management, Integration
and checkout

Liquid Propulsion Systems Centre
(LPSC) Valiamala, Mahendragiri
and Bangalore

Design, Realisation and testing of Liquid
propulsion systems and
control power plants for
launcher and spacecraft

ISRO Inertial Systems Unit (IISU)
Thiruvananthapuram

Realisation of Inertial
Navigation Systems for
Launch vehicle
and Satellite

Launch Vehicle Programme
Office (LVPO), ISRO
Headquarters, Bangalore

Launch Vehicle Programme
Planning & Customer Coordination

ISRO Telemetry
Tracking and Command Network
(ISTRAC) Bangalore, SHAR
and Thiruvananthapuram

Telemetry and tracking support
for the mission

PSLV-C2 / IRS-P4 MISSION

National Remote Sensing
Agency (NRSA), Hyderabad

Generation & Marketing of
Remote Sensing Products

Space Applications Centre (SAC),
Ahmedabad

Realisation of satellite payloads

Sriharikota Range (SHAR)
Sriharikota, Andhrapradesh

Manufacture and testing of
large solid propellant boosters.
Vehicle assembly and launch operation,
range instrumentation and safety.

ISRO Satellite Centre (ISAC),
Bangalore

Design, Realisation, Intergration and
testing of IRS-P4 satellite

LAUNCH VEHICLE

The Polar Satellite Launch Vehicle entered its operational phase with the successful launching of IRS-ID into 817 km SSPO through PSLV-C1. The vehicle configuration for PSLV-C2 is essentially same as PSLV-C1. The four stage Polar Satellite Launch Vehicle (PSLV) is developed primarily for deploying remote sensing satellites 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. A 2.8m diameter core motor and six 1.0 m diameter strapon motors (PSOMs) constitute the first stage. Four of the strapons are ignited on ground while the remaining two are ignited in flight considering the requirement of maximising payload and limiting the vehicle loads during flight. The core motor case is made of high strength steel and carries 138t solid propellant. The second stage carries 40t of propellant (Unsymmetrical Dimethyl Hydrazine & Nitrogen tetroxide) in an aluminium tank with a common bulkhead and powered by the 'Vikas' engine. The third stage using composite motor case carries 7.3t of solid propellant. It has a contoured and submerged nozzle. The fourth stage uses 2t of propellants (Mixed oxides of Nitrogen & Monomethyl hydrazine) and has two high performance pressurefed engines.

An Inertial Navigation and Guidance System (IGS) in the Vehicle Equipment Bay (VEB) 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 Heat Shield separation. The three axes attitude stabilisation of the vehicle is achieved by the autonomous control system provided in each stage. The first stage is provided 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 Reaction Control Module (HRCM) for roll control. The third stage has Flex Nozzle Control (FNC) for pitch and yaw during the thrust phase. The fourth stage is controlled during thrust phase by gimbaling 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.

