April-June 2001

SPACE india

GSLV-D1 LAUNCHED SUCCESSFULLY

INDIAN SPACE RESEARCH ORGANISATION

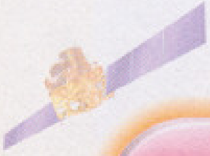
The Indian Space Programme

The setting up of the ThumbaEquatorial Rocket Launching Station (TERLS) in 1963 marked the beginning of the Indian Space Programme. The Space Commission and the Department of Space (DOS) were established by the Government of India in 1972 to promote unified development and application of space science and technology for identified national objectives.

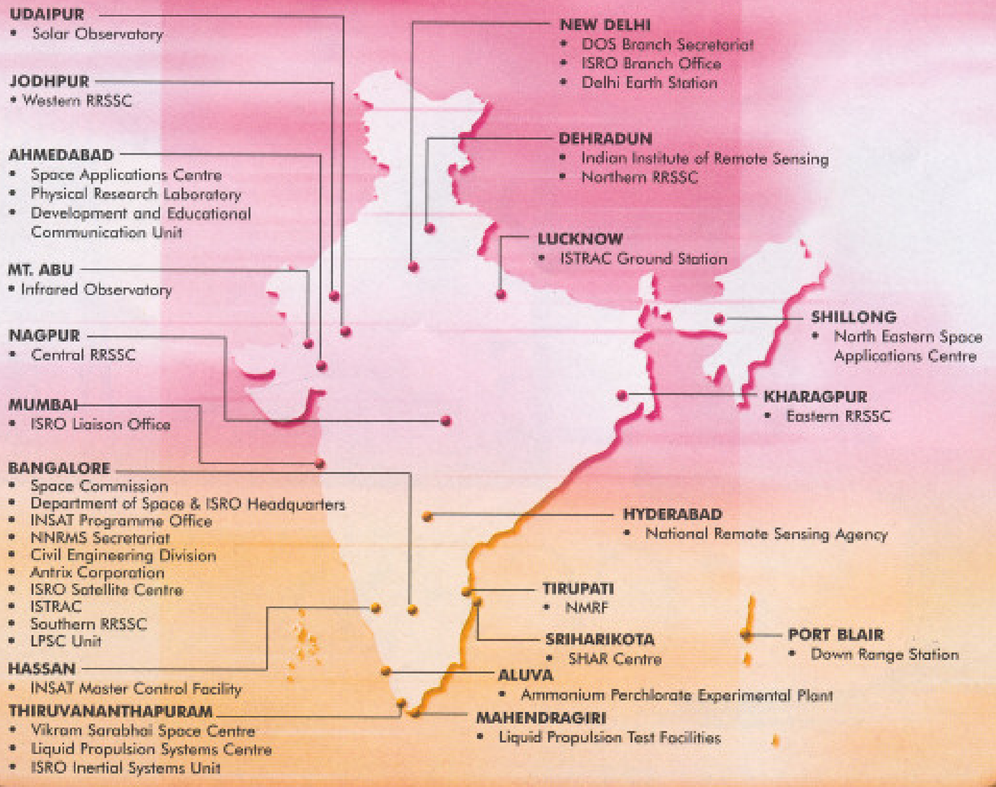
The Indian Space Programme is directed towards the goal of self reliant use of space technology for national development, its main thrusts being (a) satellite communications for various applications, (b) satellite remote sensing for resources survey and management, environmental monitoring and meteorological services and (c) development and operationalisation of indigenous satellite and launch vehicles for providing these space services.

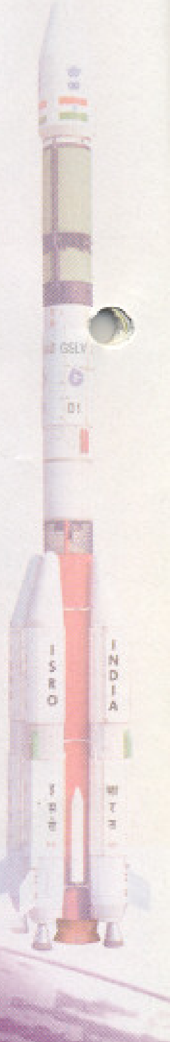
The Indian Space Research Organisation (ISRO) is the research and development wing of DOS and is responsible for the execution of the national space programme. ISRO also provides support to universities and other academic institutions in the country for research and development projects relevant to the country's space programme.

Both the DOS and ISRO Headquarters are located at Bangalore. The development activities are carried out at the Centres and Units spread over the country.



SPACE CENTRES AND UNITS IN INDIA





SPACE india

April - June 2001

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Editorial / Circulation Office

Publications & Public Relations Unit,
ISRO Headquarters, Antariksh
Bhavan, New BEL Road,
Bangalore - 560 094, India.
www.isro.org

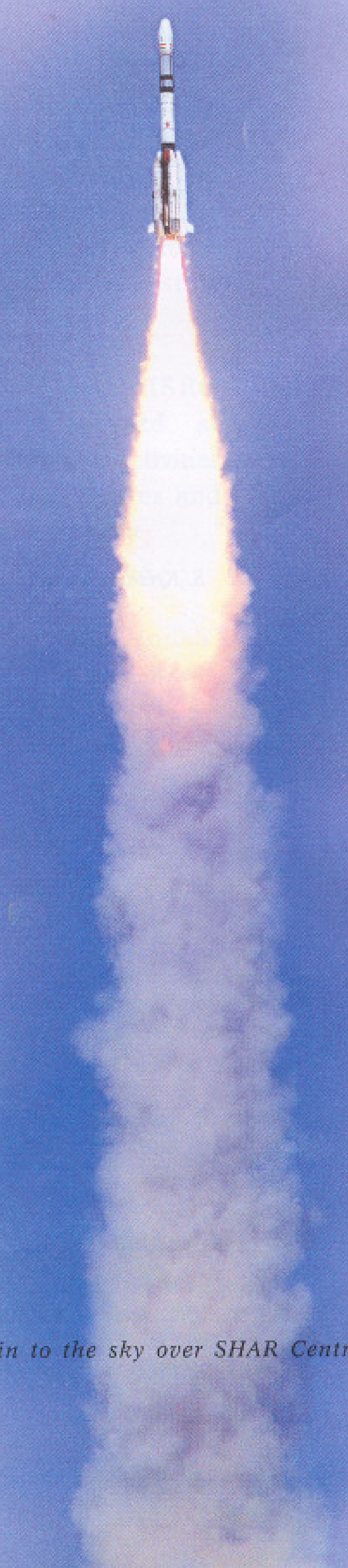
Printed at Carto Prints, Bangalore.

GSLV LAUNCHED SUCCESSFULLY

ISRO successfully carried out the first developmental test flight of its Geosynchronous Satellite Launch Vehicle, GSLV, on April 18, 2001 from SHAR Centre, Sriharikota, about 100 km north of Chennai. The launch marked a major milestone as it clearly demonstrated the capability of ISRO to launch communication satellites into geo-stationary transfer orbit. ISRO has already commissioned a Polar Satellite Launch Vehicle, PSLV, that can place about 1200 kg class satellites in 820 km high polar orbit.

