Roddam Narasimha Distinguished Lecture

Space Technology

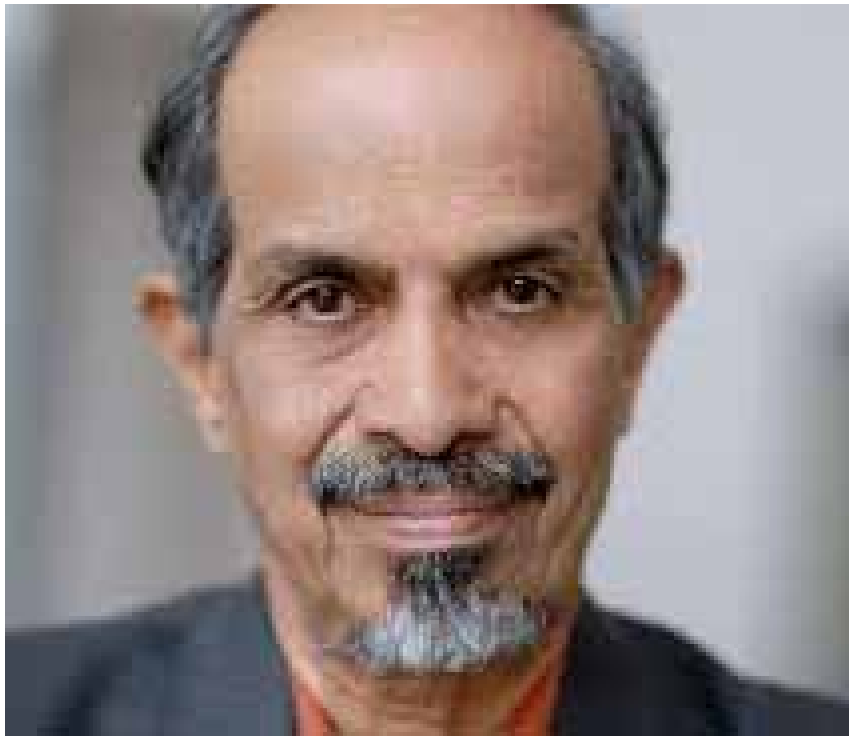
CONTRIBUTION TO INDIA'S DEVELOPMENT

AS Kiran Kumar

Chairman, Space Commission
Secretary, Department of Space
Chairman, Indian Space Research Organization

Indian Institute of Technology, Gandhinagar

August 10, 2016

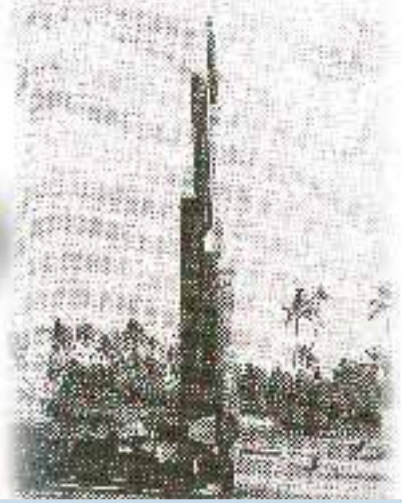


- Associated with Aerospace Technology development in the country.
- Chairman of Expert Review Panel of ASLV-D2.
- Monte Carlo (MC) simulations to meet ISRO's requirements during its inception period.
- Former Member of Space Commission.
- Co-chaired Joint Scientific Working Group for the Indo-French atmospheric research satellite Megha Tropiques.
- Outstanding teacher, a world class researcher, a dynamic leader, and a builder of institutions.

4th Oct 1957

India launches a rocket from its soil in the 6th year of the Space Age.

23rd Nov 1963



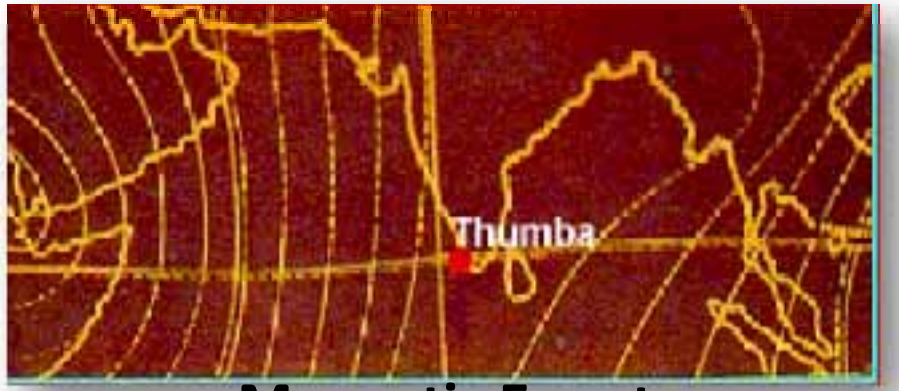
Timely Synergy of the National Vision with the Science & Technology Vision

Zero Infrastructure → Self-Reliant Space Infrastructure

Space Technology for development of the Nation

Research on Equatorial Electrojet & Upper Atmospheric Dynamics

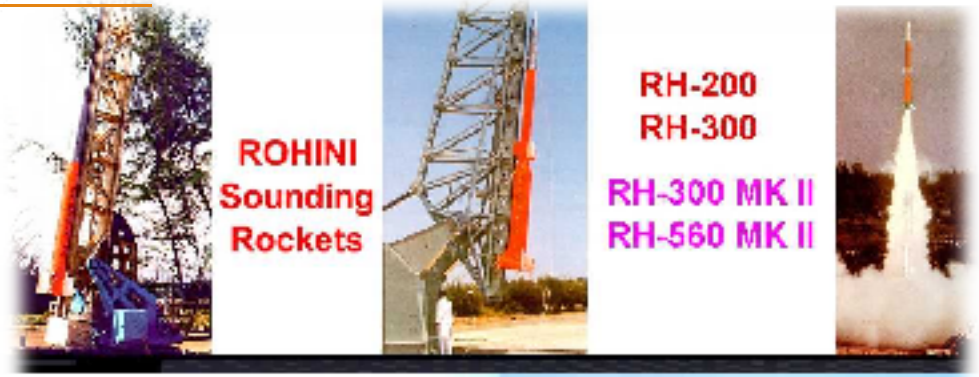
COSPAR Programme: Sounding Rockets for scientific measurements from International Rocket Launching Sites



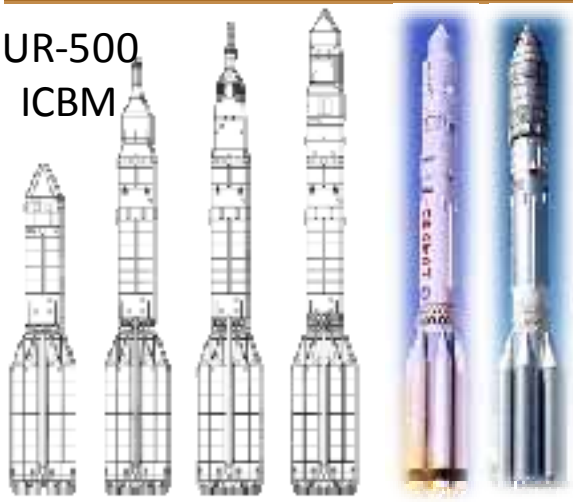
Magnetic Equator

Fishing Hamlet to a Premier Space Research & Launching Station

STEPPING STONE TO LAUNCH VEHICLE TECHNOLOGY



Space Technology Diffusion through Upper Atmospheric Research



PROTON (Russia)

