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INDIAN SPACE RESEARCH ORGANISATION

First cloud cover picture taken by the Charge Coupled Device (CCD) camera of INSAT-3A on April 17, 2003

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Cover Page: *GSLV-D2 lift-off from Satish Dhawan Space Centre, SHAR*

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INSAT System Gets Further Boost – INSAT-3A Joins Service

ISRO's multipurpose satellite, INSAT-3A, was successfully launched on April 10, 2003 by Ariane-5. INSAT-3A is the third satellite in the INSAT-3 series; INSAT-3B and INSAT-3C were launched on March 22, 2000 and January 24, 2002, respectively. INSAT-3A will augment the present INSAT capacity for telecommunication and broadcasting, besides providing meteorological services along with INSAT-2E and KALPANA-1.

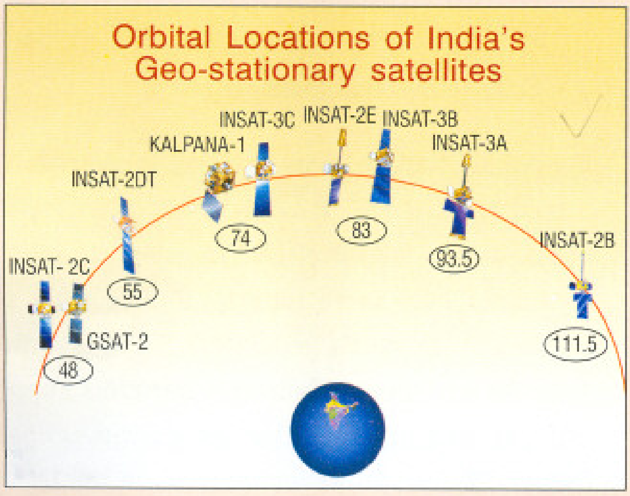
An artist's concept of INSAT-3A in orbit

The 160th flight of Ariane, carrying ISRO's heaviest satellite so far, the 2,950 kg INSAT-3A and GALAXI-XII of US, lifted off at 4.22 am IST from Kourou, French Guyana. About 30 minutes after lift-off, INSAT-3A was injected into a Geosynchronous Transfer Orbit (GTO) with a perigee of 859 km and an apogee of 36,055 km and an inclination of 1.99 deg with respect to the equator. The orbital period was 10 hours 47 minutes.

The Master Control Facility (MCF) at Hassan in Karnataka acquired the telemetry signal from INSAT-3A at 04.52 am IST. The 440 Newton Liquid Apogee Motor (LAM) of INSAT-3A was later used to raise its orbit from Geosynchronous Transfer Orbit (GTO) to 36,000 km circular Geostationary Orbit (GSO) with zero degree inclination. The LAM was fired in three phases on April 11, April 12 and April 14, imparting a total velocity of 1.411 km per second needed to take the satellite from GTO to GSO.

At lift-off, INSAT-3A carried 1,600 kg propellant and at the end of orbit raising operations, it had 505 kg of propellant, sufficient to maintain the satellite's orbit and attitude for its design life of 12 years. During the initial phase of INSAT-3A operations, MCF utilised INMARSAT ground stations at Beijing (China), Fucino (Italy) and Lake Cowichan (Canada).

About INSAT System



INSAT is a multipurpose satellite system, commissioned in 1983 with the launch of INSAT-1B. It is one of the largest domestic communication satellite systems in the Asia-Pacific region. It has six satellites in operation providing about 120 transponders in S, C, Extended C, and Ku bands besides providing meteorological services, disaster warning and distress alerts under the international COSPAS-SARSAT Satellite Aided Search and Rescue Programme.

Of the 120 transponders of INSAT system, the national TV network Doordarshan uses 26 transponders providing TV coverage to more than 85 percent of the Indian population in various regional languages besides English and Hindi. Another major user of INSAT transponders is the public sector telecom service provider Bharat Sanchar Nigam Limited (BSNL) which uses about 32 transponders for providing telecom services covering the entire country including inaccessible areas and offshore islands. The funds for the INSAT system are provided by the Department of Space (DOS) out of the budget voted to it by the Indian Parliament.

While three satellites – INSAT-3A, 3B and 3C – have already been launched in the INSAT-3 series, INSAT-3E that carries 24 C-band and 12 Extended C-band transponders and INSAT-3D, an exclusive meteorological satellite carrying a six-channel imager and 19 channel sounder besides data relay transponder are yet to be launched. INSAT-3E is scheduled to be launched by the end of August 2003. Development of the first two satellites in the INSAT-4 series has also begun. An exclusive satellite for educational applications, EDUSAT, for the Ministry of Human Resources Development is planned to be launched by GSLV in about a year or two.

The Solar Array and the two Antennas of INSAT-3A were deployed on April 15, 2003 by commanding from MCF. INSAT-3A was put in three-axis stabilization mode on April 16, 2003 followed by the deployment of the Solar Sail/ Boom on the north side. The two meteorological cameras — Charge Coupled Device (CCD) Camera and Very High Resolution Radiometer (VHRR) were tested on April 17th and the April 18th respectively.

INSAT-3A reached its space home at 93.5 deg East longitude on April 23, 2003 and the transponders have since been tested. Other INSAT satellite locations are: INSAT-2DT at 55 deg East longitude, INSAT-2E and INSAT-3B at 83 deg East longitude, INSAT-3C, KALPANA-1 at 74 deg East longitude and GSAT-2 at 48 deg East longitude.

The multipurpose satellite, INSAT-3A, carries the following communication payloads:

- 12 C-band transponders, nine of which have expanded coverage providing an Edge-of-Coverage (EoC) Effective Isotropic Radiated Power (EIRP) of 38 dBW and other three having India coverage beam providing an EoC-EIRP of 37 dBW.

