ISRO HQ
Bengaluru

Diverse Space Applications
for National Development

A Compilation

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Diverse Space Applications

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COMMUNICATION AREAS

NAVIGATION AREAS

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FOREWORD

Indian Space Programme is envisioned to harness space technology for national development, while pursuing space science research and planetary exploration. Over the years the Indian Space Research Organisation (ISRO) has been relentlessly striving to live up to this vision, and developing indigenous capabilities in achieving it. It has resulted in facilitating the use of space technology towards enabling sustainable development, disaster resilience, efficient & transparent governance, health & education, safety & security, and in enhancing the quality of life.

Integration of Earth Observation, Communication and Navigation technologies has been the highlight of space technology based solutions for development in the country. The early examples such as airborne experiment on remote sensing of coconut root-wilt disease (1970), Satellite Instructional Site Experiment (SITE; 1975-76), Joint Experiments Programme (JEP; 1978) towards defining the IRS programme etc. paved the way for orienting the space applications in the country as we see today. The outcome of space applications is channelized through the user Ministries/ Departments, towards benefiting the citizens and in achieving national development.

More than 3 decades of operational use Remote Sensing applications has culminated in adoption of the technology across many user segments. Today space based inputs are indigenously used by Ministry of Earth Sciences, Ministry of Agriculture & Farmers' Welfare, Ministry of Jal Shakti, Ministry of Mines, Ministry of Steel, Ministry of Housing and Urban Affairs, Ministry of Environment; Forests & Climate Change, Ministry of Civil Aviation etc. In the Satellite communication domain also, the technology is used for societal & commercial applications such as tele-education & tele-medicine, Television, Radio, Internet, VSAT, Cellular backhaul, and Mobile Satellite Service. Realisation of GAGAN and NavIC have been instrumental in extending location/ timing based services for a number of applications & services, including for safety of life.

The publication; "Diverse Space Applications for National Development (A compilation)" is an endeavor to appreciate the wide gamut of space applications realized in the country, highlighting a few of these for the benefit of general public. The articles cover applications of Remote Sensing, Satellite Communication & Satellite Navigation, that have been implemented by ISRO/ Department of Space and have been used by the user Ministries/ Departments for decision support or for providing citizen centric services & advisories. The articles are presented in a lucid manner, highlighting the benefits accrued to the user in using those applications.

Contd/-

The Remote Sensing Applications section highlights the use of the technology in different thematic domains such as Agriculture, Water Resources, Forestry, Urban Development, Rural Development etc., in addition to benefits of Bhuvan Geoportal. Space based support for Disaster Management and Governance are other important highlights of the section. The Satellite Communication applications section gives an insight on the use of satellite based communication technology into areas like tele-education, tele-medicine, DTH services, disaster management etc. Various location based services and applications such as vehicle tracking, train information system and articles of on NavIC and GAGAN have been included in the Satellite based navigation applications section.

The compilation presents the space applications in a way that the readers would be able to grasp without getting into the technical complexities of the topic, as the articles are written from the perspective of a common reader. It certainly conveys the use and adoption of space technology for the benefit of citizens and facilitating national development, through persistent efforts of ISRO.

I am sure that the compilation would be greatly accepted by the general public, students & researchers and also by the space sector enthusiasts. I appreciate the initiative and efforts of Dr.B.N. Suresh in shaping it up into the present form. I wish the publication gets well-circulated and creates much awareness amongst the masses about India's journey of diverse space applications.

September 26th, 2022

(सोमनाथ एस / Somanath S)

PREFACE

The Indian Academy of Engineering (INAE) communicated in January 2021, about the award of "Satish Dhawan Chair for Engineering Eminence" for a tenure of two years. It was indeed an honour and I readily accepted the offer. It was envisaged that the awardee has to choose a suitable topic of national importance, carry on the tasks related to it and prepare a comprehensive report for submission to the Academy for dissemination and follow-up actions.

It was the vision of Dr A Vikram Sarabhai, the founding father of Indian space programme, to utilize the advanced technologies of space for the benefit of mankind. ISRO over the last five to six decades has successfully implemented several well structured space application programmes in the Country in the areas of remote sensing, communications and navigation to precisely meet the vision of Dr Sarabhai and to hasten the National development.

Considering these factors, I decided to undertake the compilation of some of the important space applications already implemented by Department of Space, thus actively contributing in the tasks of National Development. Although, a good number of space applications have been implemented in the last several decades, they are not compiled in a easily readable concise format in a single book. Therefore, I discussed the issue of undertaking such a task as a part of this Chair, with the then Chairman ISRO Dr K Sivan and he also felt that such a book would serve as a quick reference material not only to all readers who are interested in understanding the diverse applications of space towards National development. Chairman ISRO also permitted me to interact with the senior officers at the directorates of Earth Observations(EOS), Communications (Satcom) and Navigation(Satnav) at ISROHQ for providing the needed materials.

ISRO has carried out the application in a large number of areas. They are no doubt diverse and most of these applications are implemented in close coordination with many of the user Departments of Government of India. The application dealt out in this document does not encompass all such application areas but by and large most of the important applications have been included here. The limited compilation from a large variety of space applications here is mainly due to the constraints of time for completion of the task within two years. It has been compiled by using a simple common format like objectives, expected benefits to society, implementation mechanism, the area coverage in India, results obtained and user's perspective.

The book contains altogether only 31 applications, 16 in remote sensing, 8 in communications and about 7 in navigation, dealing with diverse space application areas as detailed in the contents. Some of the applications areas listed encompass more than one area but for the sake of classification such applications are shown in one or other areas. Each write up has also been reviewed by the subject experts at ISRO HQ and also in other Centres of ISRO. While maximum care has been taken to avoid errors in the text, still some error/s might have crept in here and there and for all such errors the author is solely responsible. Fairly good number of scientists and engineers of ISRO have extended their full support and assistance in the preparation and review of the materials and all such support are mentioned in the acknowledgement.

The book is meant to showcase the contributions of Department of Space (DOS) towards National development and to highlight the benefits derived by the society in general and Nation in particular. The format chosen for the book is kept simple and it is chosen such that it is easily readable by common citizens of the Country to understand the contributions of ISRO towards Nation building. This compilation also would serve the administrators who are involved in the usage of space based data in country's development.

BN Suresh

ACKNOWLEDGEMENTS

The award of Satish Dhawan Fellow for engineering eminence by Indian National Academy of Engineering (INAE), New Delhi for the years 2021-22, enabled me to undertake the exercise of compiling together the diverse space applications in remote sensing, communications and navigation areas and I must thank Dr Sanak Mishra the then President, INAE who orally communicated the conferment of the award. I therefore convey my sincere thanks to Dr Sanak Mishra and also to the members of the Governing Council, INAE who have endorsed the proposal. The offer was communicated by a letter by the present President Prof. Indranil Manna, in January 2021 and extended his full support during the last two years in this venture. I am indeed thankful to Prof. Indranil Manna.

I broached the idea of taking up the compilation of Space applications with the then Chairman ISRO Dr K Sivan and he readily agreed with the proposal. He also identified the Directors of three programme offices of earth observations, Satcom and Satnav at ISRO HQ to extend the necessary help in undertaking this task. I am indeed indebted to him for his unstinted support.

Sri Somanth S, present Chairman ISRO continued his support and assistance during the last one year in carrying out this task. I also requested him to write a Foreword and he readily agreed. The Foreword nicely captures various aspects of these compilation on space applications. My heartfelt thanks to him for his full support and also for his thoughtful gesture in proving the Foreword.

Initially, I discussed the matter with, Dr K Ratnakar, programme Director of Earth Observations Dr. Hanumantharayappa, programme Director, Satcom, and Mr Manish Saxena, programme Director of Satnav and sought their help and assistance in carrying out the tasks. I also requested their help in suggesting suitable topics and also in providing the needed literature, reports and materials on each of the suggested topics, for easy compilation. I must thank sincerely all of them not only for their full support and assistance but also for identifying senior coordinators to assist me on a continuous basis during the last two years.

I must gratefully acknowledge the excellent support rendered by the senior scientists of three programme offices of ISRO HQ, Dr. John Mathew and Dr S Bandyopadyay from Earth observations, Dr Sanjeev Kumar Gupta, and Dr Hanumantharayappa from the Directorate of Satcom and Mr Manish Saxena and Mr RV Kaushik from the Directorate of Satnav. We had number of discussions, to a larger extent the topics included in the document are suggested by them and also they were gracious enough to supply the relevant reports and materials which enabled me to compile the report. I have no words to express my sincere and heartfelt thanks to each one of them and without their assistance this exercise of compiling this report would not have been possible. Each one of them also invested their valuable time in reviewing the write ups critically and suggesting the necessary corrections and modifications wherever necessary.

Once the draft report was submitted to Chairman ISRO seeking his permission to print the document under the ISRO/DOS publication group, he agreed with the proposal. He also opined that one more review by experts before printing would be useful to ensure that there are no errors and the data presented in the report is up to date. Accordingly, I requested once again the Directors of EOS, SATCOM and SATNAV for their help and assistance. They have not only reviewed the manuscripts again and also referred number of Chapters to the relevant experts at NRSC and SAC.

Dr Shantanu Batwadekar, Scientific Secretary, ISRO HQ has also gone through the entire document and has made a number of suggestions and all of them have been implemented as per his suggestions. I am very grateful for his efforts in correcting the manuscripts and also for his very valuable suggestions.