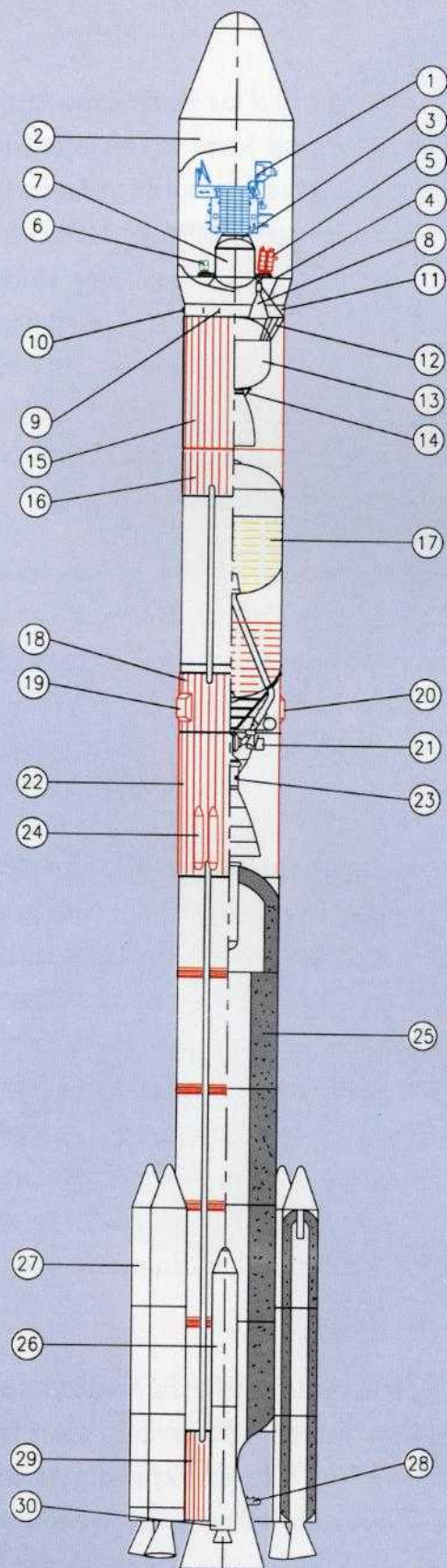
A bulbous aluminium alloy heat shield of 3.2m diameter protects the spacecraft against the hostile flight environment during ascent phase and is jettisoned at an altitude of 120 km using a pyrotechnic based linear bellow mechanism. The vehicle is provided with various stage separation systems to discard 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 sever the interstage structure and the jettisoning is achieved by eight retro rockets. Ullage rockets ensure the positive acceleration of the vehicle during stage separation to enable start up of the liquid engine of the second stage. The second stage separation is based on Merman band and jettisoning is by a set of four retro rockets. The third stage separation is through 'Ball lock' mechanism and springs while fourth stage uses Merman band with helical compression springs for imparting separation velocity.

In PSLV-C2, the layout of the Vehicle Equipment Bay has been modified and the Honeycomb deck plate beefed up to carry two auxiliary satellites at P+ and P- locations. Separation system based on 'Ball lock' mechanism are employed for the jettisoning of these satellites.

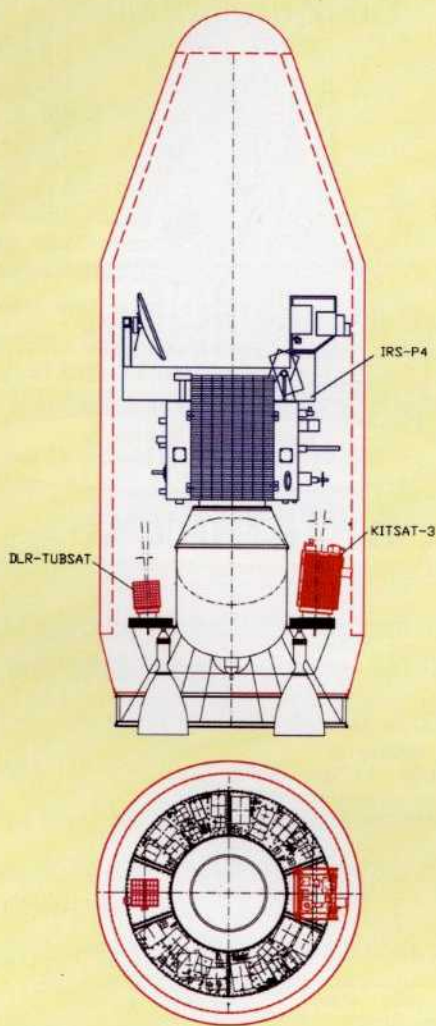


VEHICLE CONFIGURATION



1. IRS-P4 SATELLITE
2. HEATSHIELD
3. PAYLOAD ADAPTOR
4. EQUIPMENT BAY
5. KITSAT-3
6. DLR-TUBSAT
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)