Approach by Leading Space Faring Nations

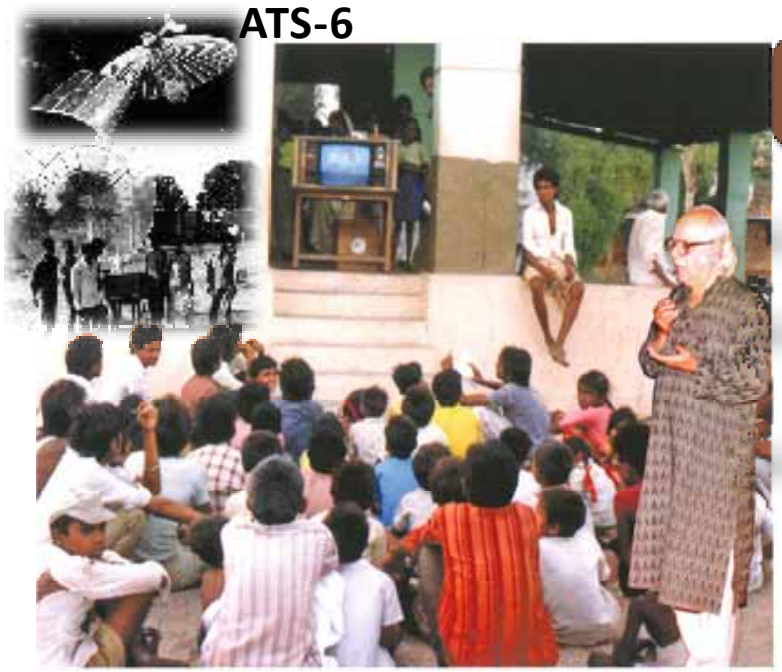
TITAN (USA)

MISSILES → **LAUNCH VEHICLES** → **SATELLITES** → **APPLICATIONS**

REVERSED TIMELINE APPROACH ADOPTED BY INDIA

LAUNCH VEHICLES ← **SATELLITES** ← **APPLICATIONS**

The Indian Approach



SATELLITE INSTRUCTIONAL TELEVISION EXPERIMENT

SITE 1975-76

- **2400** Remote Rural Villages
- Instructional programmes in agriculture, primary education, teacher training & family planning.
- Involvement of social scientists, economists, educationists and theatre artists

Largest Mass Communications Experiment ever carried out in the World

Paved the way for the INDIAN SATELLITE SYSTEM (INSAT)

The backbone of satellite communication in India

SATELLITE TELECOMMUNICATION EXPERIMENTAL PROJECT

STEP 1977-79

- Understanding problems associated with space & ground systems for telecommunication.

Capability for disaster warning systems, radio networking and transportable terminals.

Creating the First Space Applications for Societal Development

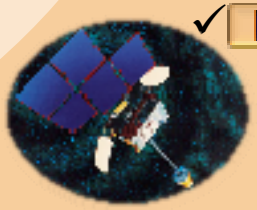
APPLE | INSAT-1 Series | INSAT-2 Series | INSAT-3 Series | INSAT-4 Series