The 401 tonne, 49 m tall GSLV, carrying a 1540 kg experimental satellite, GSAT-1, lifted off at 3-43 pm Indian Standard Time. About seventeen minutes later, GSAT-1 was placed in an orbit of 182.4 km perigee and an apogee 32140.6 km with the orbit inclination of 19.3 degree. As the count down for the launch proceeded, at 4.6 seconds before the count zero, the four liquid propulsion strap on stages were ignited and, after making sure that the strap-on motors were developing the specified thrust, the solid propellant first stage core motor was ignited at count zero and GSLV blazed into the afternoon sky. The first stage burned for 100 seconds while the liquid propulsion strap on stages continued thrusting up to 162 seconds from lift-off taking the vehicle to an altitude of 75 km. At the end of the first stage burn out, GSLV had reached a velocity of 2.63 km per second.

The second stage ignited 1.6 seconds before the burn out of the strap-on motors. The second stage burned for 147 seconds taking the vehicle to an altitude of 126 km and increasing its velocity to 5.18 km per second. The heat shield that protected the spacecraft from the aerodynamic heating during its flight through the dense atmosphere was discarded when the vehicle was at an altitude of 116 km. After the separation of the second stage at



GSLV soaring in to the sky over SHAR Centre, Sriharikota.

314 seconds, the cryogenic upper stage was ignited and burned for 693 seconds taking the satellite and vehicle equipment bay to an altitude of 195 km and increasing the velocity to 10.17 km per second. The stage was separated from the spacecraft at about 1036 seconds at an altitude of 202 km and the satellite was placed in the geo-stationary transfer orbit.

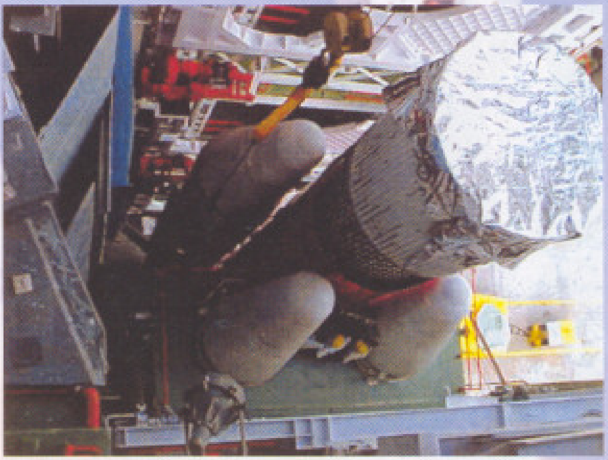
All through the flight, the vehicle was guided by the inertial navigation and guidance systems. The performance data of the GSLV was telemetered to the ground stations at Sriharikota, Port Blair in India and stations at Brunie and Biak in Indonesia that were networked with SHAR Centre.


Integration of GSLV Core stage segments.

The preliminary analysis of the flight data indicates that GSLV performed well in flight validating the design and functioning of all the vehicle subsystems, the integration procedures including the safe handling of liquid and cryogenic propellants, the navigation and control, the flight sequence including ignition of various stages, separation of spent stages and the heat-shield besides the coordinated working of a network of ground stations to track and monitor the vehicle in flight. Detailed analysis of the data will be carried out in the coming weeks, the design margins will be more realistically estimated and further improvements to the vehicle will be effected wherever required before the next developmental test flight is attempted.

With a few upgradation like operating the liquid propulsion strap-on stages at a higher pressure level, increasing the propellant in the solid core stage from the present 129 tonne to 138 tonne, GSLV can launch upto 1800 kg satellite. Later, when the third stage is replaced by the indigenously developed cryogenic stage, it can launch upto 2000 kg payload into GTO.

One of the strap-on motors being transported to the Launch Pad.



Integration of GSLV first stage.

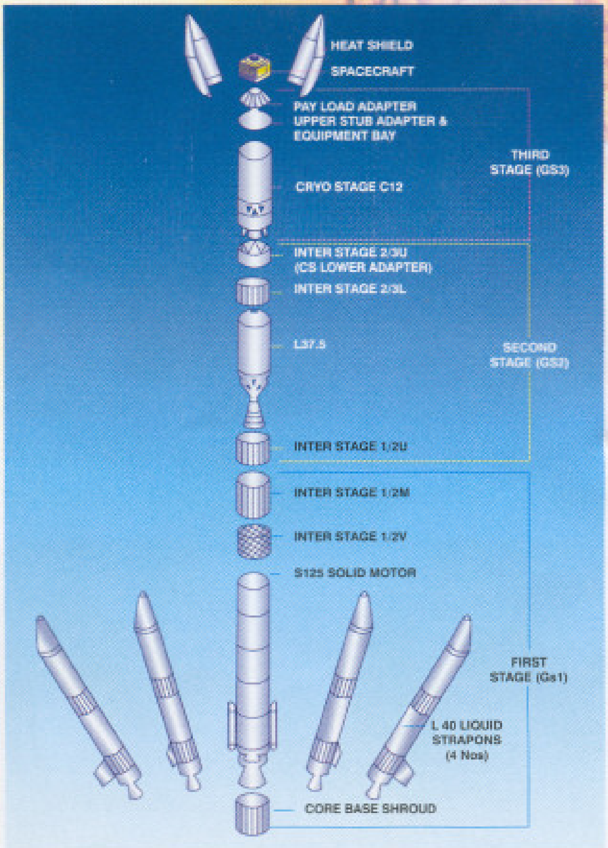
GSLV will be commissioned into service after another one or two developmental flights.

GSLV Development

ISRO initiated the development of GSLV in 1990. In its present configuration, it is a three-stage vehicle, 49 m tall and weighing 401 tonne at lift-off. The vehicle uses some of the systems that have been flight proven in ISRO's Polar Satellite Launch Vehicle, PSLV - the solid propellant first stage motor and the liquid propellant second stage motors of PSLV are used in the first and second stages of GSLV respectively. The four liquid strap-on motors are also derived from the PSLV second stage.

The first stage of GSLV comprises a solid propellant motor (S125) and four liquid propellant strap-on motors (L40). S125 stage is 20.3 m long and 2.8 m in diameter. Its motor case is made of high strength steel. It carries 129 tonne of Hydroxyl Terminated Poly Butadiene (HTPB) based solid propellant. The stage develops about 4700 kilo Newton thrust and burns for 100 seconds. The four strap-on (L40) stages are 19.70 m long and 2.1 m in diameter and they are fabricated using aluminum alloy. Each of them is loaded with 40 tonne of hypergolic propellants, namely, Unsymmetrical Di-Methyl Hydrazine (UDMH) as fuel and Nitrogen Tetroxide (N_2O_4) as oxidizer, stored in two tanks mounted in tandem.

The second stage of GSLV is 11.6 m long and 2.8 m diameter. It is loaded with 37.5 tonne of UDMH and N_2O_4 in two compartments of an aluminum alloy tank separated by a thin metal sheet known as common bulkhead. The engines used for the strap-on motors and the second stage are similar and employ a turbo-pump fed engine producing a thrust of about 700 kilo Newton in vacuum. The third stage of GSLV uses a Cryogenic Stage (CS) which is procured from Glavkosmos, Russia. The stage, that employs liquid hydrogen and liquid oxygen as fuel and oxidizer respectively, is 8.7 m long and 2.9 m in diameter. Liquid hydrogen (LH) and liquid oxygen (LOX) are stored in two separate aluminum alloy tanks connected by an inter-stage structure. With a propellant loading of 12.5 tonne, the stage can burn for duration of about 750 second producing a nominal thrust of 75 kilo Newton.