Height of vehicle - 44.4m
Lift Off mass - 294t



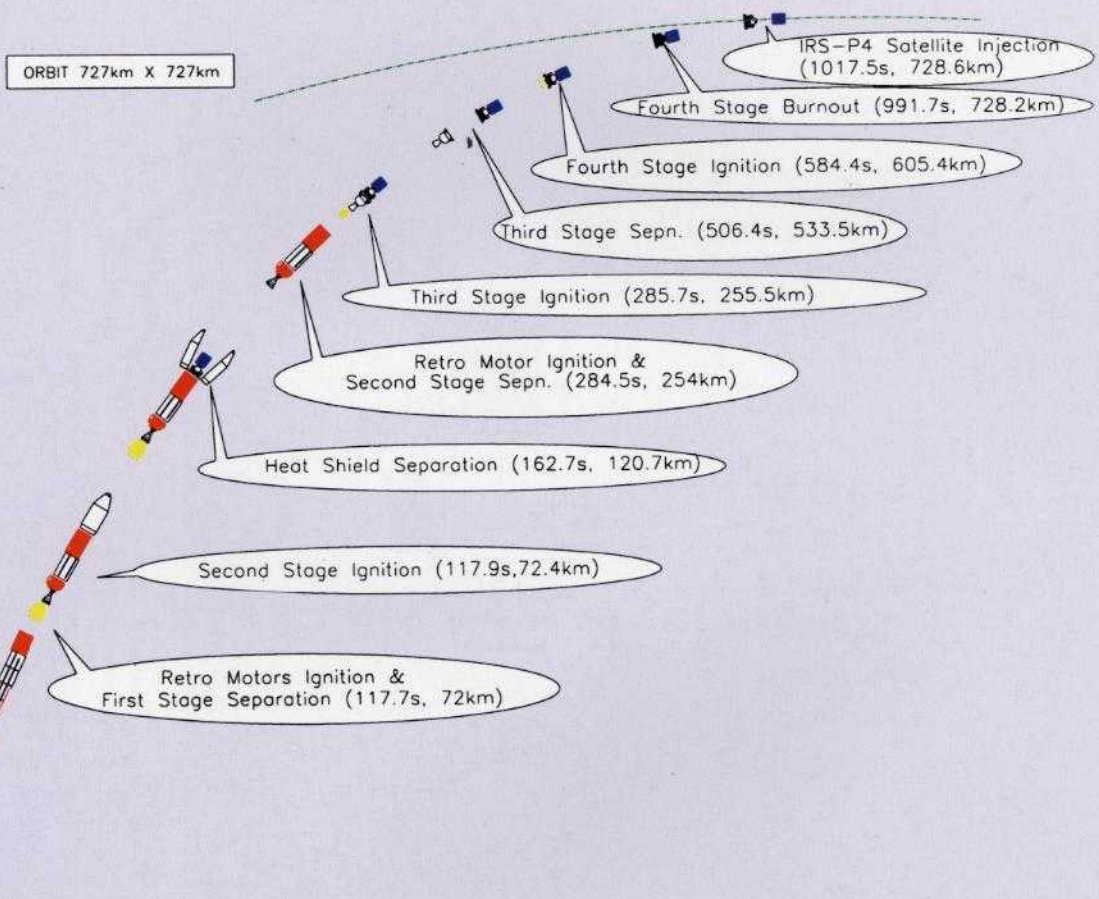
IRS P-4, KITSAT-3 and
DLR-TUBSAT in PSLV - C2 Payload Envelope

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 hardware provided onboard, enable flight termination in case of an errant flight.

FLIGHT SEQUENCE

The overall flight sequence is given overleaf highlighting the planned time, altitude and inertial velocity at critical events. However some of the events are decided onboard and the actual time of occurrence can vary accordingly. IRS-P4 is separated with a relative separation velocity of 1.14m/s, 50s after PS4 thrust cut off on reaching desired injection conditions. 50s later and after a yaw manoeuvre of 40 deg, the KITSAT is separated. TUBSAT is separated after 50s and after another yaw manoeuvre of 40 deg in the same direction. Both the satellites are jettisoned with a velocity of 1m/s. The selected sequence, the manoeuvre and the velocities ensure the collision free separation of all the satellites from the vehicle and eliminate possibility of subsequent recontact.

