Overview of NISAR Mission and Airborne L & S SAR

August, 2018

Space Applications Centre, ISRO
Ahmedabad
**NISAR Mission Concept Overview**

- Major partnership between US National Aeronautics and Space Administration (NASA) and Indian Space Research Organisation (ISRO)
- Baseline launch date: No earlier than December 2020
- Dual frequency L- and S-band Synthetic Aperture Radar (SAR)
  - L-band SAR from NASA and S-band SAR from ISRO
- NASA 3.5 Gbps Ka-band telecom system to polar ground stations (> 24 Tbits/day downlink capability)
- Spacecraft: ISRO I3K with 1 Gbps telecom system
- Launch vehicle: ISRO Geosynchronous Satellite Launch Vehicle (GSLV) Mark-II (4-m fairing)
- 3 years science operations (5+ years consumables)
- All science data (L- and S-band) will be made available free and open, consistent with the long-standing NASA Earth Science open data policy

**Ecosystem Structure**
- Biomass disturbance: effects of changing climate on habitats and CO₂

**Cryosphere**
- Ice velocity, thickness; response of ice sheets to climate change and sea level rise

**Solid Earth**
- Surface deformation; geo-hazards; water resource management

*Surface deformation; geo-hazards; water resource management*
NISAR Swath Coverage by SweepSAR

• All science disciplines require frequent coverage over global targets

• NISAR approach would acquire sufficient swath to cover equatorial ground track extent
  ➔ Global access at desired time sampling and imaging characteristics

• New *SweepSAR* technology being implemented independently by both JPL and ISRO

• Concept
  • On Transmit, illuminate the entire swath of interest
  • On Receive, steer the beam to follow the angle of the echo coming back to maximize the SNR of the signal and reject range ambiguities
  • Allow echo to span more than 1 IPP

~236 km Earth-fixed ground track spacing at equator for 12-day repeat orbit
Sweep SAR – High Resolution Wide Swath

- On Transmit, all Feed Array elements are Illuminated (maximum Transmit Power), creating the Wide elevation Beam

- On Receive, The Feed Array element Echo signals Are processed Individually, taking Advantage of The full Reflector area for each beam to maximum Antenna Gain

- Uses Digital Beam Forming (DBF) on Receive to Provide wide Measurement swath
  - DBF allows multiple simultaneous echoes in the Swath to be Resolved by Angle of Arrival

- Uses large-area Reflector to provide High aperture Gain
  - Full-size azimuth aperture for both Transmit and Receive
  - Full-size elevation aperture on receive
<table>
<thead>
<tr>
<th>Parameters</th>
<th>L-band SAR</th>
<th>S-band SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>747 Km with 98.5° Inclination</td>
<td>3.20 (9.3cm)</td>
</tr>
<tr>
<td>Frequency (wavelength)</td>
<td>1.25GHz (24cm)</td>
<td>10 MHz, 25 MHz, 37.5 MHz, 75 MHz</td>
</tr>
<tr>
<td>Repeat cycle</td>
<td>12 days</td>
<td></td>
</tr>
<tr>
<td>Time of Nodal Crossing</td>
<td>6AM / 6PM</td>
<td></td>
</tr>
<tr>
<td>Polarization</td>
<td>Single (SP), Dual (DP), Circular (CP), Quad (QP) and Quasi-quad pol (QQP)</td>
<td>Quadrature (Quad) and Quasi-quad pol (QQP)</td>
</tr>
<tr>
<td>Incidence angle range</td>
<td>33 – 47 deg</td>
<td></td>
</tr>
<tr>
<td>Available Range Bandwidths</td>
<td>5 MHz, 20 MHz, 40 MHz, 80 MHz</td>
<td>10 MHz, 25 MHz, 37.5 MHz, 75 MHz</td>
</tr>
<tr>
<td>Resolution (Azimuth × Slant range)</td>
<td>6.9m × 7.5m (for 20MHz bw)</td>
<td>6.4m × 6m (at 25MHz bw)</td>
</tr>
<tr>
<td></td>
<td>6.9m × 1.9m (for 80MHz bw)</td>
<td>6.4m × 2m (for 75MHz bw)</td>
</tr>
<tr>
<td>Max. Swath width</td>
<td>&gt; 240 Km</td>
<td></td>
</tr>
<tr>
<td>Data and Product Access</td>
<td>Free &amp; Open</td>
<td></td>
</tr>
</tbody>
</table>
NISAR Mission Objectives