- Six upper extended C-band transponders having India beam coverage providing an EoC-EIRP of 37 dBW.
- Six Ku-band transponders having India coverage beam providing an EoC-EIRP of 47.5 dBW and
- A Satellite Aided Search & Rescue (SAS&R) transponder.

The meteorological payloads include:

- Very High Resolution Radiometer (VHRR) with 2 km resolution in the visible spectral band and 8 km resolution in the infrared and water vapour bands.
- Charge Coupled Device (CCD) camera operating in the visible, near infrared and shortwave infrared bands with 1 km resolution.
- Data Relay Transponder (DRT)

INSAT-3A has the main body in the shape of a cuboid of 2.0 x 1.77 x 2.8 m. With its solar panel and solar sail fully deployed in orbit, the satellite measures 24.4 m in length. INSAT-3A's sun tracking solar panels generate 3.1 kW of power. Two 70 Ah Nickel-Hydrogen batteries support full payload operations even during eclipses. INSAT-3A, like all its predecessors in the INSAT series, is a 3-axis body-stabilised spacecraft using

Earlier INSAT Satellites

Satellite	Launch Date	Remarks
INSAT-1A	Apr 10, 1982	Failed
INSAT-1B	Aug 30, 1983	Services completed as planned
INSAT-1C	Jul 22, 1988	Premature termination of services after 6 months of operation
INSAT-1D	Jun 12, 1990	Services completed as planned
INSAT-2A	Jul 10, 1992	Services completed as planned
INSAT-2B	Jul 23, 1993	Services completed as planned
INSAT-2C	Dec 7, 1995	Services completed as planned
INSAT-2D	Jun 4, 1997	Premature termination of services after 3 months of operation
INSAT-2DT – In-orbit procurement from Arabsat		Services completed as planned
INSAT-2E	Apr 3, 1999	Operational
INSAT-3A	Apr 10, 2003	Operational
INSAT-3B	Mar 22, 2000	Operational
INSAT-3C	Jan 24, 2002	Operational
KALPANA-1	Sep 12, 2002	Operational

earth sensors, sun sensors, inertial reference unit, momentum/reaction wheels and magnetic torquers. It is equipped with bi-propellant thrusters. The satellite has two deployable antennas and one fixed antenna that carry out various transmit and receive functions.

Payload details of INSAT-3 Series

Type ✓

Payload	INSAT-3A	INSAT-3B	INSAT-3C	INSAT-3D	INSAT-3E	KALPANA-1
C-band Transponder	12	-	24	-	24	-
Extended C-band Transponder	6	12	6	-	12	-
Ku-band Transponder	6	3	-	-	-	-
S-band Transponder	-	-	2	-	-	-
S-MSS Transponder	-	1	1	-	-	-
Very High Resolution Radiometer	1	-	-	-	-	1
CCD Camera	1	-	-	-	-	-
DRT	1	-	-	1	-	1
SAR	1	-	-	1	-	-
Imager	-	-	-	1 (6-Chnl)	-	-
Sounder	-	-	-	1 (19-Chnl)	-	-

INSAT Transponders

CAPACITY	
C-Band	75
Upper Ext. C-Band	24
Lower Ext. C-Band	5
Ku-Band	11
S-Band	5
Total	120

ALLOCATION	
Doordarshan/ Prasar Bharathi	26
BSNL	32
Other Government agencies	7
PrivateVSATs	24
Private TV Channels	19
Spare	12
Total	120

GSLV Launched Successfully – Launch Vehicle for 2 Tonne Satellites in GTO Operational

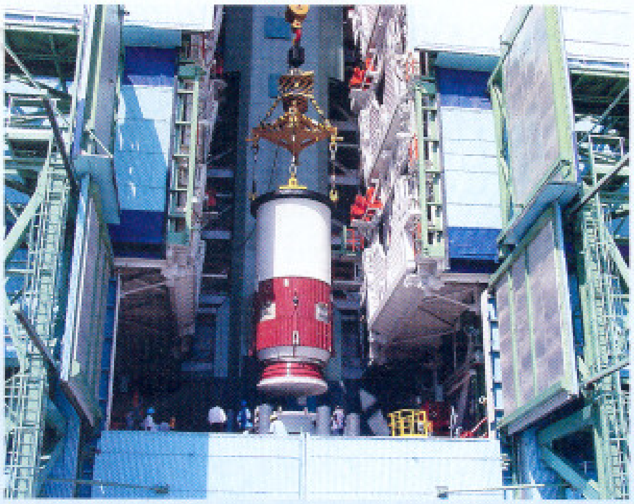
The second developmental test flight of India's Geosynchronous Satellite Launch Vehicle, GSLV-D2, was successfully carried out in the afternoon of May 8, 2003 from Satish Dhawan Space Centre - SHAR, Sriharikota, about 100 km north of Chennai, marking a major milestone in the Indian space programme. The flight revalidated the various systems of the vehicle and the improvements carried out since its successful first launch. With two successful launches, India has operationalised its geosynchronous satellite launcher, GSLV-Mk-1, for placing up to 2 tonne satellites in Geosynchronous Transfer Orbit (GTO).

GSLV-D2 – Final moments of count down

The 414 tonne, 49 m tall GSLV, carrying an experimental satellite, the 1825 kg GSAT-2, lifted off from Sriharikota precisely at the start of the launch window at 4.58 pm Indian Standard Time (IST). About seventeen minutes after lift-off, GSAT-2 was successfully placed in an orbit of 180.04 km perigee and an apogee of 36,000 km with an orbital inclination of 19.2 degree with respect to the equator. GSLV hit the bull's eye when it placed the satellite into orbit well within the specified limits of the injection parameters.

In its first developmental test flight, GSLV had placed a lighter satellite, the 1540 kg GSAT-1 into GTO. The higher payload capability for the second flight was achieved by enhancing the propellant loading in the core solid propellant motor, using high pressure engine in the four liquid propellant strap-on motors and the second stage as well as optimising structural elements.

