Indian Space Programme
Contributions to
Atmosphere and Climate Change research
for
Sustainable Development

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UNOOSA meet: Sept 11th – 14th 2007, GRAZ, AUSTRIA
Bridging The Divides...

1000 Million+ Indians

200 Million Indians
• Resource surplus
• Well-connected

500 Million Indians
• Living on Margins
• Accessed

300 Million Indians
• Poor
• Under-nourished
• Un-reached

Health
Infant mortality – 7%
Medical access – 2%

Education
300 M illiterates
School drop out – 70%

The social transformation in India lies in bridging these divides
Applications-driven Self reliant Programme

“…….we must be second to none in the applications of advanced technologies to the real problems of man and society.”

Four Decades of Indian Space Programme

48+7 Spacecraft & 23 Launch Vehicle Missions

Multifarious Applications

Applications-driven Self reliant Programme
India’s Communication Capabilities

Capacity

INSAT- 4B coverage

Ku-Band

C-Band
INSAT Applications

**BROADCAST**
- Television Broadcasting
- Direct To Home (DTH)
- TV & Radio Networking

**METEOROLOGICAL**
- Meteorological Imaging
- Data Collection Platform
- Disaster Warning

**COMMUNICATION**
- Speech Circuits On Trunk Routes
- VSAT Connectivity

**DEVELOPMENTAL**
- Tele-health
- Tele-education
- Emergency Communication

**OTHERS**
- Mobile Satellite Service
- Search and Rescue
- Satellite Navigation
Current Indian Geostationary Meteorological Satellites

Kalpana-1
INSAT-2E
INSAT-3A
Continuous Monitoring of Weather from INSAT

There are 3 INSAT systems at present covering most of the Indian Ocean. These Systems generate images and products at frequent intervals day and night using one (VIS) responsive to daylight, infrared (IR) channels responsive to the temperatures of clouds and the surface, another IR channel to measure atmospheric water vapour.
One of the more important justifications of meteorological satellites is their ability to detect, monitor and track severe tropical cyclones that can cause immense loss of life and property. Satellites play a vital role in providing information about hurricanes, enabling forecasters to track them for days before they make landfall, and helping to provide essential warnings of huge economic and social importance.
EduSat

5 Spot Beams in Ku Band
1 National Beam in Ku Band
1 National Beam in Ext C Band (6 Channels)

Teaching-End

Class Room-1
ROT Backed by solar Power

Class Room-2
SIT

Present Scenario
As part of Governmental Education Policy
24 Hr. Educational Team Channel called Gyandarshan focused on Rural Areas
Support 6 Open Universities
Development & Communication Channel since 1995
Engg College & Primary School Networks in Karnataka
Education Network in Kerala
30,000 Virtual Classrooms
Tele-Medicine

221 Hospitals
• 181 Dist/ Rural Hospitals (8 mobile units)
• 40 Super Specialty Hospitals

Far-flung & Remote Areas: North-East, Andaman & Nicobar, Lakshadweep, Jammu & Kashmir, …
Village Resource Centre

Components

- EO based Information
- Advisory related to Agriculture, Fisheries, ...
- Digital Connectivity
- Tele-Education, Tele-Medicine

Query Shell in local language

NR & Socio economic database

Village Resource Centre

Multilingual Interface

Plus more…
VRC Network

- Non redundant TDM/TDMA Central Hub
- DVB-S Forward link
- TDMA Return link
- Star network with Hub as central node
- VRCs as end nodes
- With One Ext C Transponder to start with
- Either in Edusat
- 4.5 m Antenna – 40W Power amplifier
- 8-10 Simultaneous videoconferencing
**INSAT - 3D**

**Improved Understanding of Mesoscale Systems**

### 6 Channel IMAGER
- **Spectral Bands (µm)**
  - Visible: 0.55 - 0.75
  - Short Wave Infra Red: 1.55 - 1.70
  - Mid Wave Infra Red: 3.80 - 4.00
  - Water Vapour: 6.50 - 7.00
  - Thermal Infra Red – 1: 10.2 - 11.3
  - Thermal Infra Red – 2: 11.5 - 12.5
- **Resolution**: 1 km for Vis, SWIR
  - 4 km for MIR, TIR
  - 8 km for WV