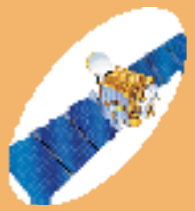
1st GEO Satellite

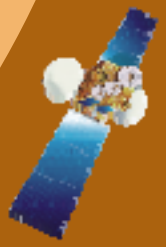
Max. applications in minimum time

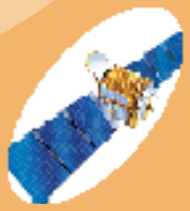
Multipurpose

- ✓ Telecom
- ✓ Broadcasting
- ✓ Meteorology









Built to ISRO specifications thru' foreign collaboration

TV Broadcasting

Built Indigenously

VSAT Services

INSAT-3D

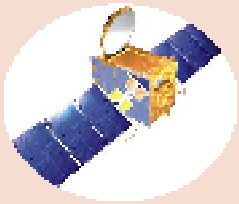
MET

DTH Services

MSS Services

High Power

Dual Gridded antennas



Hylas-1

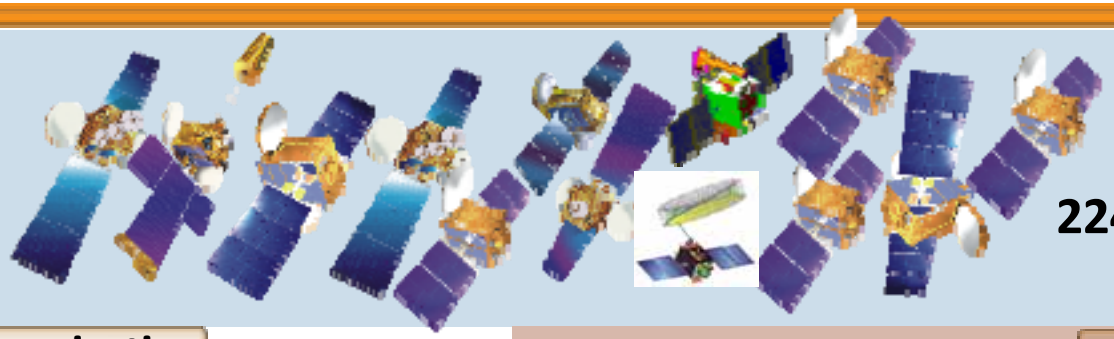
W2M

Commercial Opportunities to build satellites for customers

Building Capability for Communication Satellites

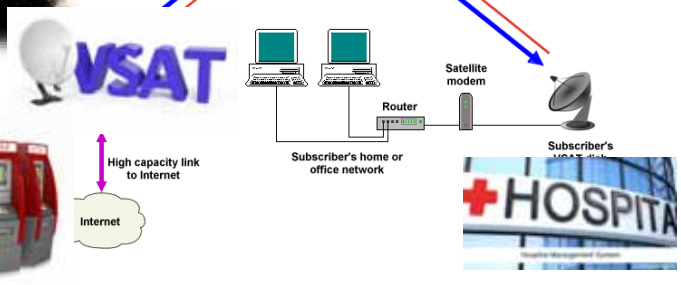
INSAT series

GSAT Series



13 satellites
224 Transponders

VSAT/Business Communication

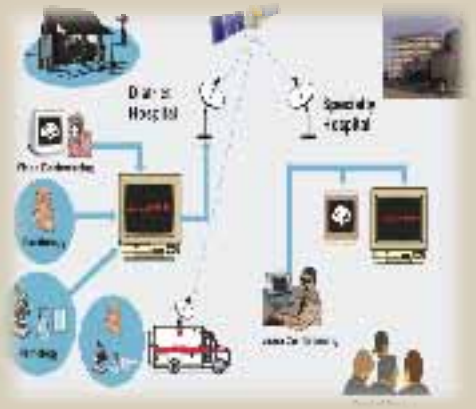


DTH & Broadcast

41 Million
Active DTH
Subscribers

Societal Development

Dedicated satellite
for Tele - education

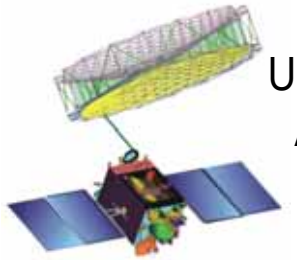


Telemedicine

Advanced Communication

Multiband
Communication

GSAT-7

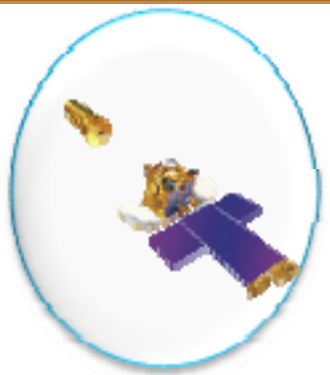


Unfurlable
Antenna

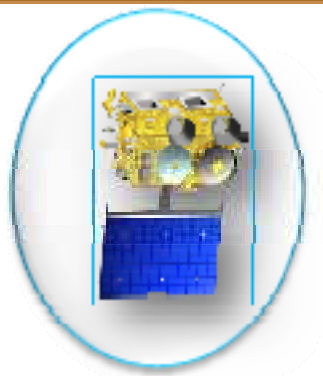
GSAT-6

Critical Services through Indigenous Communication Satellites

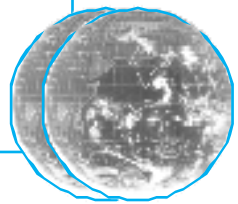
2 to 3 bands



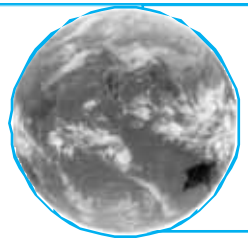
3 to 6 bands



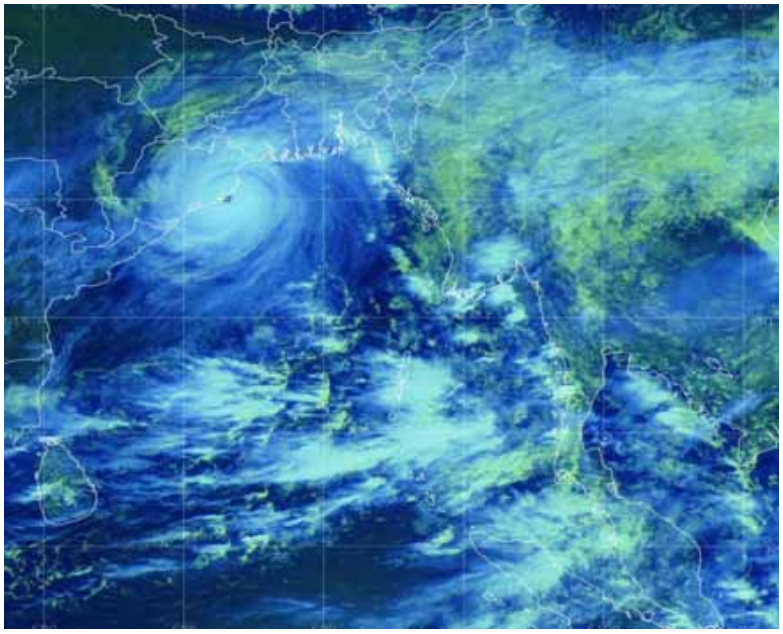
INSAT 1 Series (1983)
2 Bands (8 km)
4 images per day



INSAT 2 Series (1990)
3 Bands
4 images per day



INSAT 3 Series (2013)
6 Bands (1 km)
19 Channel Sounder
48 images per day

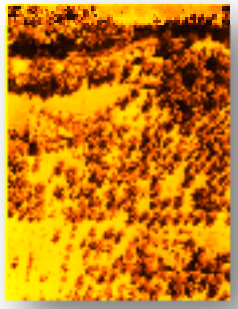


- Feeding to Weather Forecasting service

- Initially, the meteorological process software was taken from Canada
- Currently, the processing capabilities are indigenously developed and operationalised.

Complete Ecosystem for Weather Forecasting

1968	1970	1974-76	1979
Remote Sensing proposed as a tool for national development	Detecting Coconut Root Wilt Disease Study	Crop Yield Assessment Anantapur, AP Patiala, Punjab	LANDSAT Data Reception Centre

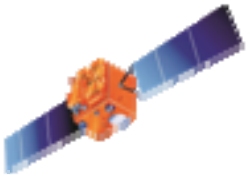
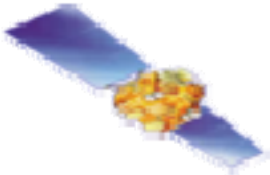


Agricultural **R**esources **I**nventory & **S**urvey **E**xperiment

Demonstration studies using LANDSAT-1 &2 Data.

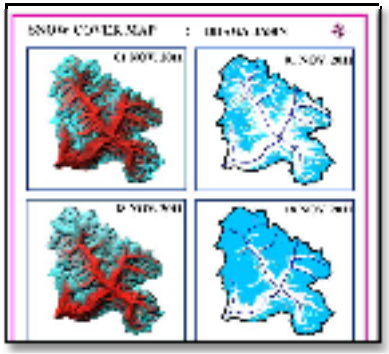
BUILDING APPLICATIONS

BUILDING SATELLITES

Bhaskara-1	IRS Series	Oceansat Series	Resourcesat Series	Cartosat Series	RISAT Series
					
1979	1988	1999	2003	2005	2012

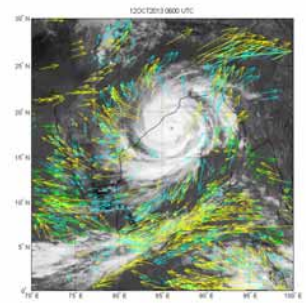
12 Satellites for Earth Observation – One of the global leaders in EO & Remote Sensing

Building Capability for Earth Observation & Remote Sensing



Monitoring of Glaciers and Snow

- Glacier Retreat
- Snow-melt Runoff Forecasting
- Input to Climate Change



Weather and Climate

- Ocean State forecast
- Sea Surface Temperature
- Sea Surface Heights
- Heat wave predictions

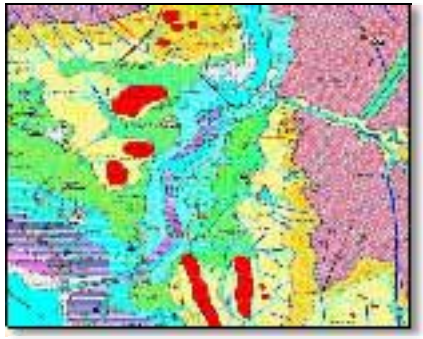
Area & Production estimation

- In-season multiple forecast
- Satellite data + agro-meteorology + market economics

- **Potential Fishing Zone** based on Chlorophyll & Sea Surface Temperature.

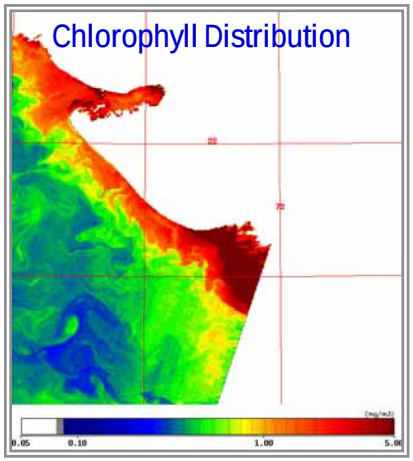
✓ Search time reduction by 60-70%
✓ Average catch per unit effort increased 2-4 times.
✓ Net profit increase by 2-5 times

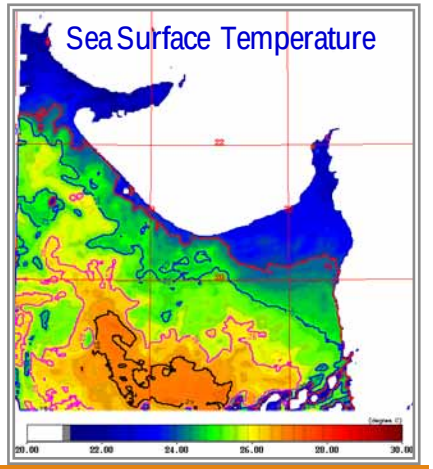
- Ground station established at Indian National Centre for Ocean Information Services (INCOIS) for enabling near real time generation of fishery forecasts.