As the count down for the launch proceeded, the four liquid propulsion strap-on stages, each carrying 42 tonne of propellant, were ignited 4.8 seconds before the count zero. After confirming the normal performance of all the four strap on motors, at



First stage integration in progress

count zero, the mammoth 138 tonne solid propellant first stage motor was ignited and GSLV blazed into the afternoon sky. The first stage burned for 105 seconds while the liquid propulsion strap on stages continued thrusting up to 148 seconds after lift-off taking the vehicle to an altitude of 69 km. At the end of the first stage burn-out, the GSLV had attained a velocity of 2.8 km per second.

The second stage, which carried 39 tonne of liquid propellant, ignited 1.6 seconds before the burn out of the first stage strap-on motors. This stage performed for 140 seconds taking the vehicle to an altitude of 131 km and increasing its velocity to 5.4 km per second. During the second stage operation, at an altitude of 115 km – well beyond the dense atmosphere – the payload fairing that protects the spacecraft from the aerodynamic heating, was discarded.

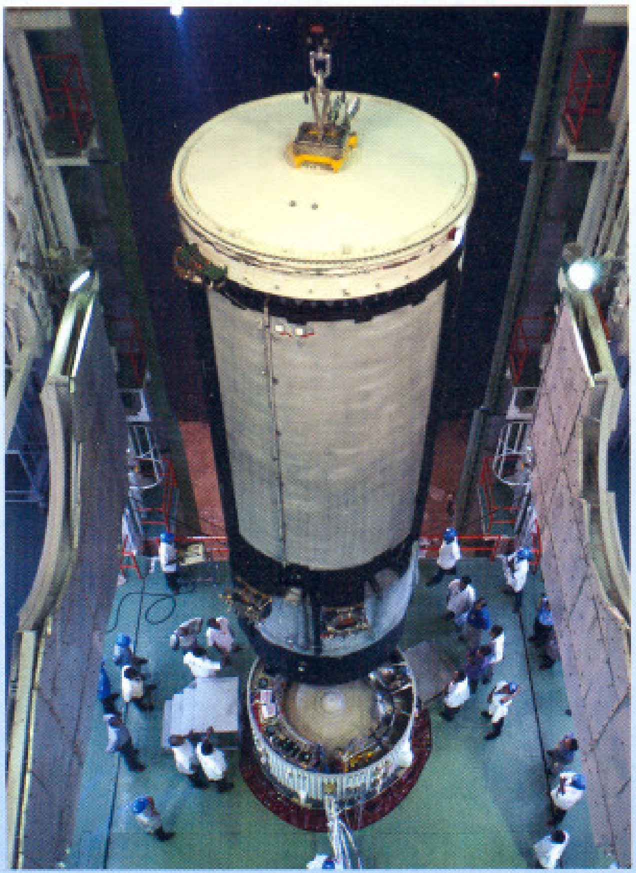
After the separation of the second stage at 292 seconds from lift off, the cryogenic stage was ignited. The cryo stage, which carried 12.6 tonne of liquid hydrogen and liquid oxygen, burned for 704 seconds taking the satellite and the vehicle equipment bay to an altitude of 206 km and boosting the velocity to 10.2 km per second as required for placing the satellite in GTO. The cryogenic stage was separated from the spacecraft at about 1013 seconds after lift off. After the spacecraft separation, the cryogenic stage was reoriented and passivated to avoid any collision with the satellite.

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 in Sriharikota, Port Blair and stations at Brunei and Biak in Indonesia which were networked with SDSC-SHAR.

The GSLV project was initiated by ISRO in 1990 with the objective of acquiring launch capability for Geosynchronous satellites. The first flight test of the vehicle, GSLV-D1, was conducted successfully on April 18, 2001 when the 1,540 kg experimental satellite, GSAT-1, was placed in GTO.

In its present configuration, GSLV is a 49 m tall three-stage vehicle weighing about 414 tonne at

Hoisting of one of the four GSLV strap-ons



Integration of the cryo stage with the launch vehicle

lift-off. The first stage comprises a solid propellant motor (S139) and four liquid propellant strap-on motors (L40H). S139 stage is 20.1 m long and 2.8 m in diameter and it carries 138 tonne of Hydroxyl Terminated Poly Butadiene (HTPB) based solid propellant. The stage develops about 4736 kilo Newton thrust and burns for 107 seconds.

The four strap-on (L40H) stages are 19.7 m long and 2.1 m in diameter. Each of them is filled with 42 tonne of hypergolic propellants – UH25 and Nitrogen Tetroxide (N_2O_4). Each produces 765 kilo Newton thrust and burns for 149 sec. The second stage of GSLV is 11.6 m long and 2.8 m diameter. It is filled with 39.3 tonne hypergolic propellants – UH25 and Nitrogen Tetroxide (N_2O_4). It produces a thrust of 804 kilo Newton. The stage burns for about 136 seconds. The third stage of GSLV uses a Cryogenic Stage (CS) procured from Glavkosmos, Russia but interfaced with ISRO developed electronics. The stage is 8.7 long and 2.9m in diameter and carries 12.6 tonne of liquid hydrogen and liquid oxygen and burns for a duration of about 705 seconds producing a nominal thrust of 73.5 kilo Newton.

The Payload Fairing, which is 7.8 m long and 3.4 m in diameter, protects the vehicle electronics and the spacecraft during its ascent through the atmosphere. It is discarded when the vehicle reaches an altitude of about 115 km.

The Redundant Strap Down Inertial Navigation System/Inertial Guidance System (RESINS/IGS), housed in the equipment bay guides the vehicle from lift-off to spacecraft injection. The digital auto-pilot and closed-loop guidance scheme ensure guided injection of the spacecraft into the specified orbit. The vehicle performance is monitored via telemetry at the Mission Control Centre. A telecommand system is employed to terminate the flight, in case the vehicle deviates from its flight path beyond the specified limits.