PSLV-C2 FLIGHT PROFILE



ORBIT 727km X 727km

IRS-P4 Satellite Injection (1017.5s, 728.6km)

Fourth Stage Burnout (991.7s, 728.2km)

Fourth Stage Ignition (584.4s, 605.4km)

Third Stage Sepn. (506.4s, 533.5km)

Third Stage Ignition (285.7s, 255.5km)

Retro Motor Ignition & Second Stage Sepn. (284.5s, 254km)

Heat Shield Separation (162.7s, 120.7km)

Second Stage Ignition (117.9s, 72.4km)

Retro Motors Ignition & First Stage Separation (117.7s, 72km)

Airlit Strapon Separation (90s, 40km)

Events

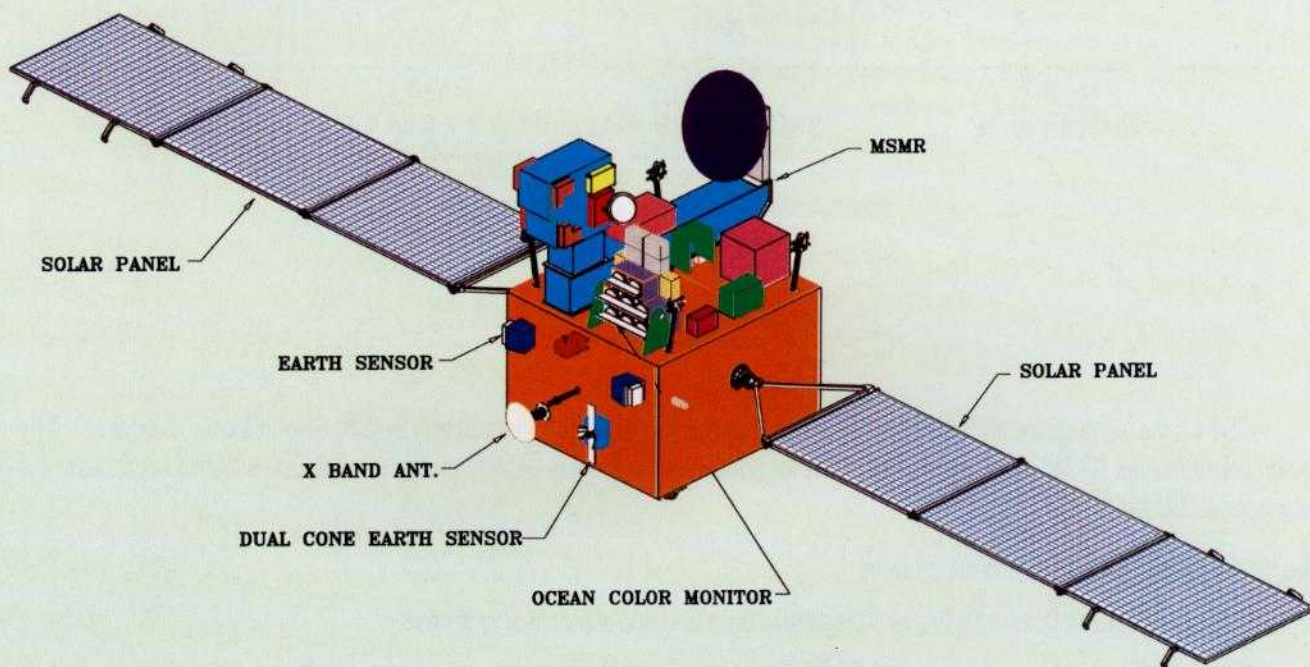
Time(s)	Altitude (km)	Velocity (km/s)	Event
0	0.02	0.45	Ignition of first stage
1.2	0.02	0.45	Ignition of 4 ground - lit strapon motors
25.1	2.43	0.54	Ignition of 2 air-lit strapon motors
68.1	23.10	1.10	Separation of 4 ground - lit strapon motors
90.1	40.21	1.52	Separation of 2 air - lit strapon motors
117.7	72.08	1.97	Separation of first stage
117.9	72.38	1.97	Ignition of second stage
162.7	120.71	2.21	Separation of heatshield
167.7	126.60	2.26	Closed Loop Guidance initiation
284.5	254.03	4.07	Separation of Second Stage
285.7	255.46	4.06	Ignition of third stage
506.4	533.57	5.97	Separation of third stage
584.4	605.44	5.87	Ignition of fourth stage
991.7	728.25	7.49	Fourth stage thrust cut - off
1017.5	728.66	7.49	IRS-P4 Satellite separation
1067.5	729.51	7.49	KITSAT Separation
1117.5	730.41	7.49	TUBSAT Separation