The recommendations received by all the experts at DOS, NRSC and SAC, ISRO have been incorporated in this final version and I have no words to express my thanks to all the subject experts who have given very valuable suggestions and corrections wherever essential.

Dr P G Diwakar, former scientific Secretary was responsible in suggesting the format for the write up and several iterations were carried out before we arrived at a final format. He also extended his support in suggesting some of the topics in earth observation areas, in reviewing some of the write ups and in incorporating the necessary corrections. I express my sincere gratitude to him for his timely help and support.

Dr VK Dadhwal Former Director, IIST and an expert in remote sensing area also supported the venture in reviewing the write up related to the agriculture and food production. My sincere thanks are due to him too.

The support and assistance extended by Mr. BHM Darukesha, Associate Director, Capacity Building Programme Office (CBPO) and Mr. N Sudheer kumar, Director, CBPO, ISRO HQ in meticulous planning, in coordinating andin executing various tasks needed for the production of the book, such as the cover page design, lay-outing of the book in a beautiful format and arranging the final print in an elegant manner are indeed very immense and valuable. I have no words to express my sincere thanks to both of them for their dedicated efforts and continuous involvement in bringing out the volume so professionally.

Maximum care has been taken to include the right information in each of the topics in the book. But the compilation has been done through the scrutiny of vast literature and notes made available by multiple agencies and each one of the write ups has been reviewed thoroughly by the subject experts as already mentioned earlier, to ensure that there are no errors. In spite of all these best efforts there could be still error/s here and there and for all such errors the author is solely responsible.

BN Suresh

ABOUT DR. BN SURESH, AUTHOR

Dr. BN Suresh is presently,Chancellor, Indian Institute of Space science and Technology, Thiruvananthapuram. He was Vikram Sarabhai distinguished professor and also Honorary Distinguished Professor at ISRO HQ, Bangalore. He was President for Indian National Academy of Engineering (INAE), Delhi, the only premier Engineering Academy of the Country for 4 years.After his degree in Science and Engineering from Mysore University he took his Post Graduate degree from IIT Madras. He got his Doctorate under Commonwealth Scholarship in Control Systems from Salford University, in Manchester UK.He joined Vikram Sarabhai Space Centre, Thiruvananthapuram in 1969. He has made significant contributions to Engineering Sciences particularly in the area of aerospace, for the design and development of different versions of Launch Vehicles. He was actively engaged in the development and successful launches of Satellite launch Vevicle (SLV-3), Augmented Satellite Launch Vehicle (ASLV), Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV). His major contributions were in the development of Inertial Guidance System, simulation, actuation systems and system engineering for all the launch vehicles of ISRO. He was actively involved in defining more advanced space systems like GSLV MK-3, reusable launch vehicle technology demonstrator, and air breathing propulsion. One of his significant achievements was to define design and implement the complex Space Capsule Recovery Experiment, involving development of several new technologies and successfully flight testing the same in January, 2007.

He took over as Founder Director for the newly established Indian Institute of Space Science and Technology (IIST) at Thiruvananthapuram in 2007 and served for three and half years. He was Member, Space Commission for four years. He is a fellow of several professional bodies like Indian National Academy of Engineering (INAE), Delhi, Indian National Science Academy(INSA), Delhi, Astronautical Society of India(ASI), Bangalore, Aeronautical Society Of India (AeSI), Bangalore, Indian Society of systems for Science and Engineering(ISSE), Thiruvananthapuram and International Academy of Astronautics (IAA), Paris. He is also Fellow and past President for System Society of India (SSI), Delhi. He was elected recently as a member of National Academy of Engineering, NAE of USA.

He is well recognized in the international arena too. He was Head of Indian delegation for the United Nations Committee for space on Peaceful Uses of Outer Space (UNCOPUOS) at Vienna, Austria during 2004-07. He was elected as Chairman of the prestigious United Nations Scientific and Technical Committee for the year 2006 from the Asia Pacific Countries. He was Chairman for the selection of members in S&T area for International Academy of Astronautics (IAA), Parisfor five years.

He has won several awards &honours and a few prominent among them are “Lifetime Contribution Award” in engineering by Indian National Academy of Engineering (INAE) in 2007 for his significant contributions for space technologies, “Karnataka State Rajyotsava Award” for 2014 for Science & Technology, the top award from Government of Karnataka, “Lifetime Achievement Award” by ISRO, Government of India, in 2016, in recognition of lifetime contributions to the Indian Space Programme, “Lifetime Contribution Award” in engineering by Karnataka Science and Engineering Academy (KSTA) for his significant contributions for space technologies, “Global Pioneer Award” by International Council of System Engineering at Washington, DC, USA in July 2018 for his pioneering contributions to space system engineering,“Engineering Sciences Book Award”, by the International Academy of Astronautics for the outstanding contribution to astronautics by Publication of ‘Integrated Design for Space Transportation System’ Springers, at International Astronautical Congress, at Washington DC in October 2019 and “IEEE Simon Ramo award 2020”, 2020, by IEEE, USA for outstanding leadership in developing space program & pioneering in space technology..

In recognition of his meritorious contributions for Science and Technology, Govt. of India conferred on him “Padmashree” the civilian Award during the year 2002 and “Padma Bhushan” the third highest civilian Award during the year 2013.

Remote Sensing Area

1. AGRICULTURE SECTOR IN INDIA: APPLICATIONS

a. Objectives:

India is predominantly an agricultural Country with 46% of the total area under agriculture. The contribution from agriculture towards national Gross Demographic Product (GDP) is around 18% during 2018 and provides the livelihood to more than 54% the working population of the country. Although, as on date the Country is assured of self-sufficiency in food, in spite of 1.3 billion population there is ever increasing demand for the efficient agricultural planning, management and decision making by introducing suitable space based techniques to assess various natural resources needed for sustainable agriculture and also to enhance the food production to meet the future needs of 350 Million Tons by 2030. The main objective of the remote sensing is to generate and provide these vital inputs needed for proper assessment of land use, land cover at certain periodicity, wastelands and wetlands identification, drought assessment, understanding the groundwater prospects, aspects of soil and water conservation, crop intensification, site suitability analysis, satellite agro-meteorology, precision farming, crop insurance, etc. which are all very important for agriculture. Space based inputs enable reliable and timely estimates and seasonal crop acreage and production estimates, which are essential for formulation of marketing strategies such as export/import, stock management, price fixation and public distribution. The conventional techniques for generating this information are highly tedious and takes considerable time.

b. Expected Benefit to Society:

Satellite remote sensing and Geographic Information System (GIS) are being utilised effectively for natural resources management by depicting the spatial distribution of the extent and monitoring. The prediction of crop response and the generation of possible solutions to various management problems have helped to increase the performance of the cropping system in a spatial and temporal dimension. A suitable blend of this technique with the relevant ancillary information has aided in efficient management of resources in enhancing the crop productivity on a sustainable basis.

Satellite data are utilised to find solutions to many of the agriculture related issues like a) Land use/ Land Cover Monitoring, b) Change Detection, c) Crop acreage & production estimation, d) Crop Health/Agriculture Monitoring, e) Soil Moisture Monitoring, f) Real Time Assessment for Decision Making and g) Drought Monitoring

Remote sensing technique has been used for Identifying and bringing additional land under cultivation (horizontal approach) thus enabling substantial increase in crop production. Advanced satellite remote sensing technologies having the requisite potential to provide a variety of vital inputs related to agriculture like use of high yielding input response, increased irrigation, integrated crop nutrition and protection on a regular basis. The satellite data with the advantage of synoptic coverage with good temporal frequency have been helping vastly to improve the cropping intensity and management (vertical approach) in a more objective manner. All these remote sensing technologies are playing a very dominant role in Indian agriculture, especially for doubling farmers' income.

c. Implementation mechanism:

The methodology used for agriculture is imaging a target through the radiation reflected/emitted by the surface at different wavelengths (blue, green, red, infrared, microwave etc.) at frequent time intervals through sensors located in the satellites. Different crops reflect/emit light differently at different wavelengths and/or at different times. These features are used for their identification, discrimination and assessment. Just to illustrate, crops have higher reflectance in the green region, low reflectance in red and blue regions (due to absorption by chlorophyll pigment) and very high reflectance in the near-infrared region (due to leaf internal structure). The varying property of reflectance for different crops, crop types, crop conditions and associated features facilitate not only its identification but also the assessment of its health. The thermal sensors, sense the temperature of the vegetation, thereby enabling the assessment of crop stress due to lack of moisture availability and water consumption pattern using surface energy balance. The microwave sensors like Synthetic Aperture Radars (SAR), are being used for rice and jute crop assessment, flood monitoring and soil moisture estimation. Thus a variety of useful information and different parameters related to crops/agriculture are derived through remote sensing, at various spatial, spectral and temporal domain. Some of the parameters are used for the identification of vegetation, preparation of crop statistics and maps, assessment of crop condition/stress, generation of crop growth profile etc. The data at regular temporal intervals from important sensors onboard Indian Remote Sensing Satellites such as , Linear Imaging and Self Scanning (LISS), Wide Field Sensor (WiFS), Advanced WiFS (AWiFS) and Synthetic Aperture Radar (SAR) enable necessary mapping and monitoring of various parameters needed for better agricultural management. The details of the Indian Remote Sensing satellites, used for agricultural management are presented in Table 1 below. Satellites, Resource sat 2 and 2A, have multiple multispectral sensors (cameras), and their data are used regularly for agricultural monitoring.