### 19 Channel SOUNDER
- **Spectral Bands (µm)**
  - **Short Wave Infra Red**: Six bands
    - (3.98, 4.13, 4.45, 4.52, 4.57 µm)
  - **Mid Wave Infra Red**: Five Bands
    - (6.51, 7.02, 7.43, 9.71, 11.03 µm)
  - **Long Wave Infra Red**: Seven Bands
    - (12.02, 12.66, 13.37, 13.64, 14.06, 14.37, 14.71 µm)
  - **Visible**: One Band
- **Resolution (km)**: 10 X 10 for all bands
- **No of simultaneous sounding per band**: Four

**CO₂ bands**  **Water Vapor bands**
Megha Tropiques

For studying water cycle and energy exchanges in the tropical belt

Low inclination (20°) for frequent simultaneous observations of tropics

- Water vapour
- Clouds
- Cloud condensed water
- Precipitation
- Evaporation

SAPHIR
- Frequency: 183.31± 0.2, 1.1, 2.7, 4.2, 6.6, 11.0 GHz
- Water vapour profile
- Six atmospheric layers up to 12 km height
- 10 km Horizontal Resolution
- Outgoing fluxes at TOA
- 40 km Horizontal Resolution

SCARAB

MADRAS
- Precipitation and cloud properties
- 89 & 157 GHz: ice particles in cloud tops
- 18 & 37 GHz: cloud liquid water and precipitation
- 23 GHz: Integrated water vapour

GPS Occultation

Contributing to Global Precipitation Mission (GPM)
Specific Atmospheric Assessment Projects (SAAP)

- Aerosol Radiative Forcing Over India (ARF)
- Atmospheric Trace Gases & Transport Modeling (ATC & TM)
- Atmospheric Dust Composition & Transport Modeling (ADC & TM)
- Atmospheric Boundary Layer Network & Characterization (ABLN & C)
- Soil & Vegetation Fluxes using Flux Towers (SV & F)

Integration Land Ecosystem & Atmospheric Projects (ILEAP)

- LULC & Impact of Human Dimensions in the Indian River basins (LULC & RB)
- Multi Proxy Quantitative Paleo-monsoon Reconstruction (QMPRC)
- Regional Climate Modeling & Impact Analysis (RCM & IA)

Intense Observational Projects (IOP)

- National Vegetation Carbon Pool Assessment (NCP-VCPA)
- National Soil Pool Assessment (NCP-SCPA)

Small Satellite Utilization Projects (SS-UP)

- Climate sats-Small satellite plans
Decadal Trends in AOD (% Yr\(^{-1}\))

**Mysore 1988-2000**
- Trend line
- Upper 95% Confidence Limit
- Lower 95% Confidence Limit

**Trivandrum, 1985-2001**
- Trend line
- Upper 95% Confidence Limit
- Lower 95% Confidence Limit

**Visakhapatnam, 1987-2001**
- Trend line
- Upper 95% Confidence Limit
- Lower 95% Confidence Limit

9.83, 3.13, 3.60, 2.99

3.50, 2.78, 5.12, 1.02

1.19, -1.12, 0.04, -6.00

Dr K Krishnamoorthy
Mineral Dust Studies & Aerosol chemistry

3 Hrly Reference Images May (1-15) 1999

Mineral Dust Study
Mt Abu, ~1700 m asl, clean site
Ahmedabad, 49 m asl, a megalcity
Rainfall ~650 mm; Jun-Aug

Arabian Sea
Bay of Bengal

Diurnal Variation of IRBT and IDDI

ΔT = 2K
Observed higher levels of ozone at a remote site, Khambat, than at Ahmedabad, an urban site. This is due to net efficient production of ozone at Khambat.

Comparison of measurements made in February - March over the Bay of Bengal with Indian Ocean and Arabian Sea.

Prof Shyam Lal PRL
Towards improving Agromet Services
Densifying Weather Observation Network

**Automatic Weather Station**
- Continuous monitoring of severe weather events

**Space Observations**
- EO instrument capabilities
  - Radiometers & Spectrometers
  - Atmospheric Sounders
  - Rain Radars
  - High resolution imagers
  - Polarimetric radiometers
  - Altimeters/Scatterometers
- INSAT-3A & KALPANA
- DP software installed at IMD
- INSAT 3D
- Development of Techniques

**Doppler Weather Radar**
- Continuous monitoring of severe weather events
- Radar network for entire coastal areas, NE region, major cities, ...
Regional Climate Simulation

- MM5 used for regional climate studies.
- Preliminary simulations made including satellite-derived land surface parameter generated at SAC for July 1998.
- Significant improvement in the simulated rainfall was detected using SAC generated vegetation fraction data to initialized the model.
High altitude balloons for GHG’s & Astrobiology Payload
National Landuse / Landcover mapping using Multitemporal AWiFS Data

LULC-Web
Land Use Land Cover Mapping Web Enabled Information System

3rd Cycle Status (2006-07):
- Geometric rectification of all products is completed
- Kharif data analysis is in progress
- Report preparation for kharif will be completed in two weeks
### Forest Density Classes (Volume in MCu.M.)