Groundlit Strapons Separation (68s, 23km)

Two airlit Strapon Motors Ignition (25s, 2.5km)

Lift off with First Stage & Four Strapon Motors Ignition





DEPLOYED CONFIGURATION OF IRS-P4 SPACECRAFT

PASSENGER PAYLOADS

KITSAT - 3

KITSAT-3 developed by Korea Advanced Institute of Science & Technology (KAIST), South Korea is the third experimental micro satellite realised by KAIST. The objective of the mission is to develop and test the following basic micro satellite technologies.

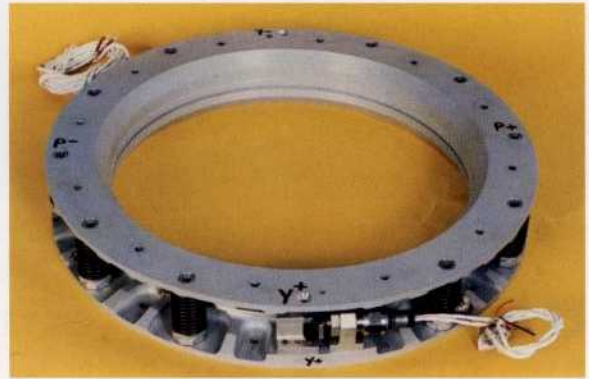
- ❖ 3 axis stabilised attitude control
- ❖ Common bus architecture
- ❖ Solar panel deployment
- ❖ High speed data transmission
- ❖ Solid state data storage

Salient features of the satellite are

- Weight - 110 kg
- Dimensions - 495x604 x 852(H) mm
- Power - Maximum 180 w, Deployable solar panels
- Attitude Control - 3 axis stabilised attitude control with star sensors, fibre optic gyros, magnetorquers and reaction wheels

- Payloads
 - Remote sensing payload
15m Ground Resolution, 3 channel Linear CCD Camera

 - Space Science payloads
Radiation effects on Micro electronics
High Energy particle Telescope
Scientific Magnetometer
Electron Temperature Probe
- Separation System - 358mm dia, ISRO Ball lock system



KITSAT - 3 separation system



KITSAT - 3



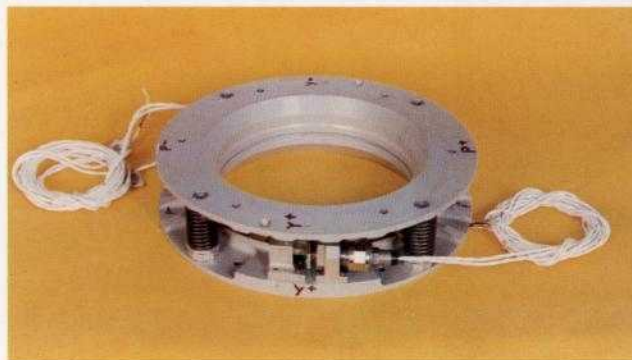


DLR-TUBSAT

DLR-TUBSAT is a joint project of the DLR Institute of Space Sensor technology and the Technical University of Berlin, Germany. The micro satellite is mainly used to carryout tests involving exact three axes attitude control and to qualify different subsystems with regard to their tasks in target pointing and high resolution earth observation.