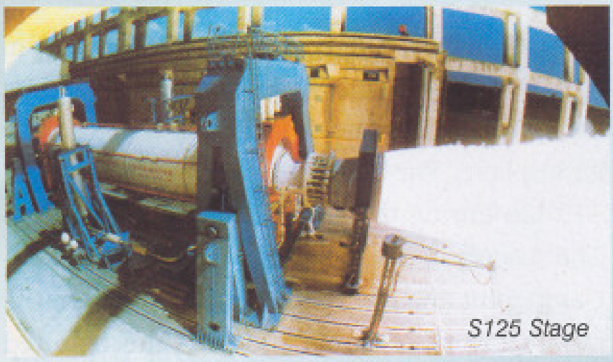


Disassembled view of GSLV.

Interstage structures which connect the different stages of GSLV also houses the avionics and control systems of the lower stage.

GSLV at a Glance

FIRST STAGE


S125 Stage

SALIENT FEATURES

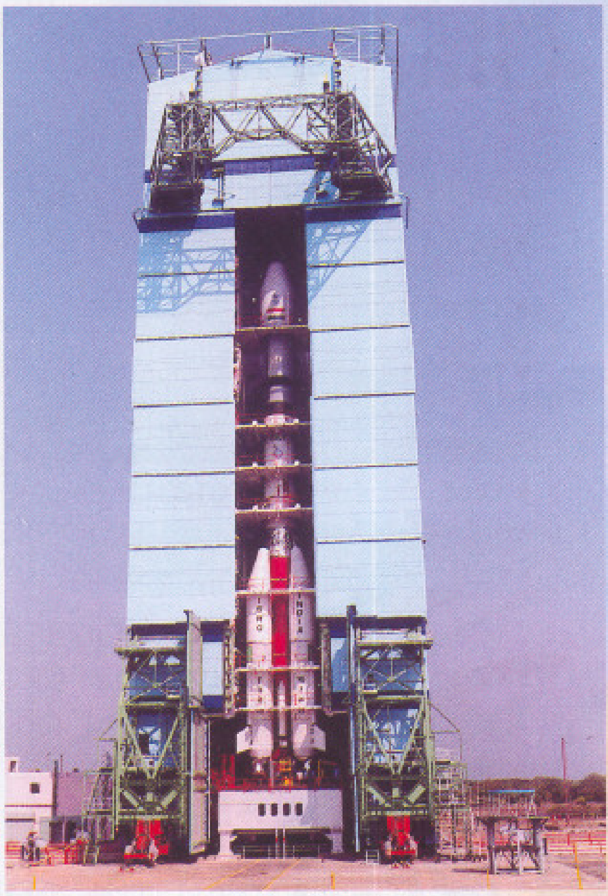
Overall length (m)	49
Lift-off weight (t)	401
No. of stages	3
Payload	GSAT-1
Orbit	GTO

SECOND STAGE

THIRD STAGE

PROPULSIVE STAGES

Parameter	GS 1 Stage (First Stage)		GS 2 stage	GS 3 stage (Third stage)
	S125 booster	L40 strapon		
Length (m)	20.3	19.7	11.6	8.7
Dia (m)	2.8	2.1	2.8	2.8
Total mass (t)	156	46	42.8	15
Propellant mass (t)	129	40	38	12.5
Case/Tank material	M250 steel	Aluminium Alloy	Aluminium Alloy	Aluminium Alloy
Propellant	HTPB	UDMH & N_2O_4	UDMH & N_2O_4	LH2 & LOX
Burn time (s)	100	160	150	720
Max. Vac. Thrust (kN)	4700	680	720	73.5
Specific impulse (Ns/kg)	2610	2750	2890	4510
Control system	Multi-port SITVC	EGC single plane gimballing	EGC two plane gimballing for pitch & yaw control. Hot gas RCS for roll control.	2 steering engines for thrust phase control & cold gas RCS for coast phase control.



GSLV fully assembled inside the mobile service tower.

The vented inter-stage between the first and second stage, enables the firing of the second stage even while the first stage has just completed its thrusting action. This design avoids use of additional systems needed to provide sufficient acceleration between the time before the ignition of second stage takes place and sufficient reduction in velocity of the first stage. The core first stage, along with the four strap on motors, is separated from the rest of the vehicle using a flexible linear shaped charge (FLSC) that severs the connection between first and second stages.

The vehicle equipment bay which houses the vehicle electronic systems like processors, navigation system, control system, guidance system, telemetry system, telecommand system, etc, is placed above the cryogenic stage. The spacecraft is mounted on the equipment bay through a payload adapter and separation system.

The heat-shield, which is 7.8 m long and 3.4 m in diameter, protects the vehicle electronics and the spacecraft during the flight through the atmosphere. The heat-shield is discarded at about 110 km during the second stage thrust phase. The spacecraft is separated by opening the band-clamp joint and the springs attached within the separation system that provides the required separation velocity to the satellite. The system is designed to ensure that no collision occurs between the spent third stage and the spacecraft.

The Redundant Strap Down Inertial Navigation System/Inertial Guidance System (RESINS/IGS), which is housed in the equipment bay computes the inertial position and velocity and guides the vehicle from lift-off to spacecraft injection. The digital auto-pilot and closed-loop guidance scheme resident in the on-board computer ensures the required attitude maneuver and guided injection of the spacecraft into the specified orbit.

The vehicle performance is monitored with extensive instrumentation. The performance data is transmitted via telemetry systems to the ground station. In addition to the performance parameters, the inertial position of the vehicle and its orientation are computed by the vehicle inertial system and computers, which are also transmitted via the telemetry to the ground stations. A telecommand system is used to terminate the flight in case the vehicle deviates from its flight path beyond the specified safety limits.

GSLV-D1 Performance

S.No.	Parameters	Specification	Achieved
1.	Perigee (km)	180±5	182.4
2.	Apogee (km)	35975±675	32140.6
3.	Inclination (deg)	19.3±0.1	19.3

A C-band transponder on board the vehicle helps in tracking it from ground based radars. The complete telemetry and tracking coverage of the vehicle from lift-off to satellite injection will be provided by four ground stations located at SHAR Centre, Sriharikota, the down range stations at Port Blair, Brunei and Biak in Indonesia. All these stations are networked with the SHAR Centre during launch to provide data in real time.

GSLV Project costed Rs 1,405 Crore, which included several developmental efforts like characterisation of vehicle, mission design and simulation, development of strap-ons, vented interstage between first and second stage, qualification of guidance control elements, cost of procuring cryogenic stages from Russia and development of electronics that interfaced with cryogenic propulsion module besides fabrication of three vehicles.