Key Scientific Objectives:
• Understand the response of ice sheets to climate change and the interaction of sea ice and climate
• Understand the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems
• Determine the likelihood of earthquakes, volcanic eruptions, and landslides

Key Applications Objectives:
• Understand societal impacts of dynamics of groundwater, hydrocarbon, and sequestered CO₂ reservoirs
• Provide agricultural monitoring capability in support of food security objectives
• Apply NISAR’s unique data set to explore the potentials for urgent response and hazard mitigation

To be accomplished in partnership of ISRO and NASA through the joint development and operation of a space-borne, dual-frequency, polarimetric, synthetic aperture radar (SAR) satellite mission with repeat-pass interferometry capability
### NISAR Science Observation Overview

- Wide swath in all modes for global coverage at 12 day repeat (2-5 passes over a site depending upon latitude)
- Data acquired ascending and descending

<table>
<thead>
<tr>
<th>NISAR Characteristic:</th>
<th>Would Enable:</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-band (24 cm wavelength)</td>
<td>Low temporal decorrelation and foliage penetration</td>
</tr>
<tr>
<td>S-band (9 cm wavelength)</td>
<td>Sensitivity to light vegetation</td>
</tr>
<tr>
<td>SweepSAR technique with Imaging Swath &gt; 240 km</td>
<td>Global data collection</td>
</tr>
<tr>
<td>Polarimetry (Single/Dual/Quad)</td>
<td>Surface characterization and biomass estimation</td>
</tr>
<tr>
<td>12-day exact repeat</td>
<td>Rapid Sampling</td>
</tr>
<tr>
<td>3–10 m mode-dependent SAR resolution</td>
<td>Small-scale observations</td>
</tr>
<tr>
<td>3 years science operations (5 years consumables)</td>
<td>Time-series analysis</td>
</tr>
<tr>
<td>Pointing control &lt; 273 arcseconds</td>
<td>Deformation interferometry</td>
</tr>
<tr>
<td>Orbit control &lt; 500 meters</td>
<td>Deformation interferometry</td>
</tr>
<tr>
<td>&gt; 30% observation duty cycle</td>
<td>Complete land/ice coverage</td>
</tr>
<tr>
<td>Left/Right pointing capability</td>
<td>Polar coverage, north and south</td>
</tr>
</tbody>
</table>

![Observation Geometry](image)

- NISAR Will Uniquely Capture the Earth in Motion
- 747 km Earth surface
- Observation Geometry
- 6 AM / 6 PM

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NISAR Program on SAR Data Processing and Analysis for Land Applications, Aug 6, 2018
NISAR Systematic Observations

Persistent updated measurements of Earth

Note: conceptual plan – does not reflect current detailed plan

No target conflicts: overlapping targets uses union of all modes specified

Colors indicate different radar modes

Repeated every 12 day cycle for the life of the mission

C. Ballard, JPL
NISAR
Mode-Specific Science Targets in Observation Plan

- Each colored region represents a single radar mode chosen to satisfy multiple science objectives over that area
- Avoids mode contention that would interrupt time series

Background Land satisfies most Solid Earth and Ecosystems objectives

Planned Acquisitions
- Background Land
- Land Ice
- Sea Ice
- Urban (small targets)
- US Agriculture
- Himalayas
- India Agriculture
- India Coastal Ocean
- Sea Ice Type
NISAR: Proposed Applications

1. **Ecosystem Structure:** 1.1 Agriculture Biomass & Crop Monitoring; 1.2 Forest Biomass; 1.3 Biomass Change; 1.4 Mangroves / Wetlands; 1.5 Alpine Vegetation; Vegetation Phenology and Vulnerability; Vegetation soil moisture; Ecosystem stress assessment.