The DLR-TUBSAT has a cubic shaped structure and consists of four aluminium shells to housepackages including payloads and sensors. The salient features of the satellite are

- Mass - 45 kg
- Dimensions - 320 x 320 x 320mm
- Payloads - Three digital cameras with 16mm and 50mm wide angle lens and 1000mm tele bus
- Power - Body mounted solar panels
- Attitude Control - 3 reaction wheels, 3 fibre optic laser gyros, 3 axis star sensor
- Battery - 4Nos of NiH2 cells with 12 AH capacity each
- Separation System - 230mm dia, ISRO Ball lock system



TUBSAT Separation System



DLR - TUBSAT

TELEMETRY, TELECOMMAND AND TRACKING SYSTEMS

Ground systems and Ground stations play a very important role in confirmation of the mission success, ensuring Range and Flight Safety and Post flight data analysis. Telemetry Tracking and Telecommand (TTC) support to PSLV is provided by the following network of ground stations which track the vehicle and acquire the telemetry data during launch.

SHAR-1 ❖ SHAR-2 ❖ THIRUVANANTHAPURAM ❖ MAURITIUS ❖ BANGALORE

During launch phase, Sriharikota, Thiruvananthapuram, Bangalore and Mauritius ground stations are configured to receive vehicle and satellite telemetry signals. SHAR has Telemetry Tracking & Telecommand facilities and with its redundant configuration, cater to the launch phase upto 680 seconds. Mauritius Down range station can track the vehicle from 700 seconds till 200 seconds after burnout of the fourth stage. Thiruvananthapuram 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 Bearslake, Biak and Welheim are also taken for the spacecraft operations in the initial phase.

Telecommand system at SHAR is used for Range and Flight safety and to enable flight termination in case of deviation of the vehicle from

the safe trajectory. Tracking is provided by two Precision Coherent Monopulse C-Band Radars (PCMC-1 & PCMC-2) located at SHAR and one PCMC-3 Radar located at Mauritius in conjunction with two onboard C-band transponders as well as through Satellite Range and Range Rate Transponder (SRRT).

Real time data processing support is provided by ground stations for Range Safety, Data display at the consoles at MCC, Preliminary Orbit Determination (POD) and Quick Look Data (QLD) analysis. TTC ground stations are linked with each other through dedicated data links. The data transmission between ground stations is largely carried out through satellite links and

partially through dedicated terrestrial links. The ISRO Telemetry Tracking and Command network (ISTRAC) ensures the co-ordinated operation of the various ground stations and provide the necessary services during the mission.



LAUNCH RANGE FACILITIES

The final vehicle and spacecraft preparations, integration, checkout and the launching of the vehicle are carried out at Launch base at Sriharikota Range (SHAR). The SHAR complex located at 80km north east of Chennai (lat. 13. 73, long. 80.24) is ideally located at the east coast of India. The main elements of PSLV launch complex are the following.

- ❖ Mobile Service Tower (MST), Umbilical Tower (UT) & Launch pedestal
- ❖ Solid Motor Preparation facility
- ❖ Subsystem preparation facility for all interstages, liquid propellant stages, heatshield and spacecrafts
- ❖ 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 which is located above the jet deflector and the two exhaust ducts enable smooth flow of the exhaust gases. 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 and 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 specialists' 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 vehicle in case of vehicle malfunction which can pose danger to men and materials on ground. The major range Instrumentation and support facilities are

- ❖ Tracking systems like Precision 'C' band and 'S' band Radars
- ❖ Telecommand System
- ❖ Support System like Intercommunication, Closed circuit TV System, Data Links, Range Timing System, Real Time Systems and Specialist display System; and
- ❖ Metereology and Technical photography

PSLV on Pad with MST withdrawn