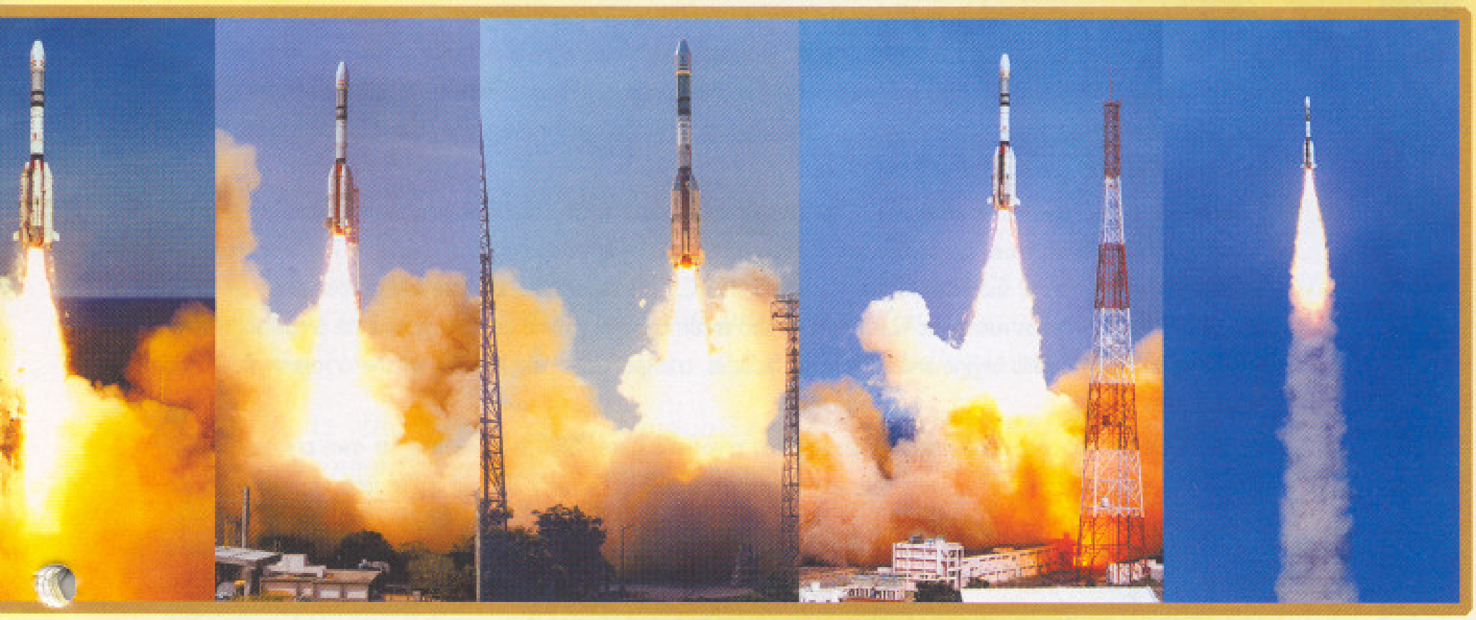
GSLV is the culmination of efforts of a large number of scientists, engineers and technicians, over the last ten years. It heralds a significant milestone towards the establishment of indigenous capability for launching communication satellites like INSAT. Having already established indigenous capability for launching IRS class of remote sensing satellites through PSLV, the launch of GSLV, makes the Indian space programme even more self-reliant while tuning the programme towards national development.

Indian Launches

Vehicle	Launch Dates	Result
SLV-3 E1	August 10, 1979	Partially successful. A jammed valve in the second stage control system resulted in the leak of oxidiser.
SLV-3 E2	July 18, 1980	Successful
SLV-3 D1	May 31, 1981	Successful
SLV-3 D2	April 17, 1983	Successful
ASLV-D1	March 24, 1987	Unsuccessful due to non-ignition of first stage
ASLV-D2	July 13, 1988	Unsuccessful . The flight was normal only up to 46 seconds after lift off
ASLV-D3	May 20, 1992	Successful
PSLV-D1	September 20, 1993	Unsuccessful due to software error on board guidance and control processor
ASLV-D4	May 4, 1994	Successful
PSLV-D2	October 15, 1994	Successful
PSLV-D3	March 21, 1996	Successful
PSLV-C1	September 29, 1997	Successful
PSLV-C2	May 26, 1999	Successful
GSLV-D1	April 18, 2001	Successful

GSLV

Worth its weight in gold! Dr. K. Kasturirangan, Chairman, ISRO (Right) presenting a model of GSLV to Prime Minister Mr. Atal Bihari Vajpayee.



lifts off...

Prime Minister Mr. Atal Bihari Vajpayee with Dr. K. Kasturirangan, Chairman, ISRO (third from right) and his ISRO team. Mrs. Vasundhara Raje, Minister of State (Space) and Mr. Brajesh Mishra, Principal Secretary to PM (Second from right) are also seen.

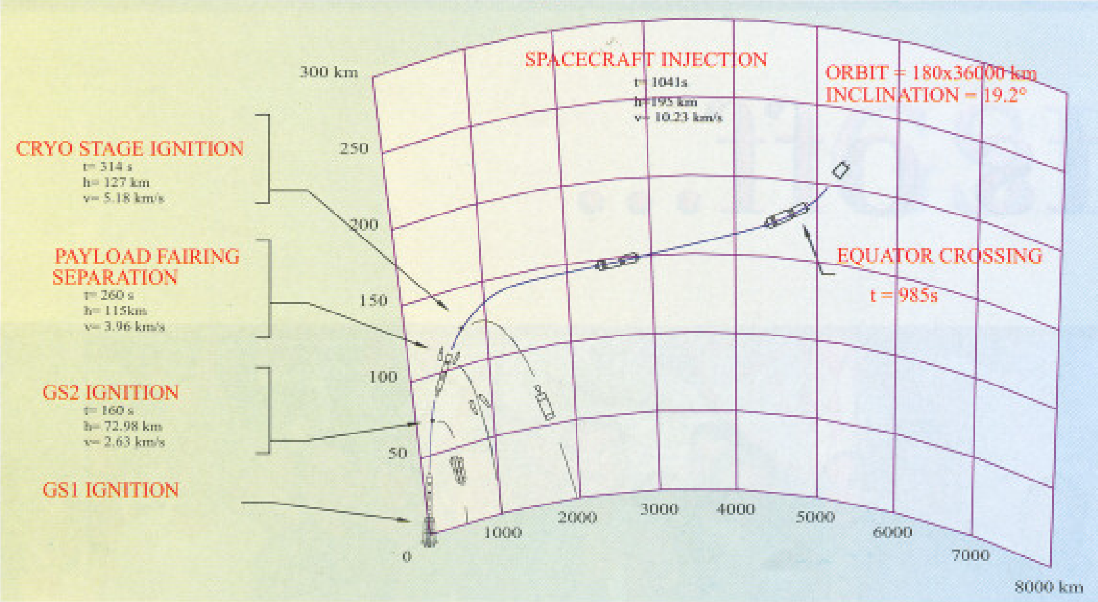
Cryogenic Stage

One of the important feature of GSLV first flight is that, for the first time, ISRO employed a cryogenic stage in its launch vehicle. Cryogenic stage is much more efficient and provides more thrust for every kilogram of propellant it burns compared to solid and earth-storable liquid propellants. Specific impulse, which is a measure of efficiency of the propellant, achievable with cryogenic fluids (liquid hydrogen and liquid oxygen) is of the order of 450 sec compared to 300 sec of earth-storable and solid fuels. This increased efficiency gives a substantial payload advantage; for every one second increase in the specific impulse, the payload gain is of the order of 10 kg.