A C-band transponder on the vehicle helps in tracking it from ground based Radars. The complete telemetry and tracking of GSLV from lift-off to satellite injection is supported by four ground stations located at SDSC-SHAR,

GSAT-2 spacecraft before payload fairing closure

Sriharikota and the down range stations at Port Blair, Brunei and Biak (Indonesia). All these stations are networked with SDSC-SHAR during launch.

Inter-stage structures connect different stages of GSLV and house the avionics and control systems. The vehicle equipment bay housing electronic systems like processors, navigation system, control system, guidance system, telemetry system, telecommand system, etc, is mounted above the cryogenic stage.

The spacecraft, which is mounted above the equipment bay through a payload adapter, is separated by a Merman clamp-band joint and spring mechanism that provides the required separation velocity.

Satish Dhawan Space Centre–SHAR (SDSC-SHAR) from where the launch of GSLV is conducted is located at Sriharikota, about 100 km north of Chennai. The vehicle is launched at an azimuth of 104 deg. SDSC-SHAR has facilities for storage, testing and integration of the various stage elements. The launch complex houses a 75 m tall air conditioned Mobile Service Tower inside which the vehicle is integrated. In addition, the launch complex has an extensive network of tracking Radars, the launch and mission control center, the facilities for spacecraft checkout and integration, among many others.

Most of the GSLV hardware including motor cases, inter-stages, heat shield, engine components and electronic modules are built by the Indian industry. About 150 industries, both public and private sector are involved. Several educational and academic as well as R&D institutions have assisted in the realisation of the vehicle. The cryogenic upper stage was supplied by Russia, while the complex electronics which controls the functioning of the stage was developed by ISRO.

GSLV is the most technologically challenging project undertaken so far under the Indian space programme. It is the culmination of efforts of a large number of scientists, engineers and technicians, for over a decade. With two successful test flights, the present GSLV, which has the nomenclature of GSLV-Mk I, is now available for launching satellites of up to 2 tonne into GTO. The first operational flight of GSLV-Mk I will be utilised for launching an exclusive educational satellite, EDUSAT, for the Ministry of Human Resources Development. Having already established indigenous capability through PSLV for launching IRS class of remote sensing satellites, the GSLV has made the Indian space programme a self-reliant one while further tuning it towards national development.

Follow-on GSLVs

The next version, GSLV-Mk II, which will carry the ISRO developed cryogenic stage in place of the present Russian one, will have a capability of launching up to 2.5 tonne satellites into GTO. This development has made substantial progress with its engine having already undergone full flight duration ground test. GSLV-Mk II will enter into service after one developmental test flight.

Development of GSLV-Mk III, which will have a capability to launch up to four tonne satellites into GTO, has also been initiated. It will be a three-stage vehicle with 110 tonne core liquid stage and two strap-on motors with 200 tonne of solid propellant each. The upper stage will be a cryogenic stage with 25 tonne of propellant. It will weigh about 630 tonne at lift off and measure 42.4 m in height. The 5m diameter Payload fairing would offer a payload volume of about 100 cubic meters.

Launches from India

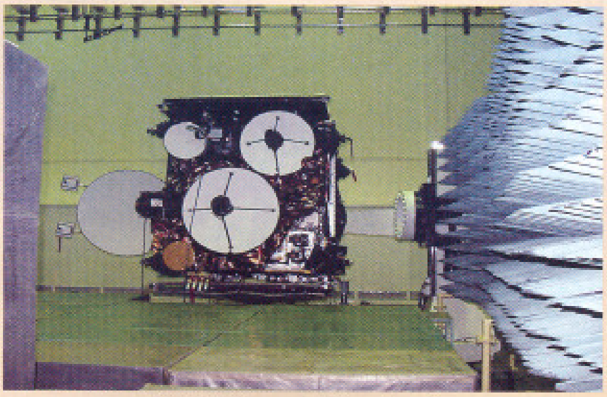
Vehicle	Launch Date	Satellite carried (Mass in kg)	Result (Orbit)
1. SLV-3 E1	Aug 10, 1979	Rohini RTP (35)	Unsuccessful
2. SLV-3 E2	Jul 18, 1980	Rohini RS-1 (35)	Successful (LEO)
3. SLV-3 D1	May 31, 1981	Rohini RS-D1 (38)	Successful (LEO)
4. SLV-3 D2	Apr 17, 1983	Rohini RS-D2 (42)	Successful (LEO)
5. ASLV-D1	Mar 24, 1987	SROSS-1 (150)	Unsuccessful
6. ASLV-D2	Jul 13, 1988	SROSS-2 (150)	Unsuccessful
7. ASLV-D3	May 20, 1992	SROSS-C (106)	Successful (LEO)
8. PSLV-D1	Sep 20, 1993	IRS-1E (846)	Unsuccessful
9. ASLV-D4	May 4, 1994	SROSS-C2 (115)	Successful (LEO)
10. PSLV-D2	Oct 15, 1994	IRS-P2 (804)	Successful (SSO)
11. PSLV-D3	Mar 21, 1996	IRS-P3 (920)	Successful (SSO)
12. PSLV-C1	Sep 29, 1997	IRS-1D (1200)	Successful (SSO)
13. PSLV-C2	May 26, 1999	IRS-P4 & KITSAT-3+ (1050) TUBSAT	Successful (SSO)
14. GSLV-D1	Apr 18, 2001	GSAT-1 (1530)	Successful (GTO)
15. PSLV-C3	Oct 22, 2001	TES & PROBA+DLR BIRD (1110)	Successful (SSO)
16. PSLV-C4	Sep 12, 2002	KALPANA-1 (1060)	Successful (GTO)
17. GSLV-D2	May 8, 2003	GSAT-2 (1825)	Successful (GTO)

