Indian Space Programme
Ensuring Stable Use of Outer Space

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“There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We are convinced that if we are to play a meaningful role in the comity of nations we should be second to none in the applications of advanced technologies to the real problems of man and Society.”

Dr. Vikram A Sarabhai
The First Indian Rockets....

Rohini-75 (RH-75)
The First rocket made by India and launched from Thumba
20-Nov-1967

Nike-Apache
The First sounding rocket launched from Thumba
21-Nov-1963
### Sounding Rockets

**ROHINI Sounding Rockets**

- RH-200
- RH-300
- RH-300 MK II
- RH-560 MK II

### Features

<table>
<thead>
<tr>
<th>Features</th>
<th>RH-200</th>
<th>RH-300</th>
<th>RH-300 MK II</th>
<th>RH-560 MK II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of stages</strong></td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Length (m)</strong></td>
<td>3.6</td>
<td>4.8</td>
<td>4.9</td>
<td>7.7</td>
</tr>
<tr>
<td><strong>Lift-off weight (kg)</strong></td>
<td>108</td>
<td>370</td>
<td>510</td>
<td>1350</td>
</tr>
<tr>
<td><strong>Payload Wt. (kg)</strong></td>
<td>10</td>
<td>60</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td><strong>Altitude (km)</strong></td>
<td>85</td>
<td>100</td>
<td>150</td>
<td>550</td>
</tr>
</tbody>
</table>

**Application**

- Meteorology
- Middle Atmosphere
- Middle Atmosphere
- Ionosphere
## ISRO Launch vehicles

### SLV-3 to GSLV Mk III

**Self Reliance through systematic learning**

- **SLV-3** (1980)
- **ASLV** (1988)
- **PSLV** (1994)
- **GSLV** (2000)
- **GSLV Mk III**

### Launch Vehicles

<table>
<thead>
<tr>
<th>Launch Vehicle</th>
<th>SLV</th>
<th>ASLV</th>
<th>PSLV</th>
<th>GSLV</th>
<th>GSLV Mk III (Under development)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lift-off weight (Tonnes)</td>
<td>17</td>
<td>40</td>
<td>295</td>
<td>450</td>
<td>635</td>
</tr>
<tr>
<td>Payload (kg)</td>
<td>40 (LEO)</td>
<td>150 (LEO)</td>
<td>1600 (SSO)</td>
<td>2000 (GTO)</td>
<td>4000 (GTO)</td>
</tr>
</tbody>
</table>

### Key Features

- **SLV-3**
  - Maraging Steel, Large Booster
  - Liquid Propulsion
  - Gimbal Control, Flex Nozzle
  - Multiple Satellites injection

- **ASLV**
  - GTO Mission
  - Cryogenics

- **PSLV**
  - Heavy Cryogenics
  - Large solid & liquid Boosters

- **GSLV**
  - Solid propulsion
  - Inertial Systems
  - Open loop guidance
  - Orbital Mission

- **GSLV Mk III**
  - Strap-on Technology
  - Closed loop Guidance
  - Onboard RTD
  - Bulbous Heat Shield
  - Vertical Integration

- **GTO PAYLOADS (KG)**
  - 3000
  - 4500
  - 10000
  - 15000
Indian Space programme

VISION: Harness space technology for national development, while pursuing space science research and planetary exploration

Satellite Communication
(13 satellites; ~240 transponders)

Space Exploration
(MOM & ASTROSAT)

Launch Vehicle
(PSLV; GSLV & MkIII)

Satellite Navigation
(IRNSS & GAGAN)

Earth Observation
(10 LEO + 3 GEO)

Space Technology Applications
Agriculture, Forestry, Fisheries, Drinking Water, Natural Resources, Snow & Glaciers, Watershed development, Urban, weather & climate, communication applications, DMS...
India’s current Space assets

Communication Satellites

- **13 Operational** (INSAT- and GSAT-Serie)
- >240 Transponders in C, Ext C & Ku bands

Remote sensing Satellites

- **3 in Geostationary orbit** (INSAT 3D, Kalpana & INSAT 3A)
- **10 in Sun-synchronous orbit**
  (RESOURCESAT- CARTOSAT- RISAT-
  OCEANSAT- MEGHA-TROPIQUES SARAL)

Navigational Satellites:

IRNSS 1A,1B,1C,1D & 1E

Space Science:

MOM & ASTROSAT
### Space applications in diversified areas

<table>
<thead>
<tr>
<th><strong>Agriculture</strong></th>
<th><strong>Drinking Water</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area &amp; Production estimation for 8 major crops</strong></td>
<td><strong>Groundwater prospect zones &amp; Recharge Sites</strong></td>
</tr>
<tr>
<td>• In-season multiple forecast</td>
<td>• 90-95% Success rate for Bore wells</td>
</tr>
<tr>
<td>• Satellite data + agro-meteorology + market economics</td>
<td>• Increased Water level</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Fisheries</strong></th>
<th><strong>Watershed Development</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Potential Fisheries Zone (PFZ) Forecast</strong></td>
<td><strong>Better productivity potential &amp; improved livelihood</strong></td>
</tr>
<tr>
<td>• Fish catch doubled,</td>
<td>• Soil &amp; Water Conservation</td>
</tr>
<tr>
<td>• Reduced search time by 60%</td>
<td>• Enhanced cropping yield</td>
</tr>
<tr>
<td>• Fuel cost by abut 30%</td>
<td>• Decrease in fallow lands</td>
</tr>
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<tr>
<th><strong>Monitoring Irrigation Infrastructure</strong></th>
<th><strong>NR Census</strong></th>
</tr>
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<tbody>
<tr>
<td><strong>Inventory &amp; Mapping of Irrigation Infrastructure</strong></td>
<td><strong>Periodic Inventory of Natural Resources</strong></td>
</tr>
<tr>
<td>• Assessment of gaps in irrigation potential created and its utilization at the ground level.</td>
<td>Land use, Soil, Geomorphology, Wetland, Land degradation, Snow &amp; Glaciers, Vegetation</td>
</tr>
</tbody>
</table>
**Forestry**

- Assessment of forest cover on a two-year cycle
- Plan conservation measures
- Rapid Forest Mapping to identify hot spot areas

**Decentralized Planning at Panchayats**

- Geospatial database
- Asset mapping & Activity Planning
- Implementation & Monitoring
- Decision Making at local level

**Snow & Glaciers**

- Monitoring of Glaciers and Snow cover area
- Glacier Retreat
- Snow-melt Runoff Forecasting
- Input to Climate Change

**Weather & Climate**

- Space based Weather parameters & Essential Climate Variables
- Assimilation into model for improved weather prediction.
- Ocean State forecast
- Sea Surface Temperature
- Sea Surface Heights
- Heat wave predictions

**National Urban Info. System**

- Multi scale (10K,2K) hierarchical Urban Geospatial database
- In support of Urban Planning, Infrastructure development,
- e-governance.
Satellite Navigation

IRNSS: Indian Regional Navigation Satellite System

- An Indigenous navigation system of seven-satellite constellation designed for providing position, navigation and timing services over Indian region.
- Five satellites are already in orbit & full constellation by early 2016

Estimated positional accuracy of 10m

Coverage area is about 1500 km beyond Indian territory

GAGAN: GPS Aided Geo Augmented Navigation

- Jointly implemented by ISRO and Airports Authority of India
- GAGAN payloads operational in GSAT-8 (2011); GSAT-10 (2012); & GSAT 15 (2015)

GAGAN has been certified for Approach with Vertical Guidance (APV) 1.0 aircraft landing
Space Science & Planetary Exploration

CHANDRAYAAN 1:
- **Objectives:** High resolution remote sensing; 3D atlas & chemical mapping
- **Instruments:** 11 (6 from other countries)
- **Major discovery:** Hydroxyl & water molecules on lunar surface material
- **Ground Segment:** Indian Deep Space Network (IDSN); Spacecraft Control Centre (SCC) & Indian Space Science Data Centre (ISSDC)

MARS ORBITER MISSION: Exploration of Mars morphology, mineralogy and Martian atmosphere

ASTROSAT: Multi-wavelength (UV to X-ray) observation of astronomical objects

Upcoming Space Science Missions
- **ADITYA:** Studying the process of coronal heating & other phenomena in the magnetosphere
- **CHANDRAYAAN-2:** Exploring Moon with Orbiter-Lander-Rover
ISRO’s International space cooperation - domains

- **Realisation of joint satellite missions** (MEGHA-TROPIQUES, SARAL, NISAR)
- **Accommodation of payloads** (CHANDRAYAAN-1, OCEANSAT-2, ASTROSAT)
- **Telemetry, Tracking & Command (TTC) stations** at Brunei, Indonesia & Mauritius
- **Disaster management** (International Charter, Sentinel Asia, UNSPIDER, SARSAT)
- **Sharing of Earth observation data** (EUMETSAT, USGS)
- **Participation in Advisory Committees on Policy Regulations** (UNCOPUOS, IADC, SFCG, CGMS, CEOS, GEO, ICG, ISECG)
- **Capacity building** (CSSTEAP & IIRS/ITEC)

Cooperative arrangements with 36 Countries & 4 multinational bodies
Space Debris - Concerns

• Growing accumulation of space debris in Space;
• Growing collision threats from Space Objects;
• Cascading Effects of Collision in Low Earth Orbits (Kessler Syndrome);
• Need for Space Situational Awareness & Space Traffic Management;
• UN treaties applicable:
  - Convention on International Liability for Damage caused by Space Objects (Liability Convention);
  - Convention on Registration of Objects Launched into Outer Space (Registration Convention).
International collaboration and activities

• Member of Inter Agency Space Debris Co-ordination Committee (IADC) since 1997;
• Hosted IADC annual meeting in 2003 and 2010;
• Significant Contributions
  • In framing IADC Space Debris Mitigation Guidelines
  • Study Team member in “Space Traffic Management” Project Report 2007 by International Space University;
• Current Representation in IADC
  • Member Steering Group
  • Deputy Chair : WG4.
UN-Space Debris mitigation guidelines