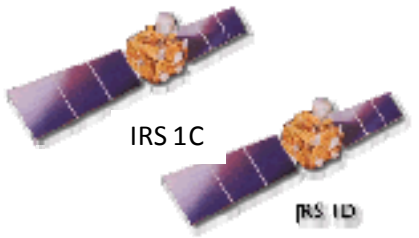
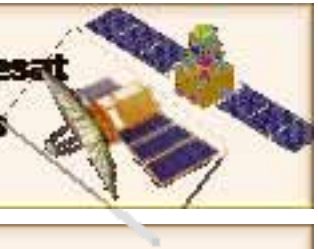
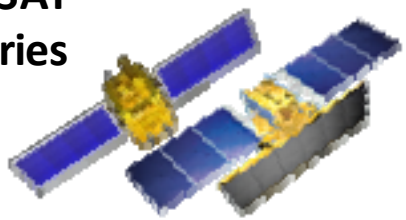
Groundwater prospect zones & Recharge Sites

- 90 -95% Success rate for Borewells
- Increased Water level

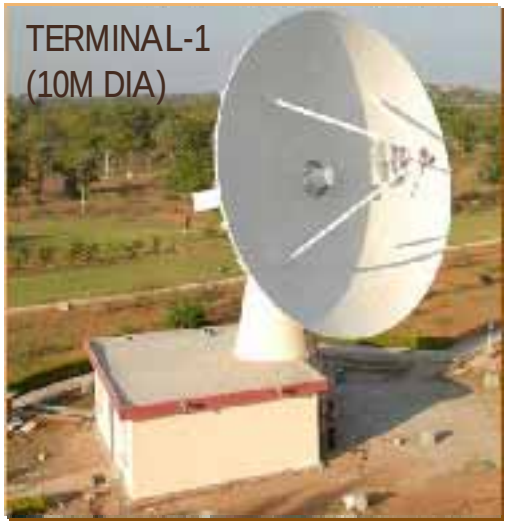




Vital National Development using Remote Sensing Data

Identification of crops in multi-cropped Regions	Better Spatial Resolution	
Detecting and quantifying moisture stress and snow-cloud discrimination	Short Wave Infrared band (SWIR)	
Ability to discriminate smaller differences in radiance values of earth surfaces(crop, snow etc)	Better Radiometric Resolution	Resourcesat series 
Applications in urban mapping, infrastructure projects and watersheds.	High spatial resolutions of 1 – 2m and stereo	Cartosat series 
Limited usability of optical remote sensing during June-Sep (Kharif) due to monsoon cloud cover & estimation of soil moisture.	Synthetic Aperture Radar (SAR) (All weather capability)	RISAT series 
Simultaneous measurement of sea surface temperature with ocean color (Fishing zones), Deriving ocean winds Sea surface height	Space borne sensors in narrow spectral bands with high radiometric sensitivity Ku-band Scatterometer Ka-Band Altimeter	Oceansat series  SARAL

Applications ⇨ Technological Capability ⇨ Satellites



ISRO established Earth Station Complex at Annaram Village, Shadnagar in 1979 to receive Landsat Data

Evolution of Data Processing Systems

Automated Operations

IRS-RS-1/RS-2/C1/C2/RISAT
1000+ products/day

IRS-2C/2D/P4
100 products/day

IRS-1C/1D
50 products/day

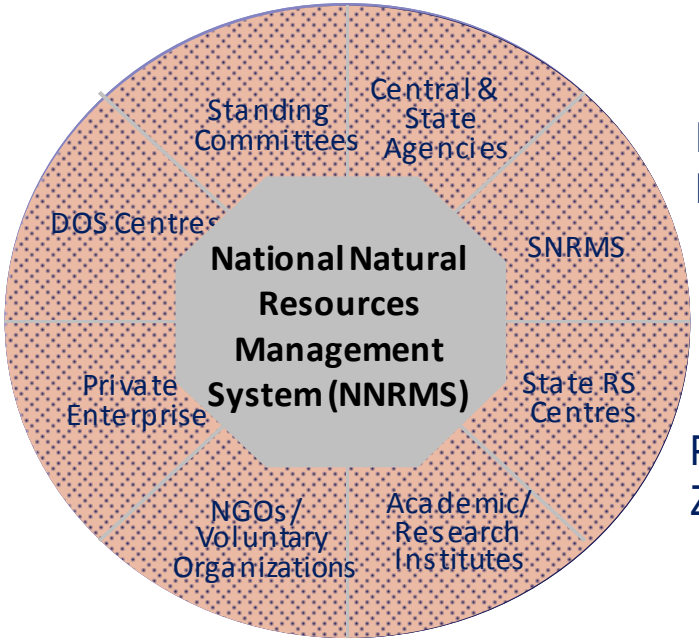
Manual Operations

IRS-1A / 1B
45 products /day

Landsat
30 Products/day

2017	Ka Band Reception	
2011	Multi-mission IMGEOS Four 7.5m antennae	
2007	7.5m Antenna, Dual Polarisation X band	2 x 320 Mbps SAR
2004	7.5 meter (Indigenous) S, X Bands	2x105 Mbps LISS IV
1987	10 meter Antenna; S, X Bands With Indigenous Feed	2 x 84 Mbps PAN
1983	10 meter Antenna; S Band	84 Mbps LISS-2
1979	10 meter Antenna; L,S Bands	

Building Capability in Satellite Data Acquisition



Started in 1983

16000 trained human resources in last 25 years, need to make the capacity building plans:

- School Children to Administrator
- Video module to Classroom

MoEF&CC
Biennial State of Forest Report

FSI 1987

- Visual to Digital Interpretation
- 1:1 million to 1:50,000 scale

MoES
Potential Fishing Zone Advisory

INCOIS 1999

- Reduced Search Time (60-70%)
- Increased Catch (2-4 times)
- Increased Net Profit (2-5 times)

MoA
Multiple Forecasts for 11 Crops
Drought Assessment for 14 states

MNCFC 2012

- Optical & Microwave Integrated
- NOAA AVHRR to Resourcesat AWiFS

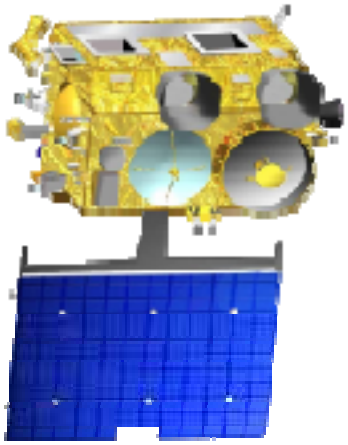
MoWR,RD&GR
Sedimentation Survey, Irrigation Infrastructure Monitoring,…