However, cryogenic stage is a very complex system compared to solid or earth-storable liquid propellant systems due to the use of propellants at extremely low temperatures and the associated thermal and material problems. The temperature of Liquid Hydrogen is -253°C and that of liquid oxygen is -195°C. The propellants, at these low temperatures, are to be pumped using turbo-pumps running at 42,000 rpm. It also entails complex ground support systems like propellant storage and fill systems, cryogenic engine and stage test facilities, transportation and handling of the cryogenic fluids and related safety aspects.

While the initial flights of GSLV use Russian supplied cryogenic stage, ISRO is developing its own cryogenic stage. The first in a series of tests of an indigenous engine was conducted in February 2000. Further tests are planned in the coming months.

GSLV Flight Profile



Launch Complex

The launch complex at SHAR Centre includes facilities for storage, testing and integration of the various stage elements. The vehicle is integrated in a 75 m tall Mobile Service Tower. An extensive network of Radars, launch and mission control center helps in the checkout and launch operations. SHAR Centre also provides facilities for spacecraft integration and check out. The launch facilities can be configured for both PSLV and GSLV launches. A Second launch Pad is now under construction to increase the frequency of launches.

GSLV in Parliament

Statement in the Lok Sabha by
Prime Minister Mr. Atal Bihari Vajpayee

I am happy to inform this august house that the first test flight of India's Geosynchronous Satellite Launch Vehicle, GSLV, was successfully carried out from Sriharikota, on April 18, 2001.

GSLV is the most technologically challenging mission undertaken so far by ISRO and its successful launch is a new landmark in our space achievements. GSLV, ones commissioned into regular service, will provide us with the capability to launch INSAT type of communication satellites into 36,000 km high orbit.

GSLV represents a confluence of sophisticated technologies with a major proportion developed indigenously by our scientists. It uses solid, liquid and cryogenic propulsion stages. The cryogenic stage has been supplied by Russia. The 49 metre tall GSLV, weighing about 400 tonnes, lifted off from Sriharikota at 3.43 pm IST carrying GSAT-1 satellite weighing 1540 kg. After a flawless countdown and 17 minutes of flight, the satellite was successfully placed into its intended orbit.

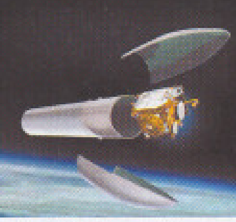
The first signals acquired from the GSAT-1 satellite indicate normal performance of the satellite. In the next few days, the satellite will be manoeuvered to reach its final geo-stationary orbit. The satellite carried instruments to conduct experiments in digital audio broadcast, internet services and compressed digital TV transmissions.

The successful accomplishment of GSLV mission is the culmination of a decade of efforts of ISRO Centres supported by industries and academic institutions in India.

I request this august House to join me in congratulating ISRO and all others who have been involved in the successful launch of GSLV.

Message read by Chairman, Rajya Sabha

Hon'ble Members, as all of you are aware, on 18th April, 2001 India successfully launched its first Geo-synchronous Satellite G-SAT-1 using the GSLV-D1 launch vehicle which blasted off from Sriharikota at 3.43 p.m. With this, India has joined an elite group of nations so far comprising only the USA, Russia, European Union, China and Japan who have launched similar satellites. The launch of the GSLV is a glorious chapter in India's scientific and technological achievements and is the fulfillment of a long cherished dream. This is yet another milestone in India's effort to harness science and technology for the benefit of the humankind. The credit for this accomplishment goes to our entire scientific establishment and in particular to the Indian Space Research Organisation (ISRO). The whole House joins me in congratulating the scientists and engineers involved in this achievement, which has done the nation proud.



GSAT-1

GSAT-1, launched by GSLV on April 18, 2001, was an experimental satellite weighing 1540 kg. The satellite was built to use the opportunity of GSLV developmental flight to test new spacecraft elements. GSAT-1 also carried two C-band transponders employing 10 W Solid State Power Amplifiers (SSPAs), one C-band transponder using 50 W Travelling Wave Tube Amplifier (TWTA) and two S-band transponders using 70 W TWTA.

GSAT-1 was placed in an orbit of 181 km perigee and 32,051 km apogee with an inclination of 19.2 degree with respect to equatorial plane. The satellite was injected with a velocity that was 99.4 percent of the intended 10.2 kilometre per second. But this minor shortfall of 0.6 percent in the overall velocity resulted in reduction of orbital apogee of the satellite. The perigee of 181 km and inclination of 19.2 deg were close to targeted values.

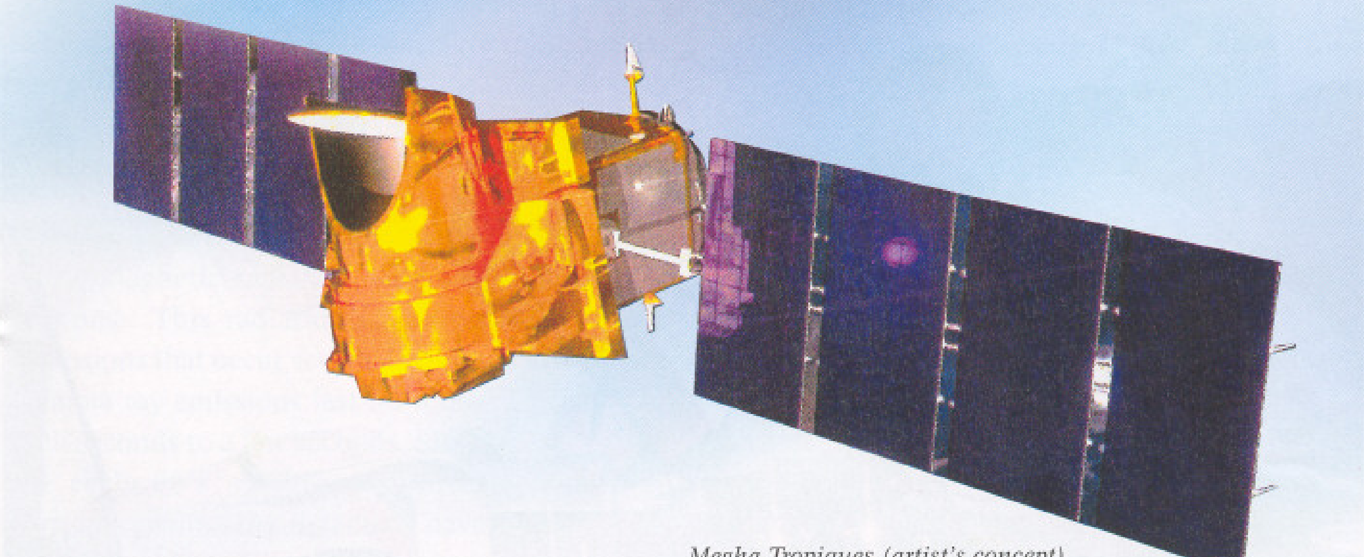
Through a series of six orbit maneuvers conducted between April 19 and April 23, 2001, the orbit of GSAT-1 was raised close to near-geo-synchronous orbit with an apogee of 35,665 kilometre, perigee of 33,806 kilometre and inclination of 0.997 degree with an orbital period of 23 hr 2 minutes. During the orbit raising operations, consumption of propellant was much more than planned resulting in a shortage of about 10 kg to achieve the geo-stationary orbit. In its near-geo-synchronous orbit, deployment of antenna, solar array and the solar sail were successfully completed and GSAT-1 was put in 3-axis stabilisation mode using momentum wheels.