2. **Land Surface Deformation:** 2.1 Inter-seismic / Co-seismic Deformations; 2.2 Landslides; 2.3 Land Subsidence; 2.4 Volcanic Deformations

3. **Cryosphere:** 3.1 Polar Ice Shelf / Ice sheet; 3.2 Sea Ice Dynamics; 3.3 Mountain Snow/ Glacier 3.4 Glacier Dynamics (Himalayan Region); Glacier hazards; Climate response to glaciers; Sea–Ice advisory on safer marine navigation in Antarctica region.

4. **Coastal Studies & Oceanography:** 4.1 Coastal erosion / shoreline change; 4.2 Coastal subsidence and vulnerability to sea-level rise; 4.3 Coastal bathymetry; 4.4 Ocean surface wind; 4.5 Ocean wave spectra; 4.6 Ship detection; Possible use of SAR for tropical cyclone; Coastal watch services

5. **Disaster Response:** 5.1 Floods; 5.2 Forest Fire; 5.3 Oil Spill; 5.4 Earthquakes / Others

6. **Geological Applications:** 6.1 Structural & Lithological mapping; 6.2 Lineament mapping; 6.3 Paleo-Channel study; 6.4 Geomorphology; Land degradation mapping; Geo-archaeology; Mineral explorations
ISRO Targets over India and Surroundings

These exclude polar targets

- India + neighbors boundary
- Agriculture/Forest/wetland
- Jute crop
- Alpine forest
- Seismic Deformation
- Land Subsidence
- Landslide
- Urban subsidence
- Volcanic deformation/studies
- Coastal region (sea 300km)
- Coastal habitat
- Coastal deformation
- Coastal mud bank
- Coastal region (land, 100 km)
- Ocean – Arabian Sea
- Ocean – Bay of Bengal
- Disaster – floods
- Disaster – forest fire
- Disaster – oil slick
- Cryosphere - Himalayas
ISRO Observation Plan

Important Obs. Modes

Background Land (Systematic Coverage)
- **S (DP/CP) 37.5/25 MHz**: Period of Obs. Jan – Dec; All 30 cycles
- **L (DP) 20+5 MHz**

Agriculture, Forest & Wetland
- **S (CP) 25 MHz**: Jan – Nov; 16/30 cycles
- **L (QP) 40+5 MHz**

Coasts / Coastal Ocean
- **S (CP) 25 MHz**: Jan – Dec; Every Alternate cycles
- **L (VV+VH) 20+5 MHz**

Indian Ocean
- **S (DP-VV+HV) 10 MHz**
- **L(SP) 5 MHz**
- **BoB: Jun – Dec; All cycles**
- **Arabian Sea: Apr- Sep; All cycles**

Indian Ocean
- **S (DP) 37.5 MHz; L (DP) 20+5 MHz**
- **Jan – Dec; Every Alternate cycles**

High Resolution Urban / Landslide
- **S (SP) 75 MHz; L (DP) 40+5 MHz**

Deformation Studies
- **S (DP) 37.5 MHz; L (DP) 20+5 MHz**
- **Jan – Dec; Every Alternate cycles**

Ice Charactn (Ant; Svalbard; Bohai)
- **S (CP) 25 MHz**: Oct-Apr (Antarctica); Dec-May (Svalbard & Bohai)
- **L (VV+VH) 20+5 MHz**

High Resolution Urban / Landslide
- **S (DP) 37.5 MHz; L (DP) 20+5 MHz**
- **Jan – Dec; Every Alternate cycles**

Polar Region (Antarctica + Greenland)
- **S (CP) 25 MHz**: Dec-May (Antarctica); Dec-May (Svalbard & Bohai)
- **L(SP) 80 MHz**
- **Ant: Every/ alternate cycle; Greenland: every cycle**

Background Land
- Agriculture & Forest
- Coastal Applications
- Ocean Applications

Deformation Monitoring
- Disaster Management
- Himalayan Snow & Glacier

Polar Science (ISRO targets)
- Polar Science (ISRO+ Joint targets)

**ISRO Observation Plan**

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- **L(SP) 80 MHz**
- **Ant: Every/ alternate cycle; Greenland: every cycle**
## Possible Observation Scenario over ISRO Targets

(Coloured bars show different imaging modes and period of observation)