RSD 1978

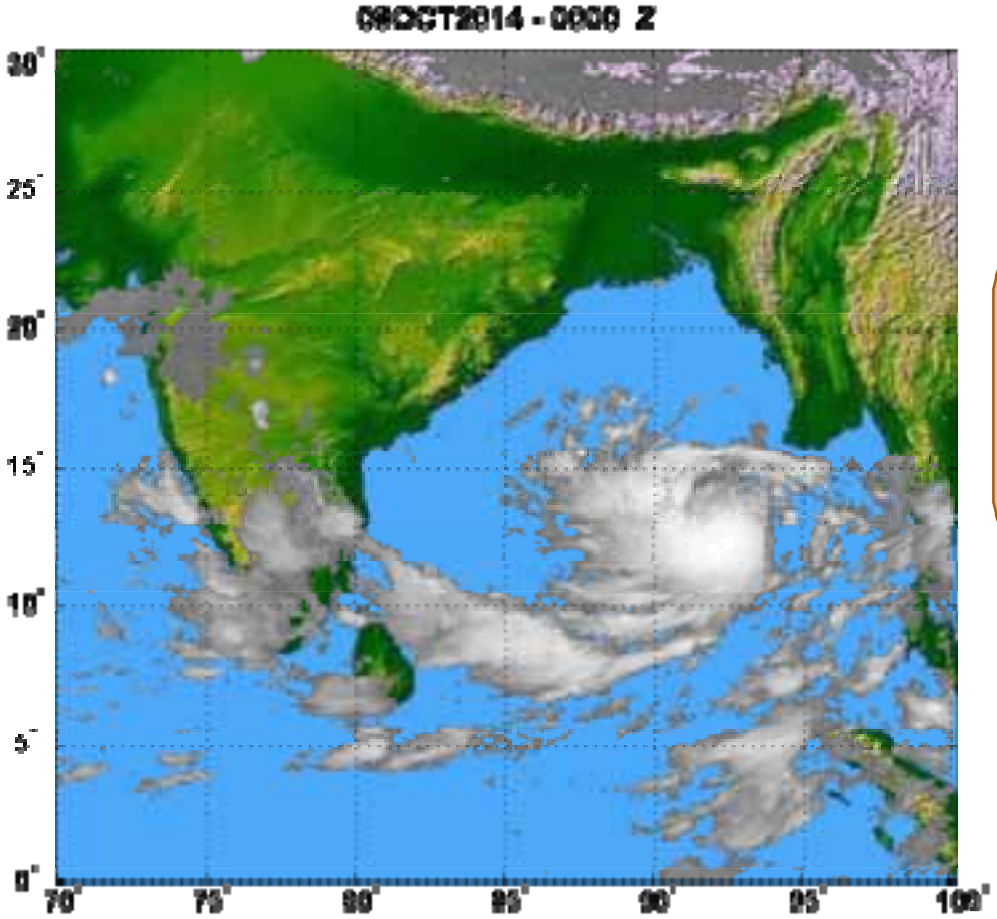
- India-WRIS Web Portal to National Water Resources Informatics Centre

FOOD ,WATER & SHELTER SECURITY | **ENERGY SECURITY** | **HEALTH SECURITY** | **INFRASTRUCTURE SECURITY** | **INFORMATION SECURITY**

INTERNALIZATION & INSTITUTIONALISATION



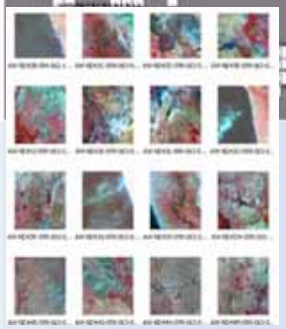
INSAT -3D
2013
VNIR
Augmenting the INSAT VHRR



Tropical Cyclone HUDHUD Track Monitoring

Real Time Prediction of Cyclones

- **Temperature and Humidity Profile Measurements to improve weather forecasting**
- **Rainfall rate & humidity profile during cloud cover**
- **Aerosol optical depth**



2016-17
0.6m Color multispectral images
Yearly update of 1m HR data

2014-15
1m Color mosaic >
260 Indian Cities

2013
2.5m Color mosaic
for Indian states

2011
NOEDA Tiles
(AWiFS and LISS-3 Tiles)

2010
Global coverage with 50m
(50m – AWiFS Global mosaic)

2009
Upto 5m for
Indian region
(5m – Synthetic L4MX
24m – L3 full India
50m – AWiFS full India)

Building Capability in Cartography

CYCLONE
- Damage Assessment
- Landfall Prediction
- Early Warning

FLOODS
- Inundation Mapping
- Hazard Zonation
- Early Warning

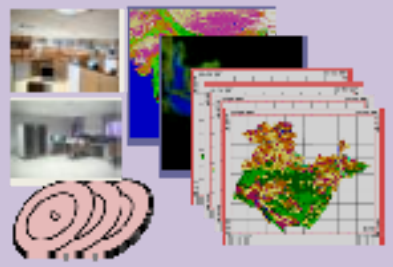
FOREST FIRE
- Fire Detection
- Fire Alert (within 30 min. of acquisition)

LANDSLIDE
- Inventory
- Early Warning

EARTHQUAKE
- Damage Assessment

Observational Systems
Satellites, Aerial, Ground

Multi-tier databases
With decision tools



Single Window
Services Delivery

Emergency Communication

- **Virtual Private Network**
- **Satellite Phones**
- **Distress Alert Terminal**
- **DTH based Warning System**

Kedarnath - 2013

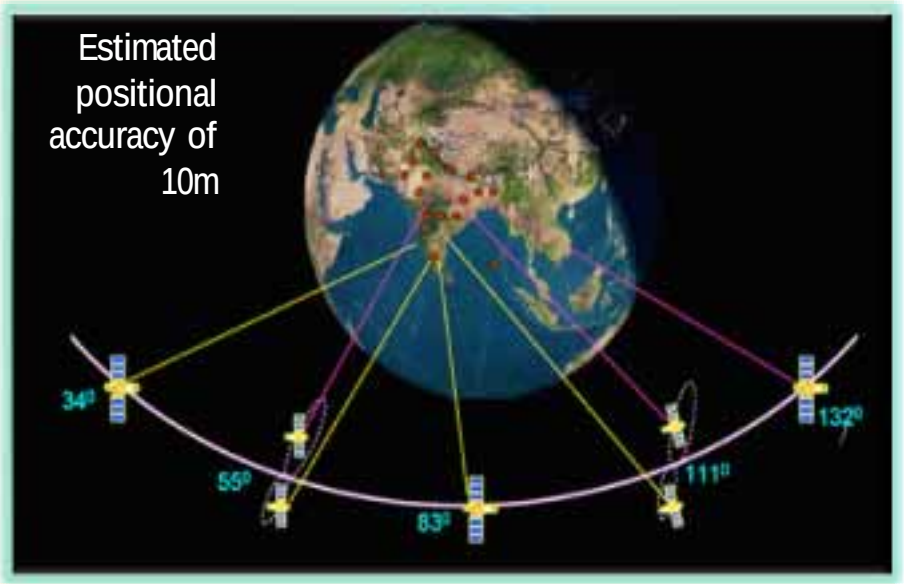
Kashmir Floods - 2014

- Disaster Communication Network
- Decision Support Centre
- National Database for Emergency Management
- North Eastern Regional Node for Disaster Risk Reduction

Disaster Management Support

IRNSS: Indian Regional Navigation Satellite System

- Indigenous navigation system of 7 satellite constellation - for providing position, navigation, timing services over Indian region
- Full constellation in orbit



Coverage area about 1500 km beyond Indian territory

GAGAN: GPS Aided Geo Augmented Navigation

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

DCGA certification for En Route Navigation and Approach with Vertical Guidance (APV) 1.0 aircraft landing

Agro Metrological Stations (AMS) -24

- Vegetation Response to Climate and CO_2 Uptake
- Sensors for Radiation balance, Energy Balance, Water balance

Carbon Flux Tower - 7

- Size of current pool of carbon in vegetation & soils
- Quantitative estimates of C flux viz., GPP, NPP & respiration

Automatic Weather Station (AWS) - 1149

Continuous Recording of:

- Temperature, atm. pressure
- wind speed and direction
- Rainfall, relative humidity
- solar radiation

Doppler Weather Radar (DWR) - 7

- Mumbai, Bhuj – Single Polarisation
- Cherapunji, Trivandrum, Gopalpur, Kochi and SHAR- Dual Polarisation