Table 1

Name of the Satellite	Year of Launch	Sensor	Specifications (Bands, Resolution, Swath, Repetition cycle)
IRS1A/1B	1988, 1991	LISS I LISS II	4 band (B,G,R,NIR), 72.5m, 148 km, 22day 4 band (B,G,R, NIR), 36.25m, 74x2 km, 22day
IRSP2	1994	LISS IIM	4 band (B,G,R, NIR), 32x37m, 66x2 km, 24day

IRS1C/1D	1995, 1997	LISSIII PanWiFS	4 band (G,R, NIR, SWIR), 23.5/70m, 142/148km, 24 day Panchromatic, 6m, 70km, 5day (Revisit) 2 band (R, NIR), 188m, 804 km, 5 day (Revisit)
Resourcesat 1	2003	LISS IIILISSIV AWiFS	4 band (G,R,NIR, SWIR), 23.5m,140 km, 24 day 3 band (G,R,NIR),5.8m, 23.9/70km, 5day (Revisit) 4 band (G,R,NIR,SWIR), 56m, 740km, 5day (Revisit)
Resourcesat 2/2A	2012, 2016	LISS III LISSIV AWiFS	4 band (G,R, NIR, SWIR), 23.5m,141 km, 24day 3 band (G, R, NIR), 5.8m, 70km, 5day (Revisit) 4 band (G,R, NIR, SWIR), 56m, 740km, 5day (Revisit)
RISAT1	2012	SAR	5.350 GHz (C-band), < 2 mto 50m, 100 - 600km
EOS-04	2022	SAR	5.40 GHz (C-band), 2 to 33 m resolution, 15 to 160km swath

IRS- Indian Remote Sensing Satellite, LISS – Linear Imaging and Self Scanning, WiFS – Wide Field Sensor, AWiFS – Advanced WiFS, SAR – Synthetic Aperture Radar.

The spatial resolution of the sensors used in these satellites range from very fine resolution multi-spectral data of 5.8 meters to moderate resolution Wide Field Sensor (WiFS) data of 180 m through 56 m data of Advanced Wide Field Sensor and 24 meter multi-spectral linear imaging self scanner data(LISS-III) with the revisit period ranging from 5 days to 24 days and swath ranging from 70 km to about 800 km. LISS-III data provides district level information of the natural resources whereas regional level information is derivable from both AWiFS and WiFS data. Presently, Resourcesat 2/2A satellites are providing the data.

Remote Sensing in optical and reflective Infra Red (IR) region, concerned with the measurement of surface and to obtain the physical, physiological properties and stage or phenology of plants and their interaction with the incident radiation is the key element in crop identification. The intrinsic ability of spectral reflectance data to identify and distinguish crops is utilised in deriving crop acreages, production estimates and to monitor and assess the crop condition. Remote sensing based crop identification and discrimination is carried out based on the concept that each crop has a unique spectral signature due to its own architecture, growing period etc., when two crops with similar spectral signatures occur in a given date, multi-date data is utilised to identify them.

d. Area Coverage: National / State / District

The entire application of remote sensing on agriculture is carried out at any identified location/s or area/s across the whole country depending upon the type of the crops involved. The Table -2 given below, gives the broad distribution of the crops in India in different districts. All areas where the major crops are grown, like wheat, rice, rabi-rapeseed, jute, potato, sugarcane, cotton and rabi-sorgum are all appropriately covered under satellite remote sensing applications. Space Application Centre, ISRO is involved in National Food Security Mission (NFSM of Department of Agriculture, Cooperation & Farmers' Welfare,DAC&FW) with the main objective of enhancing the food production in India by several schemes like, monitoring the impact on rice production, pulse crop intensification assessment and techniques development for smart sampling for crop insurance.

Table 2. Distribution of crops and soils in different parts of India

States	Crops	Soil used
Punjab	Wheat, Rice, Maize, Barley, Pulses, Rapeseed and Mustard, Sunflower, Oil Seeds, Sugarcane, Cotton, Fruits, Vegetables	Flood plain soil, Loamy soil, Sandy soil, Desert soil, Kandi Soil, Sierozems, Sodic and Saline soil
Haryana	Sugarcane, Barley, Jowar, Bajra, Gram, Rice, Wheat, Mustard, Cotton	Salt Affected soil, Alkali Soil, Saline soil
Rajasthan	Wheat, Sugarcane, Bajra, Baley, Jowar, Maize, Chili, Cotton, Mango, Rice, Vegetables, Groundnut, Oilseeds, Pulses	Sandy soil, Saline soil, Alkaline soil, Chalky soil, Clay soil, Loamy soil, Black Lava soil, Nitrogenous soil
Uttar Pradesh	Fruits, Vegetables, Spices, Floriculture, Medicinal/ aromatic plants, others like Betel vine, Mushroom, Honey production	Alluvium soil, Sandy soil, Clayey Soil, Red & Black soil
Bihar	Rice, Wheat, Maize, Pulses, Vegetables, Fruits, Sugarcane, Jute	Sandy Loam soil, Loam soil, Clay soil, Clay Loam soil
Gujarat	Rice, Wheat, Jowar, Bajra, Maize, tur, Gram, Cotton, Groundnuts, Dates, Sugarcane	The black soil, Alluvial soil, Hill soil, Desert soil
Madhya Pradesh	Wheat, Maize, Jowar, Gram, Tur, Urad, Moong, Soybean, Groundnuts, Mustard, Cotton, Sugarcane	The black soil, Red & Yellow soil, Alluvial soil, Laterite soil, Mixed soil

Maharashtra	Rice, Jowar, Bajra, Wheat, Pulses, Cotton, Sugarcane, Several Oil Seeds, Sunflower, Groundnuts & Soybean	Black-Cotton soil, Kali soil, Morad soil, Pather soil,
Chhattisgarh	Rice, Maize, Wheat, Niger, Groundnut, Pulses	Red & Yellow soil, Red Sandy soil, Red Loam soil, Black Cotton soil, Laterite soil,
Jharkhand	Rice, Ragi, Maize, Wheat, Program, Niger, Fruits	Red soil, Micacious soil, Sandy soil, Black soil, Laterite soil
Himachal Pradesh	Off-season vegetables, vegetable seeds, potato & ginger besides soybean, oilseeds, pulses, fruits	Sedimentary soil, Brown soil, Brownish soil
Jammu & Kashmir	Paddy, Wheat, Maize, Barley, Bajra, Jowar, Gram, Apple, Walnuts	Brown Forest soil, Grey Brown Podzolic soil, Red & Yellow Podzolic soil, Hills Forest soil, Mountain Meadow soil, Saline Alkali soil, Alluvial soil
West Bengal	Rice, Jute, Tea, Potatoes, Oilseeds, Betel, Vine, Tobacco, Wheat, Barley, Maize	Laterite soil, Red soil, Alluvial soil, Coastal soil, Terai soil, Colluvial soil
Karnataka	Paddy, Jowar, Ragi, Maize, Sunflower, sugarcane, Cotton, Tobacco	Red soil, Lateritic soil, Black soil, Alluvial-Colluvial soil, Forest soil, Coastal soil

e. Results Obtained: (compare with item b above)

The satellite based applications implemented for agriculture in India are very wide and include crop production forecasting, drought assessment, horticultural assessment and development, cropping system analysis, sustainable agriculture, climate change impact, disaster and flood management, soil resource assessment, irrigation management, farmers' advisory, satellite agro-meteorology, precision farming, crop insurance, etc. Detailed results on each of these applications are available in the references given below. Only a few results of these applications are given here.

The single date cloud free optical data during the maximum vegetative stage of the crop growth, district level is used effectively to estimate the pre-harvest acreage and production of large area covering crops viz., paddy, wheat, sorghum, groundnut, rapeseed-mustard and under the crop acreage and production estimation (CAPE) project. Considering the importance of this application a separate write up on this topic is given in the document. The crop estimates so generated are made available at least one month before the harvest of the crop, for the administrators to take decisions on import-export policy and all other trade related matters. Further, a new programme called Forecasting Agricultural output using Satellite, Agro-meteorological and Land Observations (FASAL) was implemented to meet the requirement of multiple pre- harvest production forecasts at district, state and national level.

Right in the beginning, econometric based forecasts are generated at the pre-sowing stage. During the mid-season moderate spatial resolution, temporal remote sensing (e.g., Resourcesat AWiFS) data is used for state-level estimation, while high-resolution data is used for district-level estimates, before harvest. Figure 1 gives the methodology used in the FASAL programme. Subsequently the technology was transferred to the new centre, Mahalanobis National Crop Forecast Centre, (MNCFC) under Department of Agriculture, Cooperation & Farmers' Welfare (DAC&FW) established in 2012, for its operationalization. Currently, MNCFC provides crop production forecasts for 9 major crops (Rice, Wheat, Rabi Pulses, Tur, Rabi Jowar, Rapeseed & Mustard, Cotton, Sugarcane and Jute) using the FASAL concept.

Regarding the horticultural crops, the high spatial resolutions LISS-IV data were used for identification of many horticultural crops viz., mango, coconut, oranges and banana. Mandal level acreages of mango crop of

Krishna district and banana crop of Guntur district, Andhra Pradesh were estimated. Using satellite data, the area under arecanut and grape were reported. The utility of aerial photographs in identification of coconut trees with wilt disease in parts of East Godavari district, Andhra Pradesh was demonstrated. The very high spatial resolution PAN data is used for better identification of plantation crops. The young and the fully-grown mango plantations were clearly discernible in the fused data products of LISS-III and PAN .