New spacecraft elements that were flown on the satellite could be evaluated using GSAT-1. These included (i) Fast Recovery Star Sensor (FRSS) which provides enhanced accuracy of measuring satellite orientation and for quick earth-lock recovery in case of loss of lock, (ii) a new earth sensor using pyro electric detectors, (iii) an alternate strategy for orbit raising using a combination of four 22 Newton thrusters (iv) thermal control using heat pipes (v) new technique of power management through charger arrays for improving the overall efficiency of power systems and (vi) orbit raising using perigee firing strategy.

When GSAT-1 was within the radio visibility of INSAT Master Control Facility (MCF), Hassan between May 15 and May 28, 2001, GSAT-1 could be used for conducting several spacecraft operations like keeping some of the heaters continuously ON, configuring the spacecraft for unattended mode of operation, and development and implementation of a special software for the onboard AOCE computer to carryout momentum dumping automatically. The software was tested initially from MCF, and then uploaded to the onboard computer by remote programming.

The Communication Payload of GSAT-1 consisting of three normal C-band transponders, and two CXS transponders was also tested on May 19, 2001. The quick-look checks indicated that all transponders worked normally. The Antenna Positioner Mechanism (APM) which can switch the antenna beam between two locations has also been tested. A few experiments like Digital Video Transmission, Digital Audio Transmission, Internet Broadcast System were also successfully carried out.

ISRO and French Space Agency Sign MOU for Atmospheric Research Mission



Megha Tropiques (artist's concept)

ISRO and the French Space Agency, CNES, signed a Memorandum of Understanding (MOU) on May 9, 2001 for the design of a joint satellite mission, Megha Tropiques, for atmospheric research. The MOU was signed by Dr K Kasturirangan, Chairman, ISRO and Prof Bensoussan, President, CNES at Antariksh Bhavan, Bangalore, the Headquarters of ISRO.

Megha Tropiques (Megha meaning cloud in Sanskrit and Tropiques meaning tropics in French) will be a satellite mission for conducting research on the contribution of water cycle in the tropical atmosphere to the climate dynamics. The satellite is proposed to carry three scientific instruments:

- A Multi-frequency Microwave Scanning Radiometer, MADRAS, providing information on rain above the oceans, integrated water vapour content in the atmosphere, liquid water in clouds, convective rain over land and sea.
- A Multi-channel Microwave Instrument, SAPHIR, providing vertical humidity profile in the atmosphere and
- A Multi-channel instrument, SCARAB, providing data on the earth's radiation budget.

Of these three instruments, MADRAS will be developed jointly by CNES and ISRO while the other two instruments will be supplied by CNES. The Megha Tropiques will use the 'PROTEUS' spacecraft platform developed by CNES.

ISRO will launch the satellite on its Polar Satellite Launch Vehicle, PSLV, into an orbit at a height of 867 km and an inclination of 20 degrees, with respect to the equatorial plane. In this orbit, Megha Tropiques can collect data repetitively over the tropics and supplement and complement the data obtained from geo-stationary and polar orbit

Dr. K. Kasturirangan, Chairman ISRO (Left) and Prof. Bensoussan, President, CNES sign the MOU. Standing behind is Dr. G. Raju, ISRO's Project Director for Megha Tropiques.

satellites. The satellite will be controlled in orbit by CNES, and the scientific data will be received by ISRO's ground station at Bangalore from where it will be disseminated to the users. The launch is planned for the end 2005.

It is well known that the tropical region is the domain of squall lines and cyclones and is characterised by large intra-seasonal, inter-seasonal and inter-annual variations that have led to several catastrophic events such as droughts and floods. Changes in energy and water budget of the land-ocean-atmosphere systems in the tropics influence the global climate to a great extent. The exchange of energy in the inter-tropical zone influences the climate of the rest of the planet. These systems interact with the general circulation of the atmosphere in ways that are yet to be fully understood. This lacuna in the understanding reduces the reliability in the prediction of the weather and climate events. It is in this context that data from the unique combination of scientific payloads and the special orbit of the satellite makes Megha Tropiques invaluable for climate research.

In addition to Indian and French scientists who will be taking part in the data analysis, international teams of scientists working on global climate related studies have also expressed keen interest in the satellite programmes.

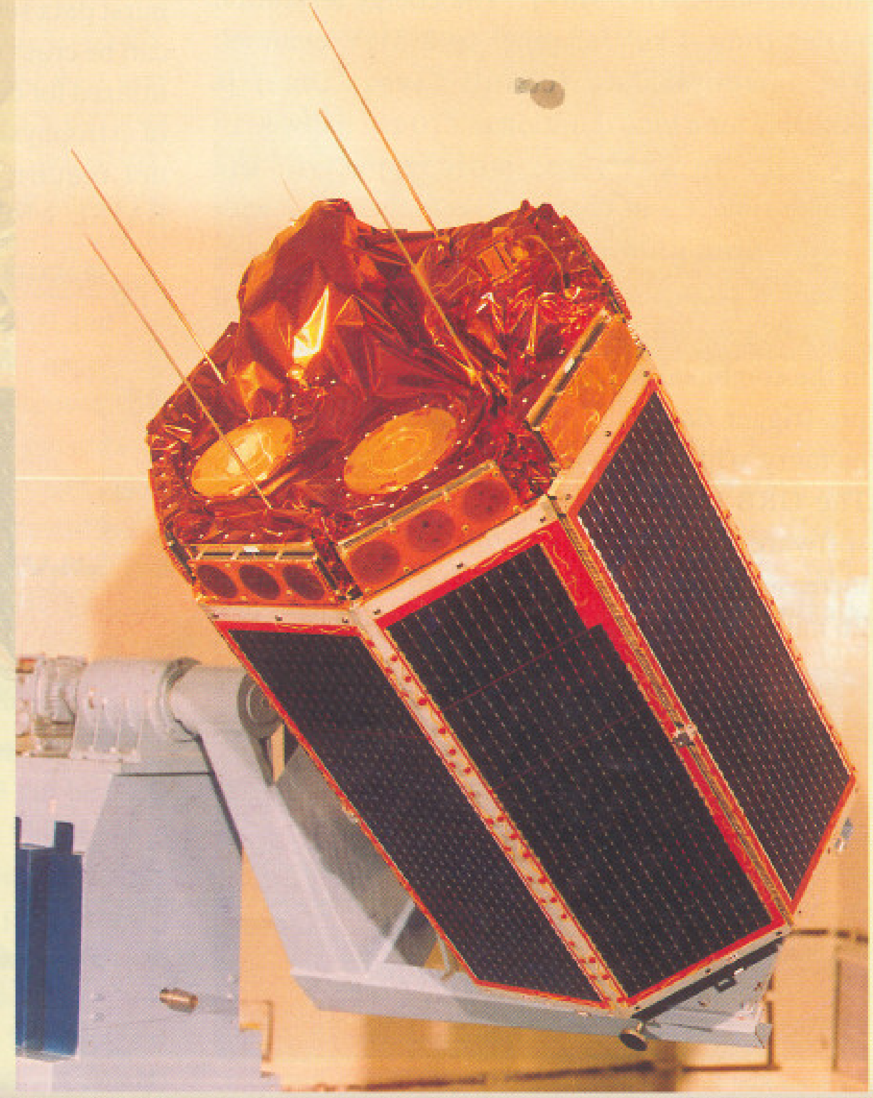
ISRO and CNES had earlier signed a Statement of Intent in November 1999 *(Space India June-Dec 1999)* for conducting the pre-feasibility studies for undertaking the joint Megha Tropiques mission. The studies conducted, pursuant to that Statement of Intent, have yielded a baseline configuration of the satellite and its instruments, the choice of the optimum orbit, the satellite launch vehicle, satellite operations and scientific research plan. The present MOU enables both ISRO and CNES to start detailed design of the Megha Tropiques mission.