LEO: Low Earth Orbit
SSO: Sun Synchronous Orbit
GTO: Geosynchronous Transfer Orbit

Experimental Satellite – GSAT-2

The experimental satellite, GSAT-2, launched by GSLV-D2 has been positioned in its allocated slot and the satellite is functioning well. GSAT-2 carries four C-band transponders, two Ku-band transponders and a Mobile Satellite Service payload. Besides the communication payloads, the satellite carries four scientific payloads:

- Total Radiation Dose Monitor (TRDM) to measure radiation doses inside the satellite using a Radiation Sensitive Field Effect Transistor (RADFET)
- Surface Charge Monitor (SCM) to indicate the state of the charging environment in the vicinity of the spacecraft
- Solar X-ray Spectrometer (SOXS) to study the solar flare emission in 4 keV-10 MeV energy range using state of the art semiconductor devices and Phoswich Scintillation Detector
- Coherent Radio Beacon Experiment (CRABEX) to investigate the spatial structure, dynamic and temporal variations of Ionosphere and several aspects of equatorial electrodynamics



GSAT-2 in anechoic chamber

Weighing 1823 kg at launch, GSAT-2 carries 840 kg of propellant (Mono Methyl Hydrazine and MON-3), a 440 Newton Liquid Apogee Motor (LAM) and sixteen 22 Newton Reaction Control Thrusters for raising itself from Geosynchronous Transfer Orbit (GTO) to its final Geostationary Orbit (GSO) as well as for its attitude control. GSAT-2 measures 9.55 m in length in its in-orbit configuration. It maintain its 3-axis stabilised posture using Sun and Earth Sensors, Momentum and Reaction Wheels, Magnetic Torquers and bipropellant thrusters. Its solar array generates 1380 W power backed up by two 24 Ah Ni-Cd batteries.

In-orbit view of GSAT-2

The first signals acquired from GSAT-2, soon after its injection, were received by the ground station at Biak. The first orbit raising manoeuvre was conducted on May 9, 2003, by firing the 440 Newton Liquid Apogee Motor (LAM) on board the satellite by commanding it from Master Control Facility (MCF) at Hassan in Karnataka. The LAM was fired for a total duration of 90 minutes in three phases — on May 9, 10 and 11, imparting a total velocity increment of 1.66 kilometer per second that took the satellite from its GTO of 180 kilometer perigee and 36,000 kilometer apogee to its final GSO. The inclination of 19.2 degree with respect to the equatorial plane at the time of its injection into GTO was also reduced to zero.

In a series of operations conducted on May 12, 2003, the two Solar Arrays and the West Antenna of GSAT-2 were successfully deployed. The satellite was positioned in its allotted orbital slot at 48 degree East longitude on May 19, 2003.

During injection and initial orbit raising phase of GSAT-2, MCF utilised INMARSAT ground stations at Beijing (China), Fucino (Italy) and Lake Cowichan (Canada).

Initial tests on the experimental payloads have been carried out. A series of small flares was detected by SOXS on June 8, 2003 which has been confirmed by the US satellite GOES.

ISRO-ESA Product Assurance Symposium

A Product Assurance Symposium with the participation of quality assurance professionals from ISRO and European Space Agency(ESA) was organized at Antariksh Bhavan,the Headquarters of ISRO at Bangalore, during May 20-21, 2003. Senior engineers from ISRO Centres and four delegates from ESA participated in this two-day symposium.

Mr G Madhavan Nair delivering the inagural address

Inaugurating the symposium, Mr G Madhavan Nair, Director of Vikram Sarabhai Space Centre, Thiruvananathapuram, traced the beginning of quality assurance activities in ISRO and recalled as to how ISRO has equipped itself with a host of test facilities and expertise to meet the challenging needs of Indian space programme. He urged the quality assurance community to suitably interact and exchange the views on advanced methods of test and evaluation and quality assurance protocols to meet the future challenges.

The symposium was organized in eight sessions covering general product assurance procedures, long life mission requirements, reliability prediction and estimation, ESA's efforts in space components and initiatives in qualifying European sources, ISRO experience in using hi-reliability parts, experience on ISO 9000 certification, qualification of materials and processes, software product assurance and test and evaluation of space systems.

Dr P S Goel, Director of ISRO Satellite Centre chaired the feedback session at the end of the symposium. The discussions resulted in the following recommendations:

- Exchange of information on the new components, materials and related process developments undertaken at the two agencies
- Use of ESA's S4S software for mission critical areas in ISRO programmes
- Exchange of information on alerts, failure analysis reports, precautions to be taken in use of non-standard components, etc
- Mutual exchange of expertise in software developed for use of worst case circuit analysis, sneak path analysis and derating.

The ISRO-ESA Product Assurance Symposium held as part of the ISRO–ESA Cooperation provided a forum for exchange of views on important aspects of quality and reliability of space systems.

Dr P S Goel (third from left) expressing his views during the feedback session

Indian Remote Sensing Satellites *for* Monitoring Reservoirs

Data received from the Indian Remote Sensing (IRS) satellites, IRS-1C and IRS-ID, has been successfully used to assess the storage loss in major reservoirs. The multi-spectral data with a spatial resolution of 23.5 m has been used to obtain information about water-spread on different dates, which, in turn, are used to estimate the storage loss due to sedimentation. Such surveys are economical and less time consuming. Capacity estimation using remote sensing satellite data can be conducted between water level fluctuations in the reservoir between Minimum Draw Down Level (MDDL) to Full Reservoir Level (FRL).