Under the CHAMAN (Coordinated programme on Horticultural Assessment & MAnagement using geo-iNformatics) programme, area assessment and production forecasting using RS technology were done for seven horticultural crops (Banana, Mango, Citrus, Potato, Onion, Tomato and Chilli) across 180 major growing districts in 11 States. Horticulture site suitability assessment was also carried out in north-eastern region (in 8 districts)

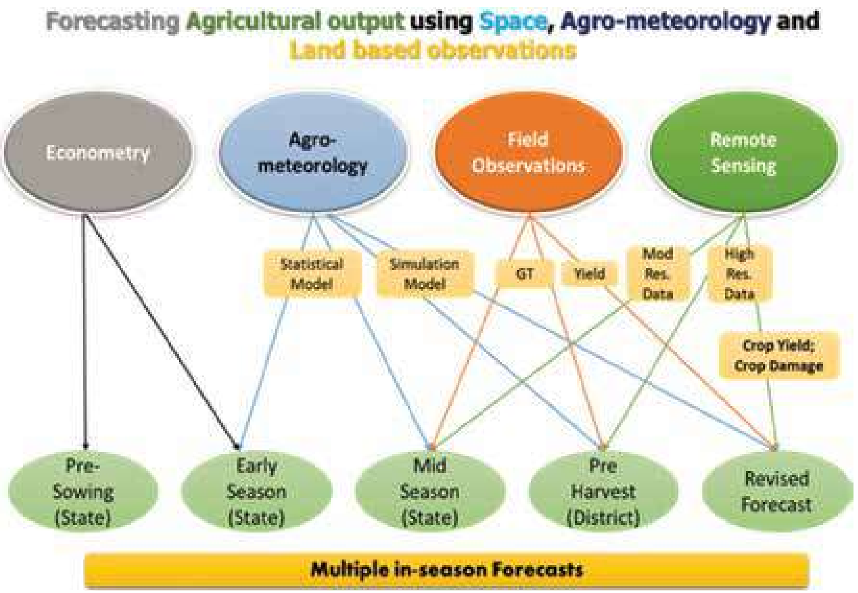

Figure1 : The methodology used in crop production forecasting under FASAL project

Cropping system analysis is carried out to ensure the sustainability of an agricultural system. The process involved is mapping various components of cropping systems, such as cropping pattern, crop rotation and sowing and harvesting pattern maps and cropping system performance indices. Time series satellite data is utilised to assess the long-term changes in the cropping system and it gives the information on spatially delineated areas, which have lost the crop diversity.

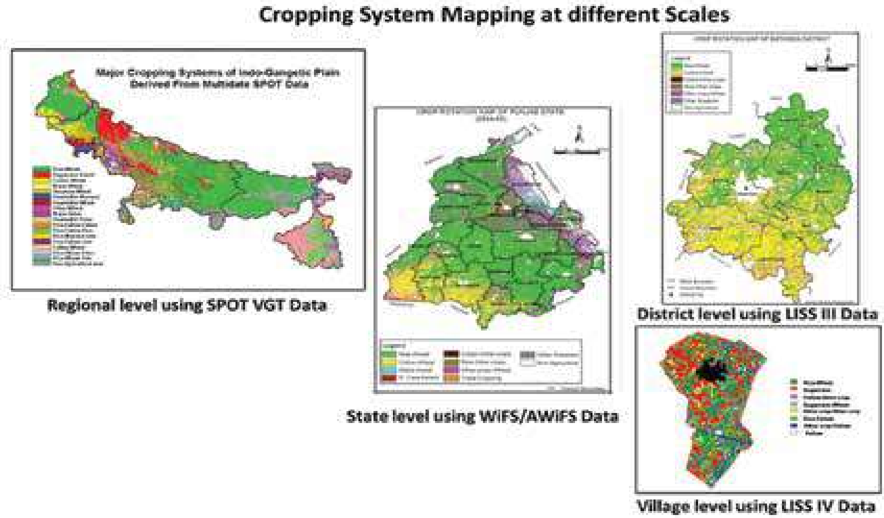

Figure 2. Cropping system using different spatial resolutions from satellites.

It is possible to use data of various spatial resolutions from satellites for cropping system analysis at different levels as given in Figure 2. In this Fig. low-resolution SPOT VGT (1 km resolution) data is used for cropping system/crop rotation mapping at the regional level, WiFS (188 m)/AWIFS (56m) data is used for state-level, LISS III (23.5m) data for district level and LISS IV (5.8m) data for village level mapping.

The government launched Pradhan Mantri Fasal Bima Yojana (PMFBY) in 2016, a yield- based crop insurance, where crop yield data on two consecutive years are compared for computing the claims. PMFBY envisages to provide the insurance cover and to meet the financial needs of the farmers when the crops destroyed by heavy rain, other natural calamities, pests or diseases. The PMFBY is using the data from remote sensing from satellite and UAV, for area and yield estimations, loss assessment, risk zoning, etc., to ensure early settlement of claims to eligible farmers against their crop yield loss. The applicable remote sensing-based approaches have already been made operational and protocols have been developed and included in the revised guidelines. (e.g., area discrepancy, yield dispute resolution, risk zoning, etc.)

f. Users' Perspective.

Initially the evaluation of FASAL was carried out in Odisha state and further extended the coverage to other states for developing suitable methods and validation. The major organizations involved in FASAL project are Directorate of Economics & Statistics (for budget management and use of estimates), Institute of Economic Growth (econometric forecasts), India Meteorological Department & Agro-Meteorological Field Units (Agromet model-based estimates), SAC (ISRO) (R&D activities for new crops), State Agricultural Departments (Field Data Collection), State Remote Sensing Centres (support to analysis and validation), and MNCFC (operational crop forecasts & project management).

The cropping system was analysed in five states of Indo- Gangetic Plains (IGP) of India, i.e., Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal and multi-date remote sensing data of IRS-AWiFS and Radarsat ScanSAR was used for state and district level cropping system mapping. The cropping system was characterised through the analysis of moderate spatial resolution multi-date remote sensing data along with the ground survey.

All users across the Country are quite satisfied with the data availability, software, processing, analysis and utilization for analysing the agricultural issues in the Country. Many applications have been made fully operational with user departments adopting the technology, which include crop forecasting and drought assessment. Government manual and protocols have been dealing extensively with the remote sensing data. (e.g. Pradhan Mantri Fasal Bima Yojana (PMFBY) guidelines, drought manual). In addition, several other initiatives have been started by the central government for the welfare of the farmers. One of the important uses of remote sensing is an important judgments of the Supreme Court of India, based on the satellite-based vegetation index generated by remote sensing data. (Reference 4: Lokur & Ramana, 2016).

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2. CROP AREA AND PRODUCTION ESTIMATION

a. Objectives:

The main objective is to utilize the satellite data gathered from remote sensing spacecraft, to estimate the production of various crops in India in identified area/s across the Country. The data on crop area and the yield estimates are generated from remotely sensed imageries. Further determination of total area under crop and prediction of the yield per unit area are essential to estimate the total yield every year. These data are effectively utilized to estimate the probable production for the identified area/district/state and even for the Country. This prediction of probale production can play a crucial role as it has a major influence on the national economy. This forecast of cereal crops production is needed for proper planning to ensure the food security for the population of a district/State and whole country. It provides a good alert to the decision makers about potential reduction/ increase in crop yield and thus allowing the policy makers to decide on the timely import and export decisions. In addition it helps various supply chain companies to plan timely supply schedule. Early estimation of grain yield accurately helps the farmers too in several areas including the crop insurance purposes.

a. Expected Benefit to Society:

Information on crop statistics is very beneficial for planning and decision making purposes, such as, distribution and storage of food grains, Govt. policies, pricing, procurement and food security and so on. Ministry of Agriculture and Farmers' Welfare, Government of India, has been effectively using contemporary techniques of satellite remote sensing in such decision making. Remote sensing data does provide many advantages over conventional methods, particularly in terms of timely decision making mechanisms, spatial depiction and coverage including cost effectiveness. Space data is used in addressing in many critical aspects, such as, crop area estimation, crop yield & production estimation, crop condition, deriving basic soil information, cropping system studies, experimental crop insurance. Other applications include agricultural drought, large disease/ pest infestation, including the locusts which migrate from Africa to Asian Countries. The important application of remote sensing satellite is in enabling the analysts to provide forecasts of major crops much before the harvest. This forecast helps to identify the gaps between the crop yield, crop production, post harvest technologies, overall pricing, and policy decisions like imports and exports at National level.

c. Implementation mechanism:

Indian Remote sensing satellites like Resourecesat 1&2, multi spectral imaging satellites, Cartosat 1, cartography satellite, RISAT-1, radar imaging satellite, Kalpana 1, a meteriological forecasting satellite, INSAT-3D & INSAT-3DR, meteorological observation satellites are used over a period to assess the crop area, agro meteorological conditions, their production estimation and many other inputs needed for agriculture in the Country. These satellites are built essentially to assist on various issues related to agriculture like natural resources inventory, crop assessment, wasteland inventory, topographic mapping & DEM, land & water resources development, weather forecasting and disaster management support. The data so generated are provided to the decision makers to incorporate suitable interventions for planning and management of various activities in agriculture sector. Table 1, given below provides the details of remote sensing satellites of Indian Space Research Organization (ISRO) indicating the satellite types, satellites and the agricultural measurement made by each one of them. They are all built during the initial period to assist several agricultural applications.

Table 1: Remote sensing satellites of Indian Space Research Organization involved in the initial period in agricultural applications.