SROSS-C2 Satellite Completes Seven Years in Orbit

SROSS-C2
Completes Seven Years

The scientific satellite, SROSS-C2, which was launched by ISRO's Augmented Satellite Launch Vehicle, ASLV, on May 4, 1994 has completed seven years of operation sending valuable scientific data from its Gamma Ray Bursts Detector (GRB) and Retarding Potential Analyser (RPA).

The GRB detects Gamma Rays, which are electromagnetic radiation with very high energy photons. This radiation is the result of violent explosions that occur several light years away. Such Gamma ray emissions last for a few milli seconds to a few seconds. Since the early 60's, orbiting satellites carrying gamma-ray detectors have reported evidence for extremely short bursts of gamma radiation that appeared to emanate from beyond earth. The primary focus of gamma-ray burst research in the 80's and early 90's was to determine the sky distribution of this emission and source localization with sufficient accuracy (<1 minute of arc) to permit observations at other frequencies. Given the poor angular resolutions of gamma-ray detectors and their limited field-of-view, the objective was to obtain as many independent gamma-ray detections as possible using widely spaced observation platforms in space. Such simultaneous observations of events with accurate arrival times (<10 sec arrival time uncertainty) permit event triangulation leading to a significantly restrictive error box on the sky. After the discovery of X-ray after-glows from GRBs by the Italian BeppoSax satellite in 1997, which provided accurate source positions, and follow-up spectroscopy by large optical telescopes such as the 10-m Keck telescope, the extreme distances to these sources (billions of light years) and hence the enormous luminosity of gamma-rays was convincingly demonstrated.


SROSS-C2 Satellite

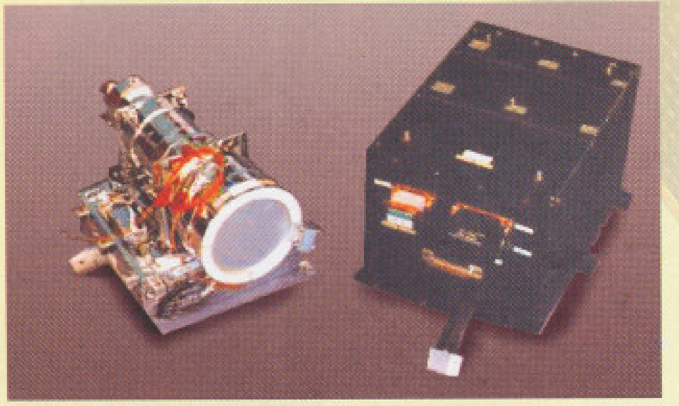
It is in the pre-1997 context that experiments to monitor gamma-ray bursts were placed on board ISRO's Stretched Rohini Satellite Series (SROSS). The primary objectives of GRB detector on board

SROSS-C2 was detection of GRBs in the 20 keV to 2 MeV range, determine intensity variation with high time-resolution (2 milli sec at peak), provide arrival time information, derive the energy distribution of photons from the burst and, in conjunction with other orbiting GRB detectors, produce sky localizations. SROSS-C2 has detected 56 GRB events to date, the latest being GRB10427 on April 27, 2001.

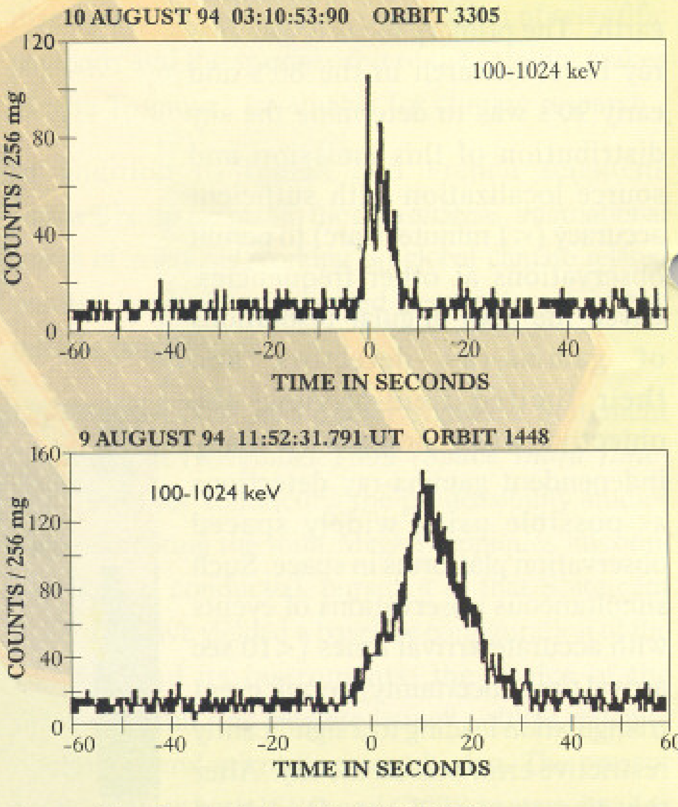
SROSS-C2 GRB monitor consists of a single CsI(Na) crystal viewed by a photo-multiplier tube. Energy spectrum of each event is determined by pulse-height analysis using 124 energy channels in the range of 20 keV to 3 MeV. Also, there are three broad-band discriminator channels — channel-1 (20-100 keV), channel-2 (100-1024 keV) and channel-3 (1-3 MeV). The energy resolution varies from 4 keV/channel to 2 MeV/channel. The temporal data (counts versus time) is available for a total duration of 270 sec (between –65.5 sec to 204.8 sec with respect to the trigger time T_0) in channel-1 and channel-2 with a time resolution of 256 m sec. In addition, temporal data is available during T_0-1.024 sec to T_0+1.024 sec with high time resolution (2 milli sec) in the combined energy channel 20-1024 keV. The pre-trigger data is obtained using a circulating memory, which can store up to 7 events at a time. The GRB trigger is generated by the on-board software if the detector registers a significant increase in count rate in either of two time intervals; 26 milli sec or 1024 milli sec.

The fluence (integrated flux), event arrival time, spectral properties and event duration have been determined for all GRB events that were detected by SROSS-C2. Efforts have been made to determine simultaneous observations by other orbiting satellites for cross-verification. Twenty-two classical GRBs, detected by the SROSS-C2 GRB monitor are common with events detected by the BATSE detectors on board the Compton Gamma-Ray Observatory; others have been simultaneously observed by ULYSSES, PVO, NEAR, etc. A study of the BATSE-correlated burst locations in galactic co-ordinates shows no preferred clustering on the sky, the angular distribution of these events being consistent with isotropy.