The fact that accelerated development and proper management of water resources are very important for any country hardly needs emphasis today. India has, therefore, embarked upon a programme to build dams and reservoirs mainly for irrigation. More than 600 major and medium storage projects have been built in the last four decades to provide productive and protective irrigation throughout the year. However, capacities of such dams or reservoirs gradually reduce due to the deposition of incoming sediment that not only affects the dead storage but also the live storage. Many of the reservoirs in India are losing capacity at the rate of 0.2 to 1.0 percent annually. About 40,000 minor tanks in Karnataka have lost more than 50 percent of their capacities.

Recent observations reveal that the reservoir sedimentation resulting from degradation of the watersheds is much higher compared to the rate that was assumed at the time the projects were conceptualised. According to Central Water Commission (CWC), New Delhi, nearly 20 percent of the live storage capacity of our major and medium dams had already been silted by the end of twentieth century, which means a loss of irrigation potential of about 4 M ha. As a result, the planning process on utilization of water for irrigation, power generation and drinking is affected. Sedimentation in the reservoirs also affects the river regime and increases the back water levels in head reaches of reservoir and formation of island deltas.

Thus, reservoir capacity surveys at regular interval that provide information about the rate and pattern of sedimentation between various operating levels assume significance. These surveys also enable selection of appropriate measures for controlling sedimentation along with efficient management and operation of reservoirs to derive maximum benefits.

Inflow-outflow method and hydrographic surveys are the conventional methods of reservoir capacity surveys. The amount of data required for inflow–outflow method is very large and cumbersome to collect. Hydrographic surveys are laborious, costly, time consuming and require experienced manpower and sophisticated instruments. In addition, the task of carrying out the field surveys is often hampered by dense forests, wild life, rains, limited accessibility and difficult inter-visibility of range pillars or stake steep fore-shores. There is also danger to the passage of survey boats during hydrographic surveys due to tall-uncut submerged trees lying hazardously. Under such circumstances, satellite based remote sensing becomes a valuable tool for surveying reservoir capacity.

Remote sensing data, by virtue of its synoptic viewing of vast terrain features at regular intervals, is of immense use in providing timely, reliable and comprehensive data on various natural resources in general and capacity surveys in particular. Its ability to map inaccessible areas helps in getting information about reservoir capacity with relative ease.

Remote sensing based reservoir capacity estimation utilizes the fact that water-spread area of the reservoir reduces at different levels as the sedimentation increases. Such water-spreads are measured by using multi-date satellite data depicting the reservoir water levels between MDDL and FRL pertaining to one operation year or two.

Water-spread area is calculated by digital image processing techniques like density slicing of individual spectral bands, ratioing or classification. Water can be easily delineated on the satellite map due to high contrast between land and water boundaries in Near Infra Red (NIR) spectral band. Water absorbs the incident energy in NIR region depending upon nature and status of water body while land reflects more energy in the NIR region. Using the water level values provided by the reservoir authorities, area-elevation graph can be plotted. Then, an appropriate mathematical formula is used to calculate the capacity of reservoir at different storage levels.

Reservoir capacities are calculated using trapezoidal, cone or prismoidal formulae which use waterspread area at different levels and the corresponding difference in the water level (height).

For the estimation of capacity loss, cumulative capacity of the reservoir is calculated by adding the capacities between different water level zones. This cumulative capacity is compared with the capacity either from original elevation-area-capacity curve generated at the time of construction of the reservoir or with the capacities previously calculated. Change in capacity gives overall loss due to sedimentation.

A customized software package, which can help the analysts in carrying out capacity estimation at a faster and systematic way has been developed by ISRO's Regional Remote Sensing Service Centre (RRSSC) at Jodhpur. The software package with the acronym "KSHAMTA" (JalaSHay CApacity EstiMation and sTorage Loss Analysis, provides end-to-end solution to process the multi-date satellite images starting from loading of satellite data to the 'area *vs* capacity' curve generation. In this regard, it provides an end-to-end solution to estimate the reservoir capacity, computes storage loss from the date of reservoir impoundment and provides a series of processing functions in a predefined sequence.

Besides, it has minimum user interaction, automates the data nomenclature at various steps of processing, loads data from different imaging sensors, does rectification using AUTOFIT option and plots the elevation-area-capacity curves.

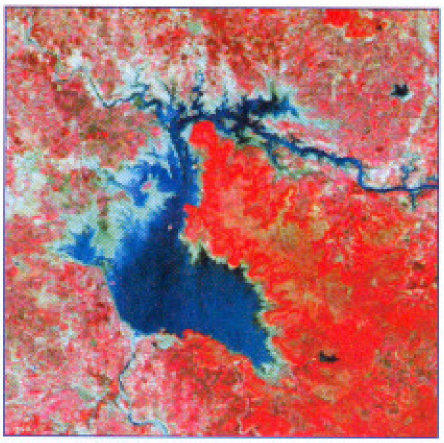
Under the Application Validation Programme, the satellite based reservoir capacity evaluation of Bhadra reservoir in Karnataka was conducted by the RRSSC of ISRO at Bangalore as early as 1987-88, in collaboration with the Karnataka Engineering Research Station (KERS), Krishnarajasagara. Subsequently, RRSSCs have carried out capacity evaluation of Upper Wardha (Maharashtra), Mahi (Rajasthan), Malaprabha, Ghataprabha, Kabini, Linganamakki and Krishnarajasagara (Karnataka) reservoirs.

Upper Wardha reservoir study shows a variation of 6 percent in estimated and observed values of capacity. Mahi reservoir shows an annual capacity loss of 1.23 percent with 12.85 percent reduction in live storage in 11 years. Annual capacity loss for Bhadra reservoir was worked out as 0.04 percent. The capacity loss in Malaprabha reservoir comes out as 3.84 percent in a time span of 17 years.

Rate of sedimentation for Ghataprabha reservoir was estimated as 0.54 percent per year and that for Krishnarajasagara as 0.04 percent per year. Reduction in live storage of Kabini reservoir is 11.7 percent with an annual rate of 0.59 percent.