Sl No	Satellite Type	Satellite	Agricultural Measurements
1	Multispectral imaging satellite	IRS-1A/ 1B, 1C & 1D, Resoucesat-1, -2 & -2A	Multispectral imaging for crop production estimates, land, water and natural resource inventory and management, and disaster management support
2	Cartography satellite	Cartosat-1	High resolution cartographic mapping, digital elevation mapping – drainage and irrigation networks, topographic mapping and contouring
3	Radar imaging	RISAT-1	All weather imaging capability targeted for kharif crop (June to November) during south-west and north-east monsoon seasons. Flood and natural disaster management
4	Meteorological forecasting	Kalpana-1	Comprehensive weather status reporting and forecasting
5	Meteorological observation	INSAT-3D & INSAT-3DR	improved meteorological observations including vertical – temperature and humidity, atmosphere weather forecasting and disaster warning

The data and value-added products derived from these satellites have benefitted the concerned user ministries/ departments in Natural Resources Inventory & Monitoring, crop assessment, wasteland inventory, topographic Mapping & DEM, land & water resources development, weather forecasting and Disaster Management Support.

Production forecasting of important agricultural crops using satellite remote sensing data was initiated under the project "Crop Acreage and Production Estimation" by Space Applications Centre (SAC-ISRO) and carried out over a period of decades at the behest of Ministry of Agriculture(MOA), Govt. of India. Subsequently a more inclusive model FASAL (Forecasting agricultural output using Space, Agro-meteorology and Land based observations) was initiated in 2007-08, and SAC entrusted with the responsibility of implementing Space technology based production forecast of crops and upgradation of the procedure with new data availability.

The spectral reflectance data of the RS satellite which has intrinsic ability to identify and distinguish crops,is utilized to estmate the crop acreages, production forecast. These data are further used to monitor and assess the crop condition. Each crop has a unique spectral signature due to its own chracterstics, growing pattern etc. In cases where two crops are having similar spectral signatures on a given date, multi date-data is used to identify them. The acreage estimation is based on the following steps:

1. Selection of single-date data related to the maximum vegetative growth stage of crop
2. Identification of representative sites of various crops and their heterogeneity on image based on ground truth
3. Generation of representative signatures for the training sites
4. Classification of image using training statistics and
5. Estimation of area of the crop using administrative boundary like districts

In cases of large areas, the study area is divided into homogenous blocks based on crop proportion and each block is subdivided into segments of 5 X 5 km. About 10-15 percent of the sample segments are randomly selected for digital analysis and standard statistical methods are employed to aggregate crop estimates at district / state levels. The analysis is further carried out for the entire area of interest like taluks or districts.

Crop yield depends on soil characteristics, meteorological conditions and influence of pests and diseases and many other associated factors. Crop spectral data is the integrated manifestation of the effect of all these factors and therefore the development of reliable crop yield models with minimal data is very crucial. Statistical, meteorological or spectral models used for crop yield estimation are based on single-date spectral index and multi-date spectral index-growth profiles. While the single-date data spectral index depends solely upon the data within a narrow critical period of maximum vegetation growth phase the multi-date approach uses the spectral data at different stages of crop growth within the season. To ensure the cloud-free multi-temporal satellite data microwave data, which has all weather and cloud penetrating capability is used.

IRS series of spacecraft like IRS-1A, 1B, and IRS-P2 provided uninterrupted remotely sensed data to Indian users for a wide variety of applications. IRS-IA and IB together provided a temporal resolution of 11 days. The satellites carried three push-broom scanner based on Charge Coupled Devices (CCD) and designated as Linear Imaging Self Scanner (LISS)-l, LISS-IIA and LISS-IIB. While LISS-I provided imageries at a spatial resolution of 72 m and a swath of 148 km, LISS-II A &B provided imagery at 36 m resolution and a combined swath of 145 km. IRS-P2 carried a LISS-II camera, combining LISS-IIA and LISS-IIB of IRS-IA/IB, in a single optics and providing a swath of about 131 km.One of the multispectral cameras named LISS-III, incorporated a Middle Infra Red band (MIR), in addition to three bands in the visible and near-infrared region. LISS-III provided imagery at a resolution of about 23 m. WiFS camera collected data in two spectral bands with a spatial resolution of 188m and a ground swath of 810 km. This camera provided data with a repeativity of five days and is useful in generating vegetation index information. An on-board tape recorder enabled the extension of the data acquisition capability by 24 minutes. Thus, the IRS series, IRS-IA, IB, IRS-P2 and further satellites in IRS series like, IRS-IC/ID, ensured continued services of the space based remote sensing data to the user community.

The satellite data at regular temporal interval provides information on the spatial distribution, extent and inter-seasonal variations in cropping patterns, cropping systems analyses and interfaces. The spatial resolution of the sensors utilised in these tasks range from very fine resolution, multi-spectral data of 5.8 meters to moderate resolution Wide Field Sensor (WiFS) data of 180 m. The other capabilities of the sensors are from 56 m data of Advanced Wide Field Sensor(AWIFS) and 24 meter multi-spectral Linear

Imaging Self Scanner data (LISS-III) with the revisit period ranging from 5 days to 24 days and swath ranging from 70 km to about 800 km. LISS-III data provides district level data whereas regional level information is generated from both AWiFS and WiFS data.

d. Area Coverage: National / State / District

The entire process on estimation of crop acreage and the production of any of the cereals can be carried out anywhere in the whole country. Once the area, crops and the time periods are identified the relevant exercise as explained in para c is carried out. All areas where the major crops are grown, like wheat, rice, rabi, rapeseed, jute, potato, sugarcane, cotton and sorgum-rabi are appropriately covered. Space Applications Centre, ISRO is involved in National Food Security Mission (NFSM of DAC) with the main objective of bringing green revolution to Eastern India (Monitoring the impact on rice production), pulse crop intensification assessment and techniques development for prototype for crop insurance.

e. Results Obtained: (compare with item b above)

Ministry of Agriculture and Farmers Welfare, MNCFC has been generating the pre-harvest crop estimates at District/State/National level for 9 major crops of the country. Both optical and microwave Remote sensing data is used for crop acreage estimation, crop condition assessment and production forecasting. A total 17 forecasts were generated for 9 crops, in the year 2017-18 for crops such as Jute, Kharif Rice, Sugarcane, Cotton, Rapeseed & Mustard, Rabi Sorghum, Wheat, Rabi Pulses and Rabi Rice.The ground truth points are collected by state agriculture departments during the Kharif and Rabi season and remote sensing based Crop cutting experiment (CCE) was carried out. Several CCE points were collected in 12 states.FASAL has been using Indian Synthetic Aperture Radar (SAR) data from Radar Imaging Satellite (RISAT-1) for pre-harvest estimates and condition assessment. The growth progress of wheat crop using the time series of IRS data is given in Fig 1. Bright red indicates Crops in the above False Colour Composite (FCC) Images

Fig. 1 The growth progression of wheat crop

Fig 2 given below indicates a typical crop monitoring utilizing Indian Remote Sensing Data from different sensors

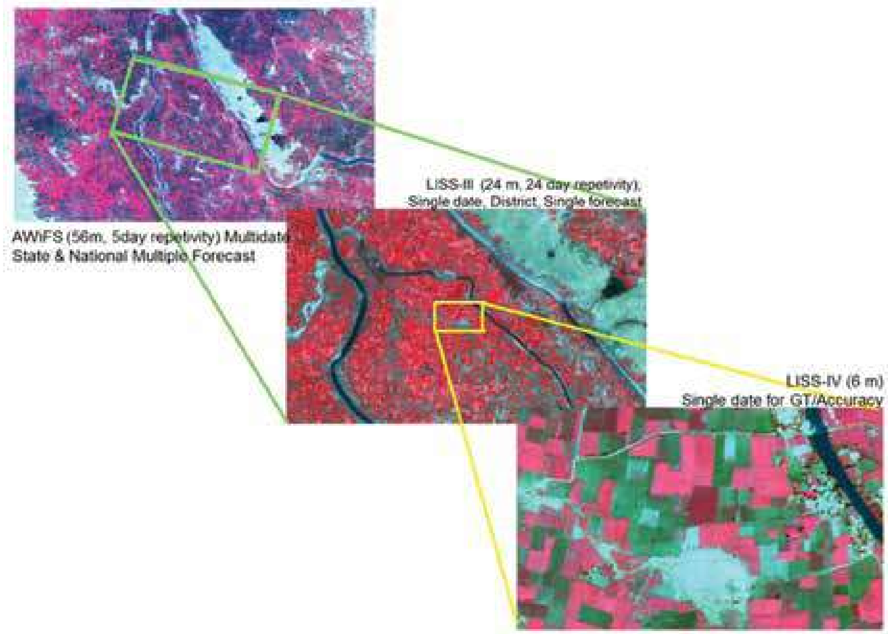

Fig 2 Crop monitoring using Remote Sensing Data from different sensors

f. Users' Perspective

The Ministry of Agriculture and Farmer's Welfare has been the key end-user of ISRO's satellite data. The Forecasting Agricultural output using Space, Agro-meteorology and Land-based observations (FASAL) project is used for the crop assessment, National Agricultural Drought Assessment and Monitoring Systems (NADAMS) for drought assessment and Coordinated Programme on Horticulture Assessment and Management using Geoinformatics (CHAMAN) for horticulture management. Additionally C(K) rop Insurance using Space technology and Geoinformatics (KISAN) have used satellite data for processing the crop insurance. ISRO introduced a new agricultural programme called SUFALAM (Space technology Utilization for Food security AgricuLtural Assessment and Monitoring) led by Space Applications Centre(SAC), ISRO since December 2018 to provide R & D support to various government inititatives for agricultural applications

Users along with ISRO agencies have established the procedures for multiple pre-harvest estimates of 6 crops viz: Jute, Kharif rice, winter potato, rapeseed/mustard, Wheat and Rabi rice. Realising the need to integrate this advanced technique in the routine crop statistics gathering, Department of Agriculture and Cooperation (DAC), Ministry of Agriculture, Govt. of India initiated steps to set up a centre for this purpose. Accordingly, the centre “Mahalanobis National Crop Forecast Centre” (MNCFC) has been set up at PUSA, Rajendranagr, New Delhi. MNCFC gives multiple preharvest crop production estimates for sevral crops, covering more than 53 precent of the total crop area accounting about 78 perent of the grain production needed for human consumption in the Country. In addition, MNCFC also uses the space-based techniques to assess the drought conditions in the country. This helps the Government to decide on relief measures for the affected areas in the country.