<table>
<thead>
<tr>
<th>ISRO Targets</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
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<tbody>
<tr>
<td>Systematic Coverage (Background Land)</td>
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<td>Deformation - Seis/subs/volc</td>
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<td>Disaster - oil spill</td>
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<td>Disaster - forest fire</td>
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<td>Disaster - flood</td>
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<td>Coastal Ocean (Coastline Buffer)</td>
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<tr>
<td>Ocean - Arabian sea</td>
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<td>Ocean - Bay of Bengal</td>
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<tr>
<td>Svalbard + Bohai Bay (NH)</td>
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<tr>
<td>Antarctica (Ice Characterization)</td>
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<tr>
<td>Land Ice - Greenland Mosaic (Dec - Mar)</td>
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</tbody>
</table>

### Colour Scheme for Obs. Modes

- **S (CP) 25 MHz; L (DP) 20+5 MHz**
- **S (DP) 37.5 MHz; L (DP) 20+5 MHz**
- **S (CP) 25 MHz; L (VV+VH) 20+5 MHz**
- **S (DP: VV+VH) 10MHz; L (VV) 5MHz**
- **S (CP) 25 MHz; L (SP) 80 MHz**
- **S (CP) 25 MHz; L (QP) 40+5 MHz**
- **S (SP) 75MHz; L (HH+HV) 40+5 MHz**

Each smallest box represents 6 days. 2 adjacent boxes jointly show one observation cycle (12 days) of NISAR.

Antarctica is considered up to 87.5° S latitude in view of Left-looking only NISAR orbit.
<table>
<thead>
<tr>
<th>THEME</th>
<th>Parameter</th>
<th>ROI</th>
<th>Validation Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oceanography</strong></td>
<td>Coastline change</td>
<td>Andhra Coast</td>
<td>To be validated using optical and <em>in-situ</em> data</td>
</tr>
<tr>
<td></td>
<td>Ship detection</td>
<td>North Indian Ocean</td>
<td>To be validated using optical/DG-Shipping Corporation data</td>
</tr>
<tr>
<td></td>
<td>Oil-spill/dark spot detection</td>
<td>Indian coastal region</td>
<td>To be validated using optical/ <em>in-situ</em> (if possible) data</td>
</tr>
<tr>
<td><strong>Mountain, Snow and glacier</strong></td>
<td>Glacier ice-velocity product</td>
<td>Bench-mark glaciers</td>
<td></td>
</tr>
<tr>
<td><strong>Geological Studies</strong></td>
<td>Mineral map</td>
<td>Selected sites in Rajasthan, Jharkhand etc.</td>
<td>To be validated through structural data collection in the field</td>
</tr>
<tr>
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<td></td>
<td>Mineral potential of structures shall be validated using geochemical analysis (XRD and Spectroscopy)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>For palaeochannel studies, GPR, DGPS and resistivity survey on palaeochannels and also detailed ground truth data collection</td>
</tr>
<tr>
<td><strong>Coastal applications</strong></td>
<td>Coastal land cover map</td>
<td>Coastal regions in Gujarat, Maharshta and Andhra Pradesh</td>
<td>Using ground truth data and ancillary data (published thematic map)</td>
</tr>
<tr>
<td><strong>Ecosystems agriculture</strong></td>
<td>Radar vegetation index</td>
<td>Selected regions in Gujarat, Indo-Gangetic plains, sites in Tamilnadu etc.</td>
<td>Validation through vegetation water content and ancillary data</td>
</tr>
<tr>
<td></td>
<td>Radar Roughness index</td>
<td></td>
<td>Through <em>in-situ</em> measurements and other sensors</td>
</tr>
<tr>
<td></td>
<td>Surface Soil moisture content</td>
<td></td>
<td>Validation through biomass and backscattering model</td>
</tr>
<tr>
<td></td>
<td>Vegetation optical depth</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hydrology studies</strong></td>
<td>Soil moisture, flood inundation</td>
<td>Kosi, Godavari, Mahanadi delta, Bikaner Rajasthan</td>
<td>Soil moisture measurements, Ground truth data for inundation, resistivity survey for perched aquifers.</td>
</tr>
<tr>
<td><strong>Ecosystems forests</strong></td>
<td>Forest Cover and Change Detection</td>
<td>Selected forests in India</td>
<td>By ground truth and published information from respective ministries</td>
</tr>
<tr>
<td></td>
<td>where change is &gt;50%</td>
<td></td>
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</tr>
<tr>
<td><strong>Soil moisture</strong></td>
<td>Surface Soil Moisture (SSM)</td>
<td>Selected core study sites over India (Gujarat, Karnataka, MP, UP and Raj. etc.)</td>
<td>To be validated using <em>in-situ</em> soil moisture stations, field campaign and satellite data products with models</td>
</tr>
</tbody>
</table>
CALIBRATION SITES (Point target Sites)