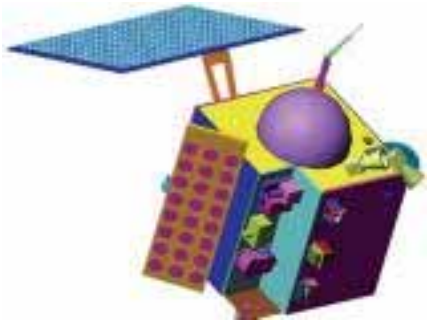
Atmospheric Boundary Level Network - 8

- Mixed Layer Heights obtained from indigenously developed GPS Sondes

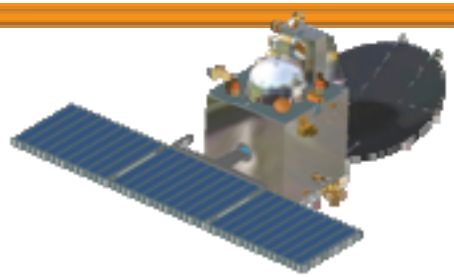
Wind Profiler Radars -3

- Indigenous Capability developed
- 50 Mhz and 205 Mhz

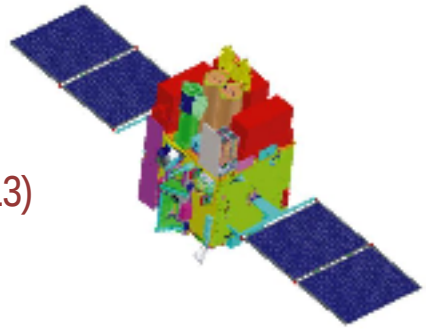
Building Capability in Ground Observing Network Infrastructure



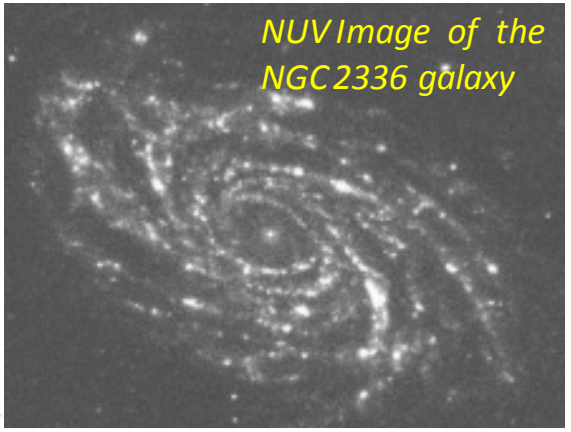
Lunar Exploration:
Chandrayaan-1 (2008)



Planetary Exploration:
Mars Orbiter Mission (2013)

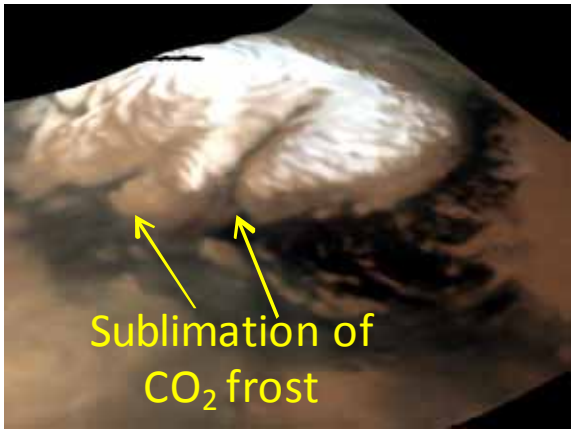


Space Astronomy:
ASTROSAT (2015)



IIA, Bangalore
IUCAA, Pune
TIFR, Mumbai
RRI, Bangalore
University of Leicester, UK

Microgravity research:
SRE (2007)



SPACE SCIENCE & ASTRONOMY – Building a Scientific Knowledge Base

Increasing Payload & Complexity

SOUNDING ROCKETS

1963

SLV-3

1980

ASLV

1992

PSLV

113 satellites

74 satellites
20 countries

1993

1700 Kg

GSLV

2001

2200 Kg

GSLV MkIII

2016

4000 Kg

Building the capabilities for Space Transportation

- Sub-orbital to Orbital Launch
- Vertical Assembly & Integration
- Payload Integration
- Multiple stages & separation
- Mission planning & Control

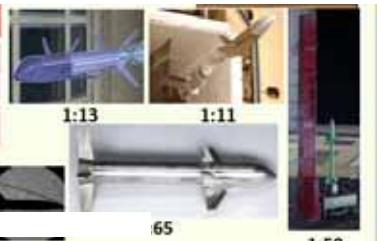
- 35 consecutive successes
- 3 variants
- Different orbits
- Lunar/interplanetary
- Multi-satellite launch

- Indigenous capability for launching communication satellites
- Cryogenic propulsion technology for the upper stage

Evolution Of Launch Capability for Satellites

Wind Tunnel Testing
(4500 Tests)

	Models
Lift Off	02
Ascent	04
Descent	11




Fuselage Load Test


Stage Separation Test


C-C Nose Cap


Base Shroud


S9 Booster Static Test


Silica Tiles

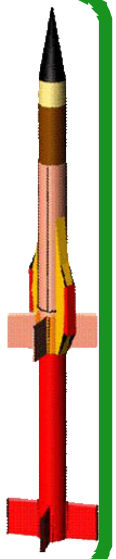

Retro Motors


RLV-TD Flight Demonstrator


Crew Module


Crew Escape System


Space Suite



National Capacity Building – Future Technologies

Liquid engine

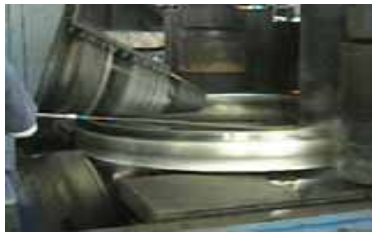
- ISRO –Industry partnership since 1976
- Sustained Industry Partnership

Structures

Fabrication

Steel rolling

Tankages



Ring rolling

Motor Case

Components

N2O4 Plant

PS4 Engine

Kevlar-Epoxy Motor case

PSLV : INDUSTRY PARTICIPATION

Raw Materials	16%
Processed Materials	12%
Propellants & Chemicals	7%
Electronic Components	12%
Fabrication by Small firms	14%
Fabrication by Large firms	19%