Thus, the Indian Government is carrying out the operational forecast of the crops from 2012-13 season onwards for major crops such as Rice (Kharif & Rabi), Wheat, Rabi Sorghum, Sugarcane, Rapeseed/Mustard, Cotton, Jute and Rabi Pulses. Further research studies are being carried out to bring in additional crops under FASAL under ISRO’s SUFALAM programme which is also addressing AI/ML-based crop mapping, area and yield estimation, satellite-baed farmers’ advisories through satellite agromet products, fodder assessment for efficient dairy management with AMUL and NDDB, developing smart solutions for crop insurance. The R&D activities to address several upcoming needs are also being pursued with other international space agencies and GEOGLAM for south-east Asia rice crop monitoring, agromet product comparison with JAXA, airborne hyperspectral science with NASA and future SAR and high-resolution thermal IR missions with NASA and CNES, respectively.

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3. FORESTRY AND VEGETATION

a. Back ground

Forests are important natural resources providing rich organic matters, purify the air we breathe, prevent soil erosion and conserve water. Forest resource management is one of the essential tasks in planning a well structured national development. The early concepts of sustainable forest management and forest inventory mostly looked at timber production, whereas the focus in the recent times is that to take a holistic view of forest ecosystems. It addresses not only timber production but also the multiple functions of forests and understanding the functioning mechanisms of forest ecosystems in totality. Forests are no doubt rich natural resources for any country's development and their assessment and monitoring are absolutely essential in understanding the structure, composition and function of different natural ecosystems. Space technology with appropriate sensors having different spatial and spectral capabilities play a major role in meeting these objectives. The data so generated by space based systems helps in assisting the regulation of developmental activities and also in sustaining the natural ecosystem. Forest resources assessment and study of forests make substantial contribution towards subsistence, employment, revenue, and raw materials to a number of industries apart from playing a critical role in ecological balance, environmental stability, biodiversity conservation, food security, and sustainable development. In India the forest resource assessment is being carried out at different levels e.g., bi-annual forest cover mapping using satellite remote sensed data by Forest Survey of India (FSI). In addition, the multiple aspects of forests like biomass, global warming, biodiversity, non-wood goods and services have gained a lot of importance. The spatial data using remote sensing is generally combined with the ground based information in geospatial domain to generate the useful databases for managing forest resources.

b. Objectives:

The objective of the space based monitoring of the forests has been to capture the various aspects of forest and vegetation like the distribution of forest ecosystems, global fluctuations in plant productivity with season and the three-dimensional (3D) structure of forests etc., through mapping. Understanding the forest ecosystems structure, processes and also biodiversity assessment are important factors. The Indian sub-continent is known to be having one of the richest flora and fauna in the world. As per the reference 3 listed below, India is ranked as one of the mega-biodiversity countries in the world with 49,219 numbers of plant species and 89,451 animal species as per the data available as on 2010. The natural terrestrial ecosystems like forests, grasslands, scrub lands, fresh water & ocean systems, microbial ecosystems, plantations etc., provide immense potential for bio-resources. India has a forest cover of 71.38 million ha (covering 21.71 % of total geographic area; Reference 4 published in 2021). Forests are widely distributed across the country and offer valuable ecosystem services as carbon sinks, soil erosion control and flood mitigation. Its rich floral diversity is represented by 47,000 plant species. Much of the demand for timber, fuel wood and fodder are met through these forests. In such a vast system it is necessary to capture the important processes like the landscape change, carbon sequestration, hydrology, generic ecosystem patterns and regional climate models. Automated forest cover retrieval, biodiversity monitoring and change assessment also form part of the objectives. High resolution and hyper spectral data from a spacecraft enables retrieval of vital forest parameters. Retrieval of essential information on forest resources greatly assists in appropriate forest planning and forest policy. Continuous efforts are on to enhance the quality of the on-board sensors with higher spatial and temporal resolution and also enhanced spectral capabilities to bridge the gaps like causes for forest fragmentation, improving upon the rapid fire system etc. Gathering of ground based information database compliments the space based data to have a better spatial understanding of the ecosystem processes and their subsequent upscaling for regional level management.

The scope of forest inventories varies considerably. The criteria and indicators for sustainable forest management have been formulated through several international, national, and nongovernmental initiatives. These criteria and indicators cover administrative, economic, legal, social, technical and scientific issues along with natural environment and climate which affect natural forests and plantations. The criteria define the essential factors against which forest sustainability has to be assessed. Each criterion relates to a key management factor. Through measurement and monitoring of selected indicators, the effects of forest management action, or inaction, should be assessed, evaluated and action adjusted to ensure that forest management objectives are achieved. Table 1 given below summarizes the criteria and indicators identified by the processes.

Table 1: Criteria and indicators for sustainable management (Ref : 3 page 51; source: Franklin, 2001)

Extent of forest resources and global carbon cycles:
Area of forest cover
Wood-growing stock
Successional stage
Age structure
Rate of conversion of forest to other use.
Forest ecosystem health and vitality external influences:
Deposition of air pollutants
Damage by wind erosion
Forest vitality indicators
Incidence of defoliators
Reproductive health
Forest influence indicators
Insect / disease damage
Fire and storm damage
Wild – animal damage
Anthropogenic influence indicators
Competition from introduction of nonnative plants

Nutrient balance and acidity
Trends in crop yields
Biological diversity in forest ecosystem :
Ecosystem indicators
Distribution of forest ecosystems
Extent of protected areas
Habitat suitability
Forest fragmentation
Area cleared annually of endemic species
Area and percentage of forest lands with fundamental ecological changes
Forest fire control and prevention measures
Species indicators
Number of forest- dependent species
Number of forest-dependent species at risk
Reliance on natural regeneration
Resources exploitation systems used
Measures for in situ conservation of species at risk
Genetic indicators
Number of forest-dependent species with reduced range
Productive functions of forests:
Percentage of forests/other wooded lands managed according to management plans
Growing stock
Wood production
Production of non-wood forest products
Annual balance between growth and removal of wood products
Level of diversification of sustainable forest production
Degree of utilization of environmentally friendly technologies

c. Expected Benefit to Society:

The benefits of space based forestry applications are several such as forest management with continuous update of forest inventories, afforestation to maintain the overall forest areas, forest terrain analysis, forest cover type discrimination, monitoring of forest fires, the delineation of burned areas etc. it also assists to identify damages caused to the forests by people, by fire, the size of the fire and the direction in which the fire is likely to spread and the precautions to be taken. It also helps to assess the damages on forests in case of a hurricane or disasters. Forest biomass estimation helps to evaluate the carbon sequestration and carbon balance capacity of forest ecosystems. Mapping of existing forest resources at large scale is an important input in preparing forest working plans towards implementing ground based management plans. Similarly the traditional rural population, the tribes / aboriginal people use a very large content of bio- resources available in forests. It is estimated that around 20,000 plant species are utilised for medicine and the medicinal value of plants. They are widely used in the form of traditional systems of medicinal sciences like, Unani, Ayurveda and Siddha. As per the estimates available about 8,000 species are used in some 10,000 drug formulations.

d Implementation mechanism:

Satellite remote sensing capabilities have undergone significant advancement over the years. Starting from coarse resolution MSS sensors during 1970s to a range of sensors in India's satellites, such as Cartosat, LiSS III, LiSS IV, AWiFS, have been put into service for sensing and monitoring various forest parameters. Similarly, from simple mappings carried out with the earlier sensors in 1980s forest remote sensing has come a long way passing through the whole gamut of applications as monitoring and change assessments, biodiversity studies, fire detection and species prediction. IRS P6 satellite having different resolution sensors like, AWiFS (56 m), LiSS III (23.5 m), LiSS IV (5.6 m) are used to study and assess different forest parameters at various spatial scales. Cartosat I data with 2.5 m resolution is used in detailed assessment of forest structure and species composition. By making use of all these sensors it is possible to acquire large range and scale of information. For monitoring forest fires, rapid forest cover monitoring, vegetation phenology, carbon sequestration and forest productivity studies at global and regional scale coarse resolution sensors, AWIFS with high repetivity are being used. LiSS III sensor having spatial resolution of 23.5 m has wide application for studying forest composition, gregarious formations, monitoring of forest stands and plantation activities. For studies related to canopy density, canopy height and mapping of individual trees of economic importance as Teak and Sal and NTFP (Non Timber Forest product) such as canes, gums, resins, fibre yielding forest species high resolution LiSS IV and Cartosat sensors are used. The major advantage of the satellite based system is the temporal revisit of the satellites and it has greatly enabled to assess and analyse changed scenario with better accuracy and precision.