<table>
<thead>
<tr>
<th>S.No</th>
<th>Forest Type</th>
<th>Dense_For</th>
<th>Open_For</th>
<th>Mangrove</th>
<th>Scrub</th>
<th>Treeclad</th>
<th>Total Volume</th>
<th>Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Evergreen</td>
<td>300.25</td>
<td>62.04</td>
<td>0.13</td>
<td>3.47</td>
<td>0.25</td>
<td>367.33</td>
<td>414.35</td>
</tr>
<tr>
<td>2</td>
<td>Semi Evergreen</td>
<td>76.02</td>
<td>9.98</td>
<td>0.12</td>
<td>1.47</td>
<td>0.18</td>
<td>84.77</td>
<td>80.97</td>
</tr>
<tr>
<td>3</td>
<td>Moist Deciduous</td>
<td>48.10</td>
<td>23.95</td>
<td>0.46</td>
<td>11.63</td>
<td>0.15</td>
<td>84.29</td>
<td>88.00</td>
</tr>
<tr>
<td>4</td>
<td>Dry Deciduous</td>
<td>334.88</td>
<td>312.03</td>
<td>2.32</td>
<td>97.55</td>
<td>0.17</td>
<td>647.57</td>
<td>676.06</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>759.25</td>
<td>366.23</td>
<td>3.62</td>
<td>114.12</td>
<td>0.74</td>
<td>1183.96</td>
<td>1259.28</td>
</tr>
</tbody>
</table>

### Forest Carbon Pool Analysis

**Forest Cover Map (1991 - 1993)**

#### Region Mean C Pool (Mg C / ha)

<table>
<thead>
<tr>
<th>Region</th>
<th>Mean C Pool (Mg C / ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Ghats</td>
<td>80.54</td>
</tr>
<tr>
<td>Eastern Ghats</td>
<td>43.38</td>
</tr>
<tr>
<td>Central India</td>
<td>22.78</td>
</tr>
<tr>
<td>North Eastern</td>
<td>128.64</td>
</tr>
<tr>
<td>National Average</td>
<td>68.835</td>
</tr>
</tbody>
</table>

**Sample Points**
- Western Ghats: 840
- East Ghat: 790
- Rakhin, MP: 311

**Regions**
- Semi Evergreen
- Moist Deciduous
- Dry Deciduous
- Plantation
- FBlank
- Overall

**Mean Volume (MCu.M) / Ha**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Forest Type</th>
<th>Mean Volume (MCu.M) / Ha</th>
<th># PLOTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Semi Evergreen</td>
<td>74.76</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>Moist Deciduous</td>
<td>62.82</td>
<td>278</td>
</tr>
<tr>
<td>3</td>
<td>Dry Deciduous</td>
<td>54.86</td>
<td>247</td>
</tr>
<tr>
<td>4</td>
<td>Plantation</td>
<td>59.32</td>
<td>175</td>
</tr>
<tr>
<td>5</td>
<td>FBlank</td>
<td>71.60</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>59.93</td>
<td>743</td>
</tr>
</tbody>
</table>
ALTM Applications-SBL

- Pre harvest ALTM
- Post Harvest ALTM
- Aerial Photo-Preharvest
- Aerial Photo-Post Harvest

Vertical Structure
Canopy Height
Ground Elevation

~30-25m
Multi-Satellite Launch: PSLV-C7

4 satellites of 1292 kg in 635 km PSSO
Cartosat-2 : 680 kg  
SRE-1       : 550 kg  
LAN TUBSAT  : 56 kg  
PEHUENSAT-1 : 6 kg  

9th Consecutive successful flight

Capability for Small Satellite missions

Dual Launch Adopter (DLA)

Launch:
January 10, 2007
Space Capsule Recovery Experiment

- Providing a platform for Micro-gravity experiments in space
- Demonstration of technology for recovery of space capsule