• Limit debris release during normal operations ✓
• Minimize break-up potential during operations ✓
• Limit accidental in-orbit collision probability ✓
• Avoid intentional destruction & harmful activities ✓
• Limit the probability of post-mission break-up ✓
• Limit the long-term presence of spacecraft and launcher orbital stages in the LEO protected region. ✓
• Re-entry objects must not pose an undue risk to the ground population ✓
• Limit the long-term interference of spacecraft and launcher orbital stages with the GEO protected region. ✓

• ISRO follows all guidelines to the maximum extent possible.
Major activities

- Space Debris Mitigation;
- Collision Avoidance studies for Launch Vehicle Lift-off clearance (COLA);
- Space Object Proximity Analysis (SOPA);
- Space debris Modeling;
- Long term evolution of Space Debris scenario;
- Establishment of Multi-Object Tracking RADAR;
- Joint activities with IADC;
- Outreach programs.
Spacecraft Data

Resident Space Object Data

Object Size

Propagation of Spacecraft & Resident Space Object

Close-Conjunction Report
Is generated by filtering conjunctions with min dist ≤ 1 km and/or repeated conjunctions and hence identify the risk objects

Collision Probability Computation

$P_{col} \geq 10^{-3}$

No

Alert issued

Yes

Maneuver Strategy

- Mandatory for Lift-off clearance for all Launch vehicles
- Identification of possible threat during Ascent phase and Orbital phase;
- Inputs- TLE of space objects from NORAD, preflight injection conditions and dispersions;
- In 2014 PSLV-C23/SPOT-7 mission was delayed by 3 minutes to avoid close conjunction with debris objects.
Multi Object Tracking Radar

For safe operation of ISRO’s space assets and space situational awareness:

• Being established at Satish Dhawan Space Centre, SHAR.
• Capability to track simultaneously 10 objects of size 0.25m² Slant range of 1000 km
• Antenna with beam steering capability;
• Provides data related to close approach of space debris to satellites in LEO.
2013 – Test Object – Gravity Field and Steady-State Ocean Circulation Explorer (GOCE);
Orbit at beginning of campaign – 215X233 km (21st Oct. 2013) at 96.55 deg. Inclination;
Actual re-entry – 11th Nov 2013 - 00:23 UTC

2014 IADC Campaign Test object: COSMOS-1939 (NORAD No. 19045) satellite; IADC Campaign begin on 15 Oct 2014
Satellite was launched on 20 Apr 1988 with mass of 1900 kg
Orbit at beginning of the campaign: 215 X 233 km @ inclination 96.55°
Declared Reentry by IADC: 29 Oct 2014 15:14:34 UTC; Final prediction by ISRO: 29 Oct 2014 15:14 UTC
Re-entry prediction – GSLV CUS stage

- The spent upper stage (GSLV-D5/CUS) orbit of 181.03 X 35630.974 km
- Mass = 2484.24 kg and dimensions: 8.5mX2.9m
  - 36X36 Earth gravity model,
  - Atmospheric drag perturbations with Jacchia-Roberts density model,
  - Daily values of F10.7 and $a_p$; luni-solar gravity effects.
  - Prediction by RSM and GA.

There are no Indian spent stages in GTO

<table>
<thead>
<tr>
<th>Space object</th>
<th>Launch date</th>
<th>Decay date</th>
<th>Orbital lifetime (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1/CUS</td>
<td>18-04-2001</td>
<td>18-01-2003</td>
<td>639.334</td>
</tr>
<tr>
<td>D2/CUS</td>
<td>08-05-2003</td>
<td>24-02-2005</td>
<td>657.292</td>
</tr>
<tr>
<td>F01/CUS</td>
<td>20-09-2004</td>
<td>24-11-2007</td>
<td>1159.313</td>
</tr>
<tr>
<td>F04/CUS</td>
<td>02-09-2007</td>
<td>08-02-2011</td>
<td>1254.213</td>
</tr>
<tr>
<td>D5/CUS</td>
<td>05-01-2014</td>
<td>08-06-2014</td>
<td>153.994</td>
</tr>
</tbody>
</table>
Space Debris modeling

Modeling of sunspot cycles

- LEO Debris Breakup Model (ASSEMBLE)
- LEO Space Debris Environment Model (SIMPLE)
- Evolution of Debris Objects based on Equivalent Fragment Concept (EQF);
- Fast and Accurate orbital propagator;
- Studies on GTO lifetime;
- Modelling and Prediction of Sunspot numbers;
- Re-entry Prediction models.

• Eight invited talks and 40 contributed papers;

• 150 delegates attended the conference;

• Talks on Space Debris under the auspices of various societies like Aeronautical Society of India, Astronautical Society of India etc. to generate awareness among the scientific community.
ISRO has well laid plan for future activities in moving towards -

- Augmenting our constellation of EO, Com and Navigation Satellites;
- Building capabilities to explore universe;
- Sustaining the vibrant application programme to touch everybody’s, everyday’s life;

And to ensure stable use of Outer Space.

- Space Debris mitigation guidelines are followed in lift off, trajectory, spacecraft injection and orbital phases, and in monitoring the re-entry of spent stages.