International Point Target Sites
- Rosamond CR array, California, USA
- Australian CR array, Queensland

Distributed Target Sites
- Amazon rainforest
- Congo rainforest

IMGEOS, Shadnagar
Desalpar, Rann of Kutch
Ahmedabad
Amrapura, Little Rann of Kutch
Indian Sites

- It is planned to permanently deploy different types and sizes of corner reflectors at additional sites (educational institutes, regional remote sensing centres) in each state of India to cover all the beams of S-band.

- In the first phase, permanent deployment of CRs in six Indian states (Gujarat, West Bengal, Rajasthan, Chhatisgarh, Karnataka and Madhya Pradesh) has been initiated.

- For L-band beams, campaign modes will be carried out in various Indian sites in joint-mode with S-band for the external calibration.

International Sites

- It is planned to develop point target site at Antarctica (near Indian stations Bharti and Maitri).
## L&S band Airborne SAR System Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform</td>
<td>Beech craft B-200</td>
</tr>
<tr>
<td>Aircraft Height</td>
<td>8.0 kms</td>
</tr>
<tr>
<td>Platform Velocity</td>
<td>120 m/s</td>
</tr>
<tr>
<td>Operating Frequency</td>
<td>1250MHz (L) &amp; 3200MHz (S)</td>
</tr>
<tr>
<td>Chirp Bandwidth</td>
<td></td>
</tr>
<tr>
<td>Resolution - (Az X SL)</td>
<td></td>
</tr>
<tr>
<td>Chirp Bandwidth</td>
<td>10MHz</td>
</tr>
<tr>
<td>Chirp Bandwidth</td>
<td>25MHz</td>
</tr>
<tr>
<td>Chirp Bandwidth</td>
<td>50MHz</td>
</tr>
<tr>
<td>Chirp Bandwidth</td>
<td>75MHz</td>
</tr>
<tr>
<td>Resolution - (Az X SL)</td>
<td>2m X 15m</td>
</tr>
<tr>
<td>Resolution - (Az X SL)</td>
<td>2m X 6m</td>
</tr>
<tr>
<td>Resolution - (Az X SL)</td>
<td>2m X 3m</td>
</tr>
<tr>
<td>Resolution - (Az X SL)</td>
<td>2m X 2m</td>
</tr>
<tr>
<td>Sampling Frequency (MHz)</td>
<td>250 (Output Samples decimated according to bandwidth)</td>
</tr>
<tr>
<td>SAR Mode</td>
<td>Stripmap</td>
</tr>
<tr>
<td>Polarization Modes</td>
<td>Single Quasi-Quad Pol Dual Pol Compact(CP) Full Pol</td>
</tr>
<tr>
<td>Effective Antenna dimensions</td>
<td>1.0m (Azimuth) x 0.35m (Elevation)</td>
</tr>
<tr>
<td>Antenna Configuration</td>
<td>Co-Located</td>
</tr>
<tr>
<td>Antenna Roll Bias</td>
<td>37° - Nominal</td>
</tr>
<tr>
<td>Antenna Roll Bias</td>
<td>51°</td>
</tr>
<tr>
<td>Antenna Roll Bias</td>
<td>64°</td>
</tr>
<tr>
<td>Imaging Swath (S+L)</td>
<td>5.9km @ 37°</td>
</tr>
<tr>
<td>Imaging Swath (S+L)</td>
<td>10km @ 51°</td>
</tr>
<tr>
<td>Imaging Swath (S+L)</td>
<td>15km @ 64°</td>
</tr>
<tr>
<td>Imaging Time (Nominal)</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Imaging Sessions / Flight</td>
<td>5</td>
</tr>
<tr>
<td>Integrated Ambiguities</td>
<td>&lt; -20dB</td>
</tr>
<tr>
<td>Sigma Naught Threshold</td>
<td>&lt; -20dB</td>
</tr>
<tr>
<td>Radiometric Resolution</td>
<td>3dB-Single Look</td>
</tr>
<tr>
<td>RF Power Transmit</td>
<td>40W (L) &amp; 165W (S)</td>
</tr>
<tr>
<td>Incidence Angle Range</td>
<td>24° to 77°</td>
</tr>
</tbody>
</table>