Under Decision Support Centre (DSC) activities at NRSC, a comprehensive system “Indian Forest Fire Response and Assessment System (INFFRAS)” has been established considering the importance of forest fire management in India. INFFRAS has provided value-added forest fire alerts for the past decade. In addition to the fire alert products INFFRAS also provides forest departments with satellite remote sensing and GIS based inputs for preparatory planning for fire control, damage and recovery assessment and mitigation planning. The primary user of the fire alert system (dissemination in near real time by emal) is the Forest Survey of India (FSI) and also hosted on Bhuvan geo portal, in near real time.

Hyperspectral remote sensing which is useful in many applications such as water vapour, cloud properties, aerosols, mineral exploration etc., are also useful in forestry applications such as forest production, biomass burning, chlorophyll & leaf water content, cellulose and pigment, etc.

A diverse array of sensors and platforms (Figure 1) are available for monitoring the forest ecology and its management.

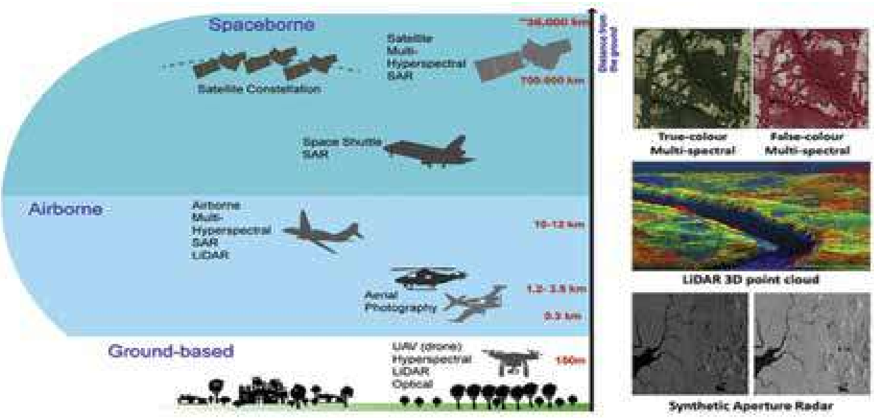

Figure 1 : Remote sensing data from RS platform and sensor combinations

(Courtesy: Reference 1)

Passive as well as active sensors from the platforms viz., earth observation satellites, aircraft, and unmanned aerial vehicles (UAVs) are used for collection of remote sensing data. Optical imaging systems can acquire data beyond the visible wavelengths (i.e., infrared and thermal wavelengths), across the electromagnetic spectrum. Optical sensors vary in terms of the number of bands (and the widths of those bands) from which image data are captured. Multispectral sensors used in a spacecraft have a limited number of bands, whereas hyperspectral sensors have thousands of much narrower bands. Optical systems (and thermal systems) are passive sensors, which rely on reflected sunlight or emitted thermal energy. Therefore, it cannot penetrate clouds or smoke and cannot be used at night. Active sensors like light detecting and ranging (LiDAR) and synthetic aperture radar (SAR) systems can overcome this problem. SAR sensors can differentiate land-cover features according to their surface roughness, the 3D structure of the targets, and water content. L-band SAR data, due to high canopy penetration capability, helps in estimating above ground biomass and also enhance the accuracy of forest disturbance monitoring.

Table 2. Satellite Remote Sensing sensors and potential in Forest applications

Scale	Data Source	Forest Attributes	Spatial Resolution	Temporal Frequency	Mapping Scale	Monitoring Cost
Global	VIIRS (NPP/ JPSS) MODIS AWiFS (IRS)	Phenology Types Forest/ Non-forest Net Primary Productivity Deforestation Biomass burning	1km to 56m	Daily	>1:5000,000	Low
Regional	LISS-III (IRS) MSI (SENTINEL) OLI (LANDSAT)	Forest / Habitat types Secondary types Disturbances-(logging/ fire/roads/ encroachments) Plantations Ecotones Wetlands Gregarious formations Target species with gregarious distribution	10m to 30m	5 to 16 days	>1:50,000	Low
Local	IRS-Cartosat-2Series IRS-Cartosat-3 Series Aerial Imaging (LIDAR/ MX)	Target species with gregarious distribution Forest disturbance Canopy gaps Plantations Harvest rates Degradation level	<1.6m	User defined	>1:10,000	Moderate to High

Biodiversity assessment is one of the important applications of course resolution remote sensing. The primary inputs for this study are satellite image data for mapping and monitoring of global land-cover, biomass burning, estimating geophysical and biophysical characteristics of terrain features. The table 2 given above is a typical satellite Remote Sensing sensors and potential in biodiversity assessment (Murthy et al., 2003; Reference 3)

e Area Coverage: National / State / District

The area covered is the entire region of Indian subcontinent including the remote places, Himalayan and western Ghats region. Regional to local assessment are also done on case to case basis. Forest working plans are prepared State-wise for forests under the States' jurisdiction. Satellite data from both Indian and foreign spacecraft like Cartosat-2S/3, World view, Pleiades etc. are also used to derive the forest crown based information for microlevel monitoring and forest condition assessment.

f Results Obtained: (compare with item c above)

Figure 2: Forest cover assessment of India (Source: FSI, reference 5)

In India satellite based data is widely used in several forestry applications as discussed in earlier sections. As one of the earliest works for forest cover assessment, the Government of India undertook the task of assessing forest cover in 1986. NRSA assessed the National forest cover mapping during the periods 1972-75 & 1981-83 using Landsat MSS data at 1:1 million scale. The data provided was total forest area information such as crown density classes, an index of condition of forests. Forest crown density refers to the per cent area covered by tree crown per unit ground area. NRSA initial study indicated the significant loss of forests during 1972-83 and the alert was passed on to the conservation of forests. A typical forest cover of India prepared in 2003 is given in the Figure 2 below. (Reference 3)

In addition, the operational methodology for national cover mapping and technology was transferred to Forest Survey of India (FSI). Since then, FSI has made several biennial assessments. First the forest cover was interpreted visually for first seven cycles at 1:250,000 scale. Subsequently the digital approaches are followed for the subsequent cycles (1:50,000) for two crown density classes of 10-40% and >40%. As spatial resolution improved, classes > 70 %, 40 – 70%, 10-40 % and scrub have been delineated in addition to the tree cover outside the reserve forest areas. The assessment made in the year 2021 represented the classes Very Dense Forest (canopy density >70%), Moderately Dense Forest (canopy density 40-70%) and Open Forest (canopy density 10-40%) (with total forest cover as 71.38 Mha, i.e. 21.71% of the geographic area of the country).

The combination of ground data, remote Sensing, GIS and GPS data have several advantages in forestry applications and it helps in describing the four distinct major components namely, the greenness, crown closure, mixed vegetation types and the species assemblages. The ground measured parameters are climatic, topographic and socio- economic. They have to be integrated with remotely sensed data into GIS. With the help of GIS analysis, a number of outputs needed by several users like forest managers, researchers and academia are obtained and made available.

Some other applications have been, using IRS PAN, IRS LISS IV sensors data at 1:25,000 scale for forest division and micro level planning the detailed forest crown density mapping were prepared along with crown density interval of 20%. These databases were used for monitoring and evaluation of afforestation and reforestation. The forest crown density levels, rehabilitation and selection working circle are utilised to the conservation and harvest plans. The satellite data from CARTOSAT, IKONOS and QUICKBIRD are used to derive the forest crown based information and these data bases are prepared for micro-level monitoring and forest condition assessment.

Using IRS 1B data, broad-scale mapping of Western Ghats was carried out in 1:1,000,000 scale and 205 patches belonging to 11 different landscape types consisting of topography, climate, population, agriculture and vegetation cover etc., were delineated. The nature and the extent of forest degradation and its causes have been identified, using mesoscale analyses of forest condition in the region of Western Ghats. The spatial data generated by remote sensing is used in biodiversity monitoring and conservation efforts. Datasets from IRS 1C/1D LISS-III have been effectively utilized in mapping the pure plant colonies in the Spiti region of India. The temporal monitoring of forest cover, facilitates analyzing biodiversity losses. A few examples of such studies conducted in southern Western Ghats of India and Vindhyans of central India and North-East India have provided details about vegetation type transitions. These transitions, when coupled with ground-based species databases, have helped in analysing and quantifying biodiversity losses.

Biodiversity characterization at landscape level was jointly done by DoS and DBT during 1998 – 2010 in different phases as input for biodiversity conservation and management. Vegetation type map and other terrain and vegetation parameters were derived as outcome of the project. The project enabled classification of about 150 vegetation and land use types, enumeration of more than 7,700 plant species through a field sample plots of over 16,000. Analysis of spatial pattern of landscape units, generation of terrain complexity, biotic disturbance buffer and their integration along with economical, phytosociological and ecological attributes for qualitative labelling of biological richness in various ecological habitats were done under the project, to characterize the biodiversity at country level along with fragmentation and biotic disturbance gradients.