80%
PARTICIPATION

Industry Participation

Hypersonic Wind Tunnel Facility

Plasma Wind Tunnel Facility

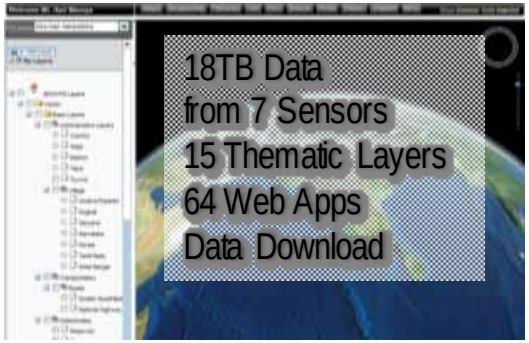
Multi Object Tracking Radar

Li-ion battery

Thermo-vacuum Chamber

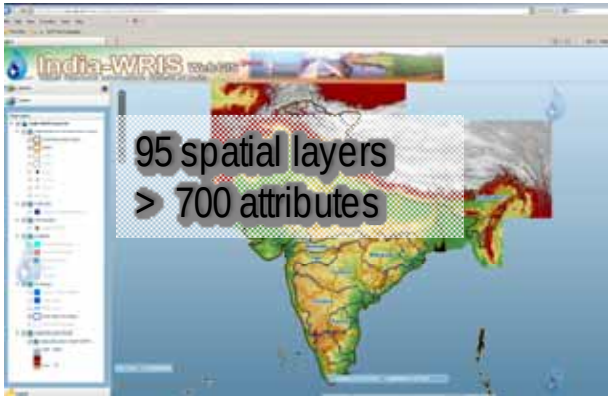
180nm CMOS Fab

Bhuvan



Natural Resources Database

Water Resource Information



SGL

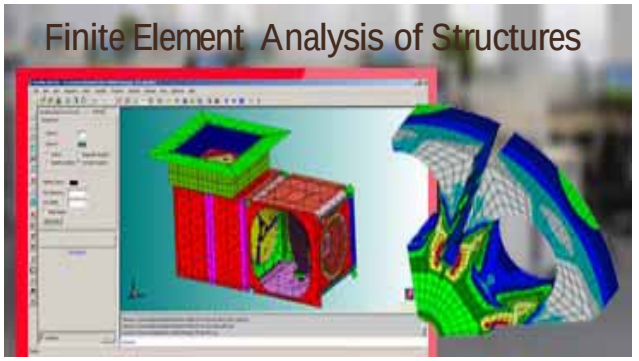
Software for image processing and GIS

IGiS

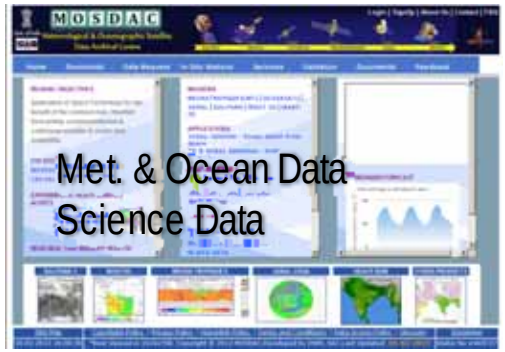
Geomatics Revealed

bhuvanPanchayat Portal

FEAST



MOSDAC



CFD – Computational Fluid Dynamics Software

National Capacity Building in Software and Computation

Vacuum Induction Melting Furnace

Roller Hearth Furnace

Vacuum Arc Remelting Furnace

Ring Rolling Facility

Drop Bottom Furnace

Reheating Furnace

Maraging Steel Indigenisation Programme (MSIP) :1982

Paved the way for the Development of Ultra High Strength Steel Material

The backbone of Indian Launch Vehicle

The first Maraging steel ring

The first Maraging steel ring

S139 Motor Segment

S200 Motor Segment

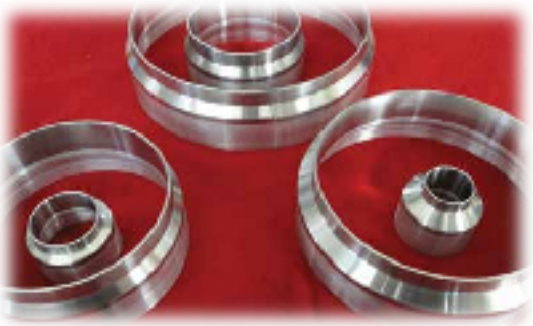
National Capacity Building – Indigenous Material Development

Titanium Sponge

AA2219 Shaped Forging

Ti6Al4V Forging

Hafnium sponge



Bimetallic Rings for Cryo Stage

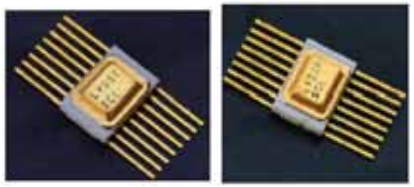
SiC for Satellite

Ti Impeller

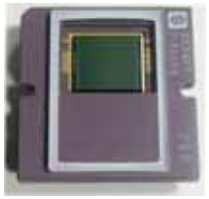
Investment Castings

Heat Pipes for Satellites

180nm CMOS Fab



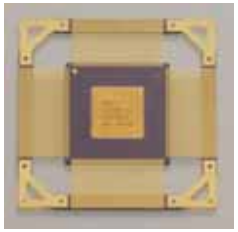
LVDS Tx & Rx



1K X 1K FT CCD

14bit ADC

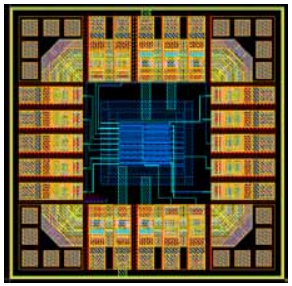
Vikram Processor

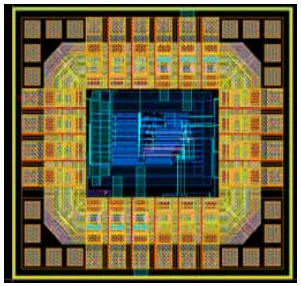


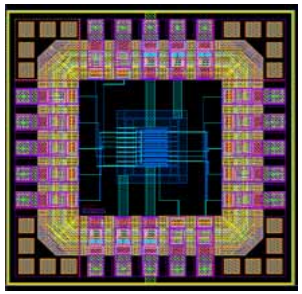
OBC 1.1

Σ-Δ ADC

Radiation Hardening Solutions (RHBD)







TID Tested upto 500 Krad (Si) & SEE Tested ; No upset / latch upto 50 Mev- cm2 / mg

Indian Institute of Remote Sensing (IIRS) at Dehradun

- Offers 8-weeks course on RS & GIS under Indian Technical Economic Cooperation (ITEC) sponsored by MEA

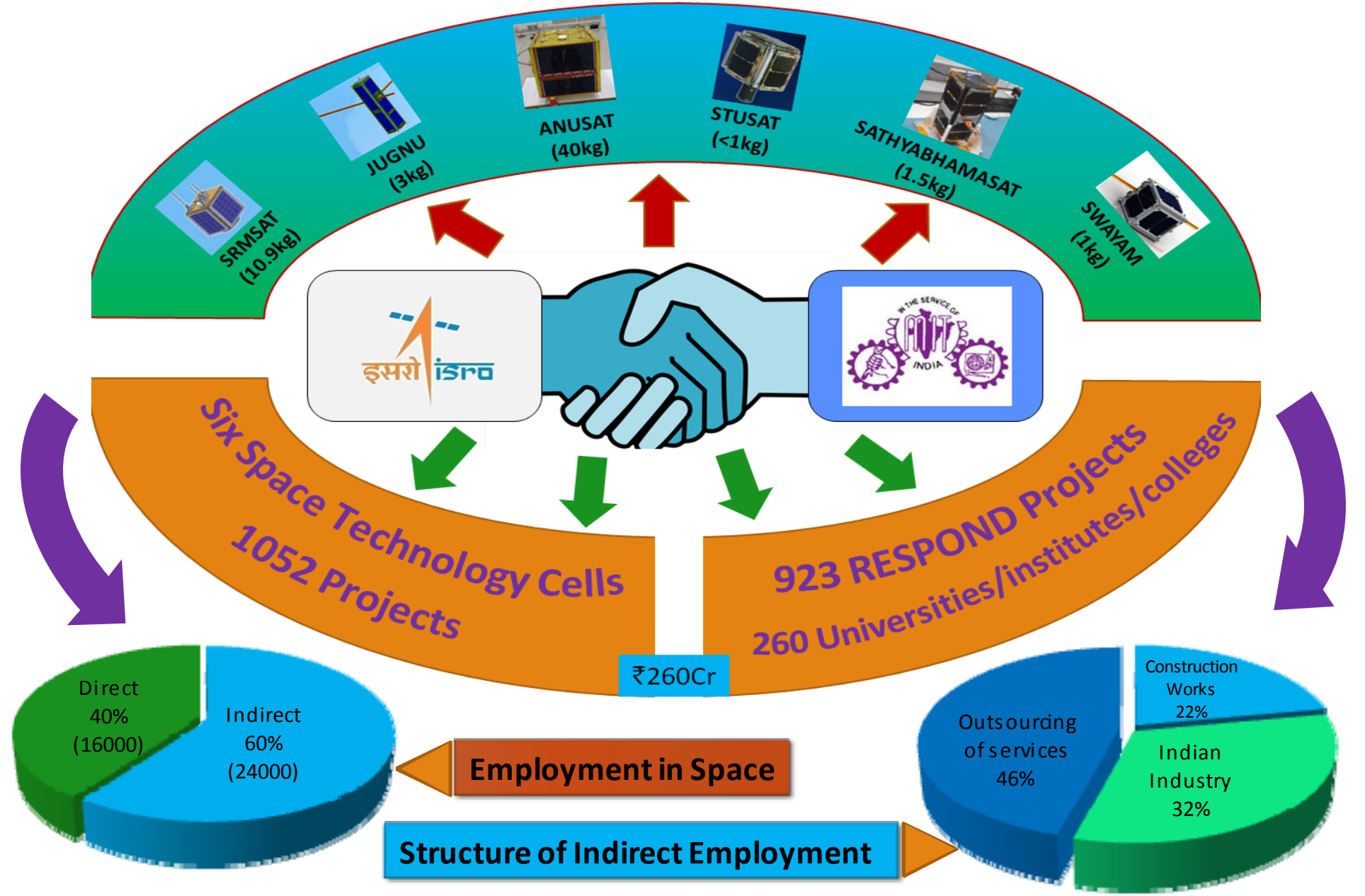
UN affiliated Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), Dehra Dun (Nov 1, 1995)