Any bandwidth can be combined with any polarization mode at all three roll bias angles. This makes total possible imaging combinations as $4 \times 5 \times 3 = 60$. 
L&S band Airborne SAR Campaign

Sites Planned for Airborne Campaign

Summary of Project Proposals submitted under A.O

Total proposals: 75
Institutions: 45

Total sites: 66
Scientific Plan and Research Announcement for L&S Airborne SAR

Region-wise distribution of Project Proposers

Airborne SAR R.A. Project Proposal Statistics:
77 Proposals; 45 Institutions

List of Participating Institutions:

1. ADRIN - Secunderabad
2. All Saint's college, Trivandrum
3. Amity University, NOIDA, UP
4. Anand Agricultural University
5. Andhra University, Hyderabad
6. APSAC, Vijaywada
7. BITS-Pilani, Hyderabad
8. Central University, Gujarat
9. Central University, Jharkhand
10. CEPT University, Ahmedabad
11. Dharwad College of Forestry, Karnataka
12. IARI, New Delhi
13. IIRS - Dehradun
14. IISSc-Bangalore
15. IISER, Bhopal
16. IIT, Kharagpur
17. IIT, Madras
18. IIT, Mumbai
19. IIT, Roorkee
20. IIT, BHU
21. Jadavpur University, Kolkata
22. Jain University, Bangalore
23. Jyothi Institute of Technology, Bangalore
24. M G Science Institute, Ahmedabad
25. Milliya Arts, Science & Management Science College, Beed
26. MS Univ, Baroda
27. Naval Physical and Oceanographic Laboratory
28. NGRI, Hyderabad
29. Nirma Univ, Gujarat
30. NIT, Kurukshtetra
31. NIT, Raipur
32. NRSC - Hyderabad
33. Odisha Space Applications Centre
34. PDPU, Gandhinagar
35. Punjab Remote Sensing Centre, Ludhiana
36. RRSC-East
37. RRSC-West
38. SAC - Ahmedabad
39. SASE, Chandigarh
40. SDSIC, SHAR, ISRO
41. University of Petroleum and Energy Studies, Noida
42. Vidyalankar Institute of Technology, Mumbai
43. Vidyasagar University, Midnapore
44. VIT University, Vellore
45. BIT-Mesra, Ranchi

TREES Program on SAR Data Processing and Analysis for Land Applications, Aug 6, 2018
• First Phase of imaging over Gujarat region completed in June 2017
• Data Processed and given for security clearance
• Second phase over Orissa, West Bengal, Hyderabad sites are planned in Oct-Nov 2017
L&S Band Airborne SAR Flight Campaign

Phase 1: (June 2017)
Area: Gujarat Sites (8 nos)
Base: Ahmedabad

Phase 2: (Feb 2018)
Area: Orissa/Westbengal/Andhra/Telegana Sites (6 nos)
Base: Bhubneshwar & Hyderabad

- Ground truth was collected along with the flights

Themes Covered:
- Agriculture
- Soil Moisture Study
- Urban Applications
- Hydrology/Flood Mapping
- Wetland Mapping
- Coastal Applications
- Oceanography
- Mangroves
- Geological Applications
- Forest

Present Status:
- Security vetting of the Phase 1 data is under progress. Expected to released to user by June 2018.
- Phase 2 data is processed and given for Security vetting
Gulf of Khambhat

- Mangrove (a)
- Reclaimed mudflat with mud dumping (b)
- Aquaculture Pond
- Reclaimed tidal channel
- Bank erosion (c)
- Embankment (d)
- Intertidal mudflat with mangrove
SALT PANS
L&S Band Images over Gulf of Khambat

L-Band

S-Band