Various tests have been conducted on the GRB events with regards to burst characteristics. The SROSS-C2 events provide another independent burst data set on which many of the BATSE findings can be cross verified. The well known V/V_{max} test is utilized for determining homogeneity of a population of astrophysical objects. Interestingly, this test does not require knowledge of the source distances. BATSE, which probes deeper into the Universe with



Gamma Ray Burst Payload



Gamma Ray Bursts dedected by SROSS-C2

its higher sensitivity, showed evidence for a cut-off in the spatial distribution. The average value of V/V_{max} SROSS-C2 events is 0.50 ± 0.05, indicating that in the nearby Universe, GRBs are distributed homogeneously in Euclidean space.

The peak counts distributions in channel-1 and channel-2 are consistent homogeneous distribution of burst sources. The T90 duration shows evidence for the bimodel distribution of burst duration (division around 2 sec). There is also marginal evidence for a class of short duration events in the SROSS-C2 data. Nine bursts are of short (~ few milli sec) duration. One of these events is that on November 7, 1998 which was also detected by the NEAR spacecraft. It has a very hard spectrum (peak hardness ratio equal to 2.43 ± 0.29) and a T90 equal to 272 milli sec.

The other instrument on board SROSS-C2, namely, the Retarding Potential Analyser (RPA), has provided data on the F-region ionospheric electron and ion temperatures, total ion densities, irregularity structures in electron and ion densities, composition of positive ions, and supra-thermal electron flux up to 30 eV along the satellite path over the Indian region covering equatorial and low latitudes. Data for more than 4,400 orbits have been collected in the past 7 years. The data covers the full cycle of solar activity — from periods of minimum solar activity in 1996 to the present peak. Coordinated campaigns with Mesosphere-Stratosphere-Troposphere (MST) radar, Leonid Meteor Shower events, satellite beacon observations and Ionosonde have also been organised.

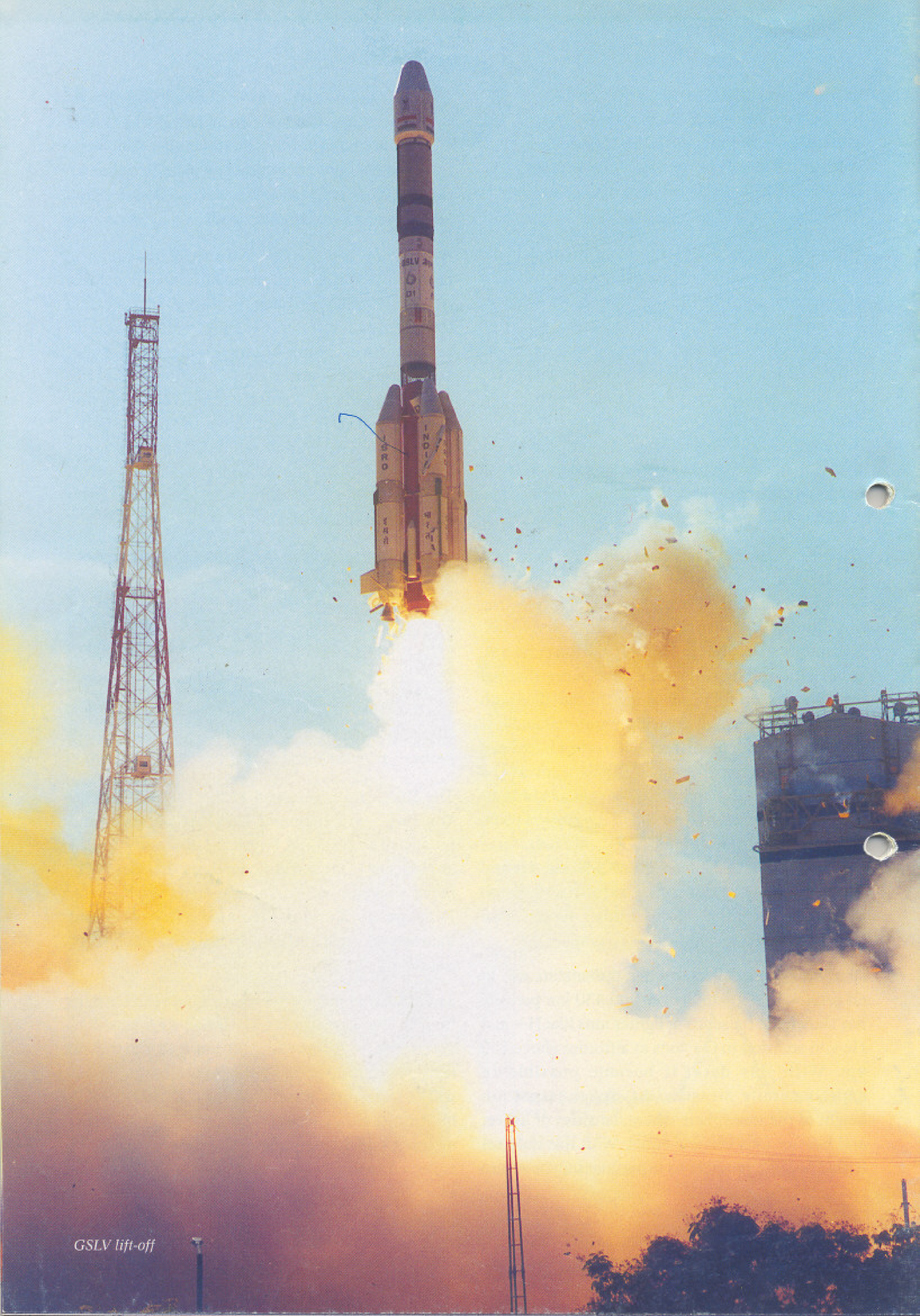
Analysis of data collected when the satellite was in an orbit with 930 km apogee and 430 km perigee, has shown the presence of lighter ions like H+ and He+ in addition to O+ ions at altitudes above 650 km. With this data, it became possible to experimentally measure the upper transition height of the ionosphere where densities of lighter and heavier ions become equal. With this data set it also became possible to experimentally measure the diurnal and latitudinal variation of upper transition height. During the Leonid meteor showers in November 1998 and 1999, presence of heavy metallic ions like Fe+, Mg+, Ni+, Ca+ was recorded at F region altitudes along the satellite path.

Apart from the regular features of ionospheric plasma like occurrence of Equatorial Ionospheric Anomaly (EIA), sharp increase in electron temperature after sunrise, ion and electron temperatures being equal during night time, some new and anomalous features like the enhancements in electron temperature during evening hours in the absence of direct source of heat input, magnetic disturbance events associated with large increase in electron temperature at low latitudes, etc, have been observed from the data.

Retarding Potential Analyser Payload

The RPA data is received at the ISRO Telemetry Tracking and Command (ISTRAC) station and processed at National Physical Laboratory (NPL) at New Delhi for scientific analysis. Besides NPL, seven universities — Andhra, Banaras, Kolkata, Dibrugarh, Kerala, Osmania, Roorkee and Saurashtra — are involved in scientific analysis of the RPA data.

SROSS-C2 which has been providing valuable data from its two instruments, GRB and RPA is now in an orbit at a height of 350 km and during its remaining expected life of about six months, efforts will be to get maximum possible data. This will also be a unique opportunity to collect data at low altitudes and comparing the same with data collected earlier.



GSLV lift-off