- Offers short-term training courses and 9-months PG Diploma for officials from this region on space technology applications
- 5 Themes: RS&GIS, SATCOM, SATMET, Space Science & GNSS
- Uses facility & expertise of IIRS, SAC, PRL

CSSTEAP

More than 1600 officials from 93 Countries are offered training by IIRS & CSSTEAP

HUMAN RESOURCE DEVELOPMENT



CREATING A FUTURE "SPACE READY" GENERATION

Pressure Transducers

Artificial Polyurethane Foot

CASPOL – Fire resistant coating

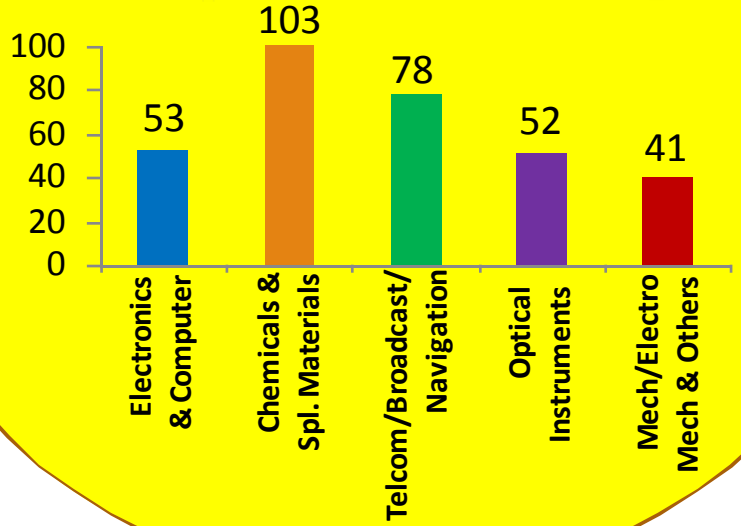
Automatic Weather Station

INSAT MSS (Type C) Reporting Terminal

327

TECHNOLOGY TRANSFERS

197 Spin-Off Technologies



Distress Alert Transmitter

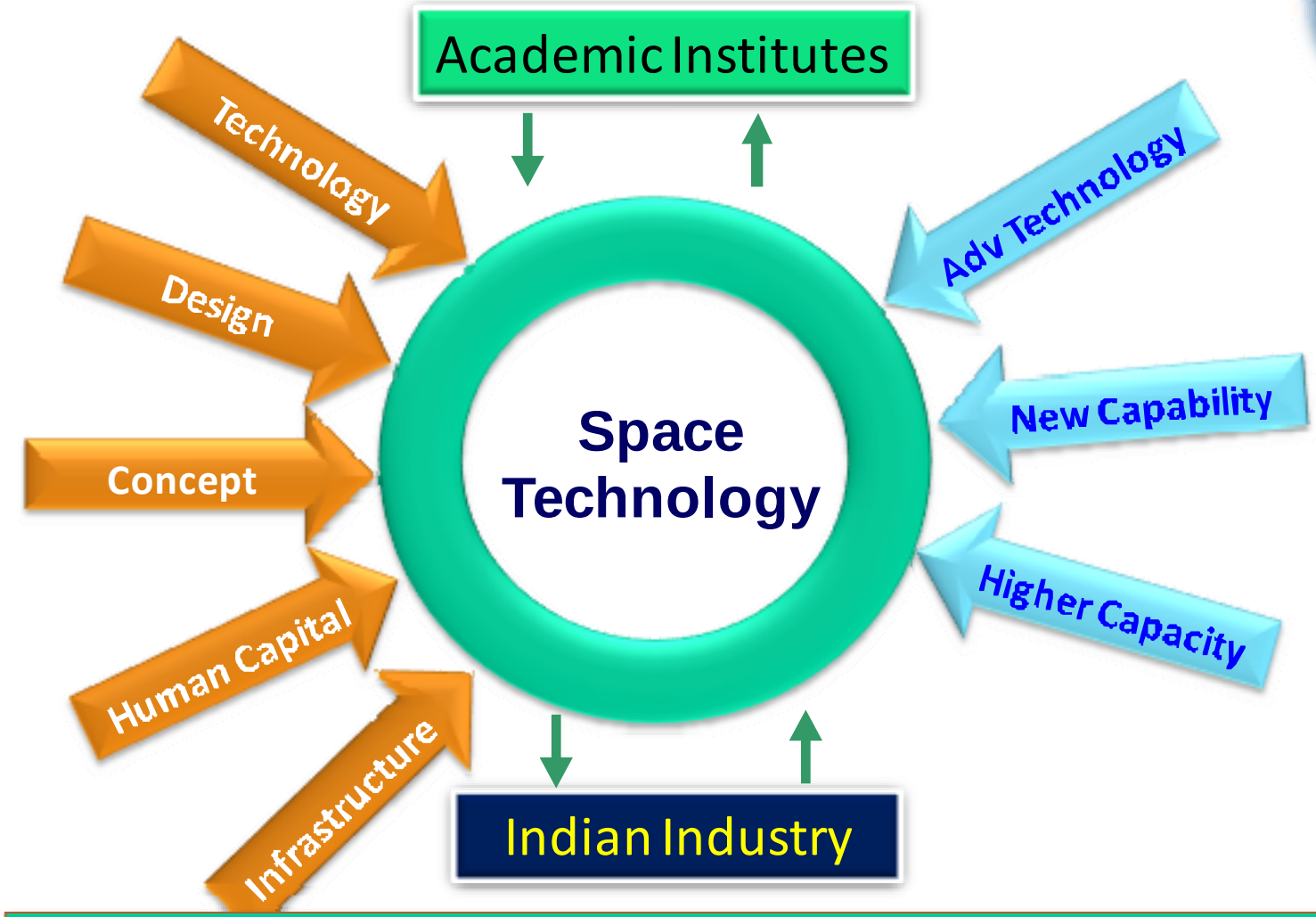
Search and Rescue Beacon

Silica Aerogel

Slip-rings

ISRO Silica Cloth

“Harnessing Space Technology for National Development”



Addressing the developmental needs of the country

To Bring In or To Bring Together for National Development

THANK YOU