Sedimentation rate for Linganamakki reservoir was estimated as 0.34 percent per year. Amongst all the reservoirs studied, Krishnarajasagara reservoir, which is quite old, has lowest rate of siltation. Initial rate of siltation is generally very high for newly constructed reservoirs, hence there is a need to do capacity surveys for such reservoirs at closer intervals.

Thus, the Indian Remote Sensing satellites can play a very significant role for monitoring the capacities of the reservoirs in the country. With the Ministry of Water Resources, Government of India proposing to take up sedimentation studies for more than 100 reservoirs in the country, the methodology developed by ISRO for satellite based survey along with the software package, KSHAMTA, becomes invaluable.



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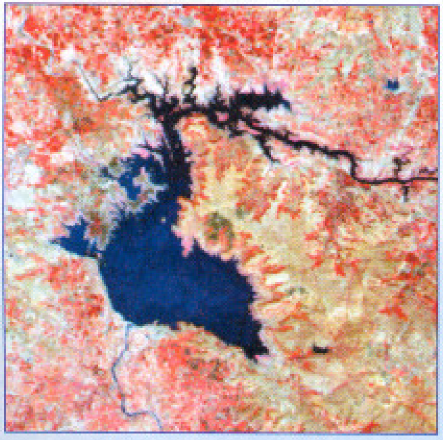

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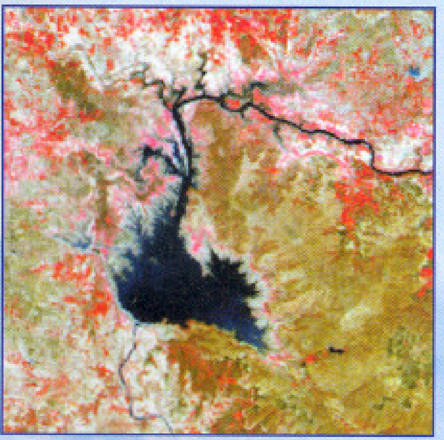

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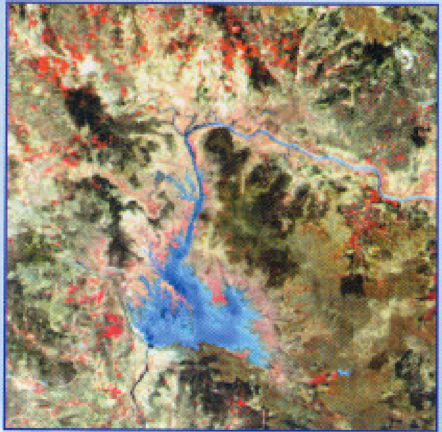

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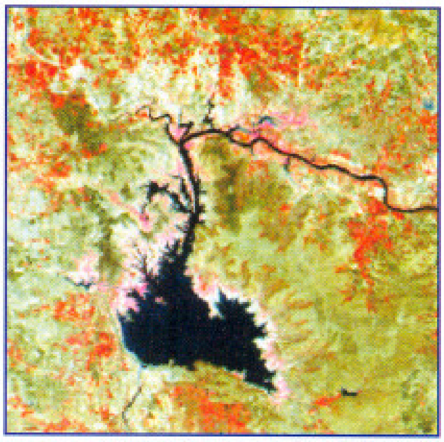

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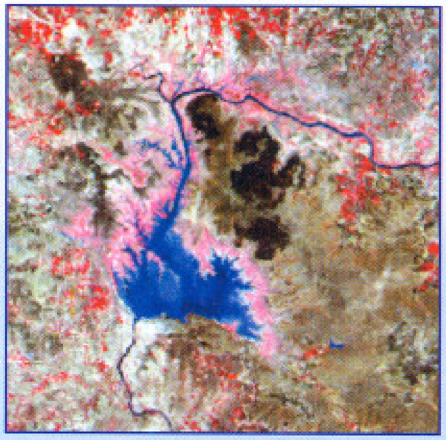

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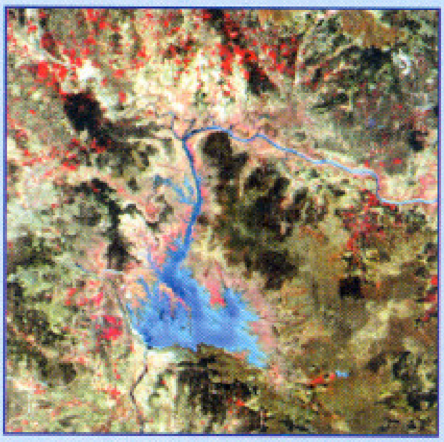