MISSION PROFILE

- Micro-gravity exp
- 3 axis stabilisation
- Sun pointing
- SRE launch in PSLV
- SRE Injection CARTO
- 2 Injection
- Acquisition & orbit determination
- SRE first burn
- (Change to daily repeating elliptical orbit)
- Coast phase attitude manoeuvering
- Deorbit
- Recovery
- Floatation system
- UHF Beacon
- Parachute deployment
- Reentry
- Atmospheric braking
- elliptical orbit (REO)
- Daily repeating
- SSPO
- T0 + 35 min Velocity: 8000 m/s
- T0 + 44 min Velocity: 47 m/s
- T0 + 46 min Velocity: 12 m/s
- 20th Jan
- 22nd Jan
- De- boost
- Re- entry

TECHNOLOGIES

- Thermal Protection Systems
- NGC for re-entry
- Hypersonic aero thermodynamics
- Deceleration system
- Floatation system & recovery operations
- 10th Jan
- 20th Jan
- 10th Jan
Indian Satellite Navigation Programme

Augmentation System

GAGAN: GPS and Geo Augmented Navigation

INRESs
INMCC
INLUS
INRESs

GPS
GEO (Navigation Payload)
GPS

IRNSS: Indian Regional Navigation Satellite System

Improved GPS accuracies (from 30m to 6m)
Correction signals transmitted to user through Geo-satellite

Gagan Uplinking Facility

Ref. Station Antenna
Earth Observation - Applications

**AGRICULTURE & SOIL**
- Crop Acreage & Production
- Soil & Land Degradation Mapping
- Watershed Development
- Horticulture Mission

**LAND**
- Land use/Land cover Mapping
- Wasteland Mapping
- Urban Sprawl Studies

**FOREST, ENVIRONMENT, BIO**
- Forest Cover & Type Mapping
- Forest Fire and Risk Mapping
- Biodiversity Characterisation
- Environmental Impact Studies

**WEATHER & CLIMATE**
- Extended Range Monsoon Forecasting
- Ocean State Forecasting
- Regional Climate Model

**WATER**
- Drinking Water Prospect Zones
- Command Area Management
- Reservoir Sedimentation

**OCEAN**
- Potential Fishing Zone (PFZ)
- Coastal Zone Mapping

**DISASTER MGT. SUPPORT**
- Flood Damage Assessment
- Drought Monitoring
- Land Slide Hazard Zonation
700 M. Indians depend on Natural Resources for their Livelihood and Marketable Surplus

Water availability: 420 Mham/yr
Use: ~50 Mham/yr

Declining availability of water per capita
(Source: Engelman & Roy 1993)

India's Annual Soil Loss: 5334 Mt

- 29% Lost to sea
- 10% Dam deposit
- 61% River deposit

Loss to 4.5% of the GDP due to Degradation of Natural Resources
- TERI: 1998

Space Perspectives:
- Efficient Land and Water Resources Management
- Empowering People for Sustainable Development
Land Resources
- Wasteland inventory (55 Mha in 2003)
- Natural Resources Census
- Natural Resources Repository

Water Resources
- Potential Drinking Water Zones (~200,000 wells drilled with ~90% success; over 7000 recharge structures)
- Command Area Management
- Reservoir Sedimentation

Ocean Resources
- Potential Fishing Zone - PFZ (Search time reduced by 30-70%)
- Coastal Zone Mapping

Rural Connectivity Corridors
- Under Bharat Nirman
- High potential with Cartosat 1 & 2 products

Risk Reduction
- Agri. Drought Assessment
- AWS

Agri. Insurance
- Small area Statistics,
- Area Yield
- Weather Indexing
- Access to Credit

Precision Agriculture
- Soil Variability
- Yield Variability
- Crop Weather Interaction
- Crop Simulation Model
EO Products & Services
For Enhancing Agricultural Productivity

In-season forecast…
CAPE/ FASAL: Area Statistics (MoA)
Wheat (2004-05)
74.9 Mt (FASAL) Vs 74 Mt (MoA)

Horticultural Inventory
National Horticulture Mission (MoA)
Banana; Maize; Tobacco; Chillies; cotton; Paddy

Crop intensification/ extensification
Salinity Mapping for reclamation (CWC)
Part of Ahmednagar Dist. (LISS III of April 2002)

Diversification…
Cropping System Study (MoA)

Effective Input/ Output Management
Fertiliser Req. Assessment (IFFCO)

Empowering farmers…
Farmers’ Advisory & Decision Support (Plg. Commn.; GoK)
ERROR: stackunderflow

OFFENDING COMMAND: ~

ERROR: stackunderflow