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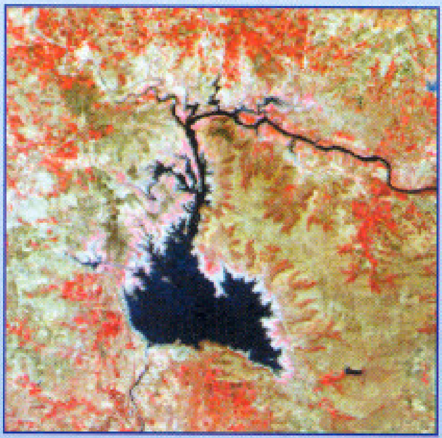
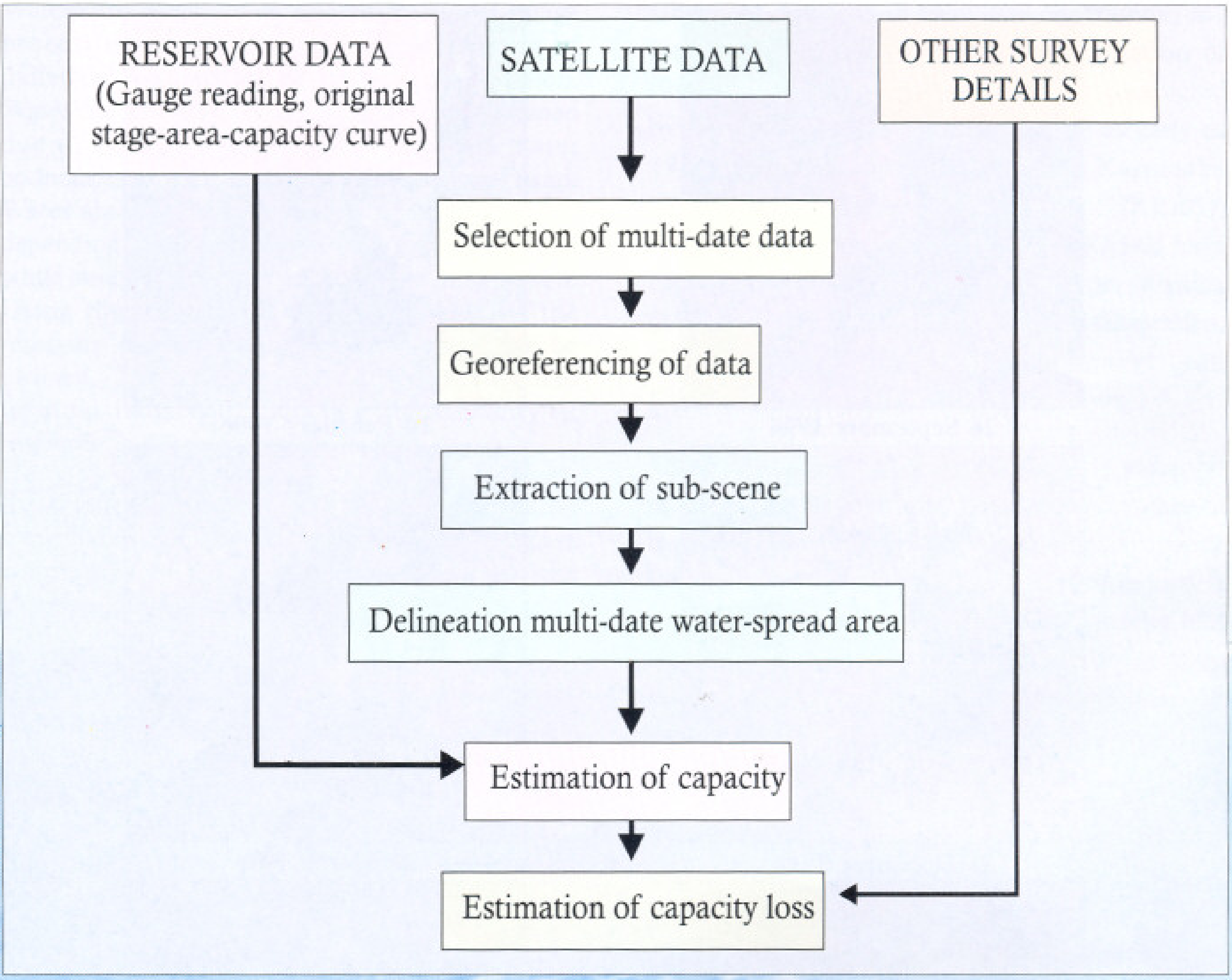


3 June 1996

False Colour Composite (FCC) of Upper Wardha reservoir showing water-spread areas on different dates (generated from IRS data)



Methodology for reservoir capacity estimation

A Few terms...

Band ratioing: It is a technique of enhancing discriminability of a feature of our interest in a multispectral image. The ratio between the reflectance of features in near-infrared band to red band is generally used for enhancing the discriminability of vegetation and water.

Dead storage: Water stored in a reservoir upto MDDL

FRL: Full Reservoir Level is the water level upto crest gate.

Head reaches: Area of water entry into reservoir

Hydrographic surveys: Method of assessing the capacity by measuring the water depth using echo sounder at different positions in the reservoir with the help of a boat and interpolation techniques.

Inflow-outflow method: Method of assessing the capacity loss through daily measurement of sediment load in the river before entering and after leaving reservoir.

Live storage: Water stored in a reservoir between FRL and MDDL

MDDL: Minimum Draw Down Level is the waterlevel below which water cannot be drawn/ utilised for various purposes including irrigation.

River regime: A section of the river morphology influenced by sedimentation

(This article was contributed by Mr S Adiga, Director, NNRMS-RRSSC (National Natural Resources Management System - Regional Remote Sensing Service Centres) and Dr D Gowrisankar, Scientist, Central Management Office of RRSSC, ISRO Headquarters)

ISRO Scientists Congratulated

With two successful missions to its credit in less than a month – April 10 launch of INSAT-3A and May 8 launch of GSLV-D2 — ISRO got the well deserved kudos. The President of India, Dr A P J Abdul Kalam, the Vice President, Mr Bhairon Singh Shekhawat, Prime Minister Mr Atal Behari Vajpayee and Minister of State (Space) Mr S B Mookherjee, among others, congratulated ISRO on the successful launch of its multipurpose satellite INSAT-3A and again on the successful launch of GSLV-D2.

Mr S B Mookherjee made a statement on the successful launch of INSAT-3A in both the houses of Parliament on April 10, 2003. The Parliament joined him in wishing ISRO team all the very best.

The Prime Minister announced the successful launch of GSLV in Parliament on May 8, 2003, a few minutes after the event. The following day, Minister of State (Space) made a detailed statement in Parliament about the launch.

Dr K Kasturirangan, Chairman, ISRO, along with the key personnel of INSAT-3A and GSLV-D2/GSAT-2 missions posing for photograph with the President, Dr A P J Abdul Kalam (at the centre with a folder in his hands) and ....

....With the Prime Minister, Mr Atal Bihari Vajpayee and Mr Satyabrata Mookherjee, Minister of State (Space)

The fully integrated GSLV-D2