DOS and DBT have just initiated a new study 'Biodiversity Characterisation at Community Level' for developing an Earth Observation based strategy for mapping biodiversity at the community level in India. It aims generating a fine-grained description of vegetation structure, function, pattern and composition from detailed field studies and Remote sensing data from a range of Earth Observation platforms (https://www.isro.gov.in/biodiversity)

g Users' Perspective

The data provided by IRS satellites with different resolution sensors on the same platform such as AWiFS (56 m), LiSS III (23.5 m), LiSS IV (5.6 m) have been useful for many forestry related studies which provided different forest parameters at various spatial scales. Cartosat-1 data with 2.5 m resolution have been effectively utilised by the users in detailed assessment of forest structure and species composition. Coarse resolution sensors with high repetivity like AWiFS, help in monitoring burnt areas due to forest fires and also rapid forest cover monitoring. Forest Survey of India (FSI) has been carrying out biennially forest cover mapping which is decipherable from remote sensing data based on tree canopy density characteristics. Periodic assessments help to understand the trend of forest cover in the country, so that appropriate interventions could be planned and to prioritize conservation of forest cover at the regional level. It also provides a base for future research on the impacts of deforestation on carbon stocks and biodiversity.

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4. LAND USE AND LAND COVER (LULC) APPLICATIONS

a. Background:

Land use essentially describes the human use of land for economic and cultural activities, e.g., agricultural, residential, industrial, mining, or any other uses) at a given identified location. It largely depends on the activities people undertake in a certain land cover. Land cover is the observed (bio) physical cover on the earth's surface, to describe vegetation and man-made features. The land use in a way establishes a direct link between land cover and the actions of people. While the land cover is what covers the surface of the earth, the land use deals with how the land is used. Examples of land cover include: water, snow, grassland, forest, bare soil etc. Land use includes agricultural land, plantation, urban, industrial, recreation area, wildlife management area etc. Rapid changes are happening in the Earth's land cover, over a period due to increased economic development and also due to increase of the population all over the globe. No doubt the economic activities are going to increase inleaps and bounds in future. The changes in the land cover can affect the land substantially to sustain the human activities. Space based Earth observation is a powerful tool to meet the demand for timely and accurate land cover information over large areas. Therefore, using the space based observation, the systematic assessment of Earth's land cover is highly beneficial to assess the inter-annual variability. At the same time it has to be done at appropriate spatial detail so that it is quite useful to carry out the study of human induced changes. Land cover, in a way has most crucial properties of the Earth system. The land cover is closely linked to the atmosphere, which leads to regulation of the hydrologic cycle and energy budget. This data is essential for weather and climate prediction. In addition, the land cover plays a major role in the carbon cycle, acting as both sources and sinks of carbon. The land cover also linked with the availability of food, fuel, timber, fiber, and shelter resources for human populations, and serves as a critical indicator of other ecosystem services such as biodiversity. The land use planning and management is an important ingredient for inclusive growth and development in various sectors, like food and water security, climate change etc.

b. Objectives:

The objectives are to carry out space based surveys using Land use / Land cover (LULC) maps which play a significant role in planning, management and monitoring programmes at local, regional and national levels. These are aimed towards the socio economic development of the country using both spatial and non-spatial dataset generation. In this effort the satellite generated information assists not only in improving the understanding of land utilization but also in framing the right policies and programme required for development planning. Space based monitoring of land use/ land cover (LULC) pattern over a period of time is essential to ensure sustainable development. Regarding the urban development, generation of such planning models vastly helps to ensure that every piece of land is used in most rational and optimal way utilising the present and past land use/land cover information of the area. The changes that are happening in the ecosystem and also in the environment are to be assessed by using the detailed Land Use/Land Cover studies. The results thereof are utilised to frame the right policies and programmes to save the environment. LULC information on an yearly basis, covering national spatial database enables regular monitoring of temporal dynamics of agricultural ecosystems, forest conversions, surface water bodies, etc. on annual basis and helps to understand the changes in any of these systems. In summary the objectives have been

a. To generate the land use/ land cover data base using three seasons (Kharif, Rabi & Zaid) LISS multi spectral satellite data and update the same at every 5 years period and AWiFS data at annual cycles.

b. To create the digital data base based on standard codification and integration at district/state/national level.

c. To provide the land use report covering the whole country with details for each district/ state for planning exercises at various levels.

d. To report the land use / land cover change with scale maps and assessment report to enable sustainable development.

c. Expected Benefit to Society:

Land use and land cover maps play an important role in several areas including policy making for agriculture, environment, industry etc.. Land cover data are used as basic information for sustainable management of natural resources and they are increasingly needed for the assessment of impacts of economic development on the environment. The LULC maps are used at broad level for many other important developmental tasks such as a) Scientific research involving carbon cycle, hydrologic cycle, energy budget studies, weather / climate prediction etc. b) Siting of industries, SEZs etc. c) Land improvement programmes d) Watershed management e) Coastal zone management f) Agricultural productivity improvement, g) Disaster Management and similar developmental programmes at National level.

d. Implementation mechanism:

The spacecraft used for Land Use / Land Cover studies are mainly optical sensors from Resourcesat 1, 2 and 2A. The sensors used are AWiFS (56m) at a scale of 1:250000, LISS- 3 (24m) with a scale of 1:50000 and LISS- IV (5.8m) with a scale of 10000. Similarily for wasteland mapping on 1:50,000 scale LISS-3 (24m) sensors are used. Whereas LISS- IV of Resourcesat and Cartosat-2S have been used and for hotspot analysis of wasteland regions. Satellite remote sensing provides a synoptic view of the landscape at all levels right from the local level to the global level. The advantage of satellite-based remote sensing sensors is that they capture the electromagnetic spectrum in ranges other than the visible region and can split the complete electromagnetic spectrum into various bands. The big advantage in this is the extraction of information about the variability of the earth's surface due to the reflective property of the surface to the different electromagnetic wavelengths

Land Use Land Cover information on 1: 50,000 scale was generated in the country using three seasons data (IRS LISS-III) once in five years like; 2005-

06, 2011-12 and 2015-16. 54 level-III classification system is used while mapping the land use / land cover. These maps address i) Generation of spatial database on land use/land cover, ii) Generation of land use/land cover change database along with change matrix with respect to previous time frame and iii) Identify areas of major change. Subsequent to the successful completion of the 1st cycle using satellite images (2005-06) and 2nd cycle (2011-2012) of Land Use / Land Cover Mapping using 3 seasons (viz., Kharif, Rabi and Zaid) data, the 3rd cycle (2015-16) mapping has also been completed using the satellite data of 2015-16. Apart from mapping, the Land Use / Cover changes with respect to 1st and 2nd cycles database is also done in the third cycle. Similarly, at 1:250,000 scale, 17 cycles of Land Use / Cover Mapping are completed since 2004-05. Bhuvan Geoportal provides the actual digital map for further exploration through an online process.

In the multilevel land use and land cover classification system, information at Levels I and II are of interest to users who are looking for a data on a nationwide, interstate, or statewise basis. Level III and IV land use and land cover data are more detailed and used more frequently for generating the local information at the intrastate, district, panchayat or municipal level. The latter levels of categorization are generally developed by the user groups themselves, so that their specific needs are met with. At the more generalized levels the classification helps to utilise the data for use in land use planning and management activities.

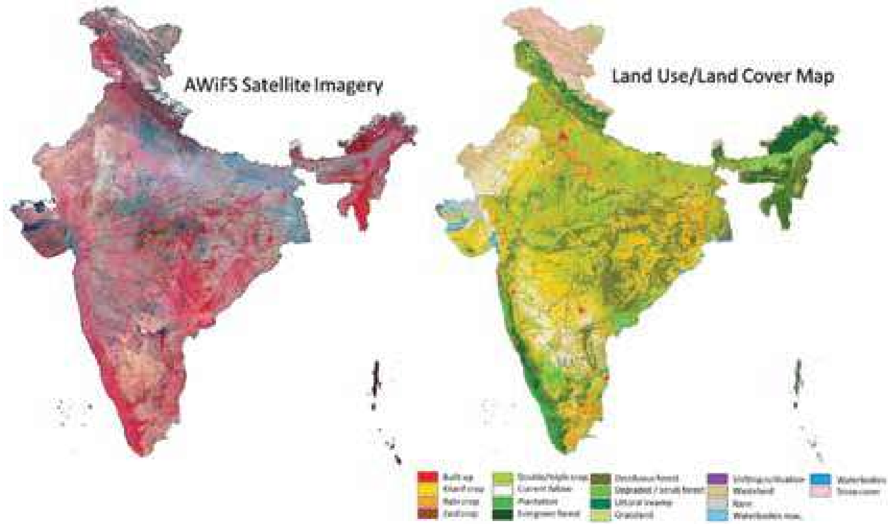

Figure 1. Land Use/ Land Cover Map of India through digital supervised classification.(Courtesy:Reference 2)

The General Methodology of Land Use / Land Cover Analysis involves the following. The land cover mapping from satellite data is carried out in four steps: data acquisition, pre-processing, analysis/classification, product generation and documentation. The pre-processing in principle entails geometric and radiometric corrections; analysis and classification involves converting image data into land use / land cover data. Land cover information that can be gleaned from satellite images is the spectral and spatial attributes of individual cover types.

A wide variety of classification / analysis methods have been developed to derive the needed information from remotely sensed data. They are using visual approach, digital analysis approach or hybrid approach in which both are combined. In recent times newer approach involving object based approach, segmentation approach and knowledge based with integration of several approach are increasingly being used. These methods range widely in complexity, sophistication, and accuracy. The most widely used of these techniques is the Normalized Difference Vegetation Index (NDVI). A typical Land Use/ Land Cover Map of India generated through digital supervised classification technique from IRS-WiFS image in February 2002 is given in Figure 1.

The approach used in the generation of LULC database involves several steps and the details are as given in Figure 2.

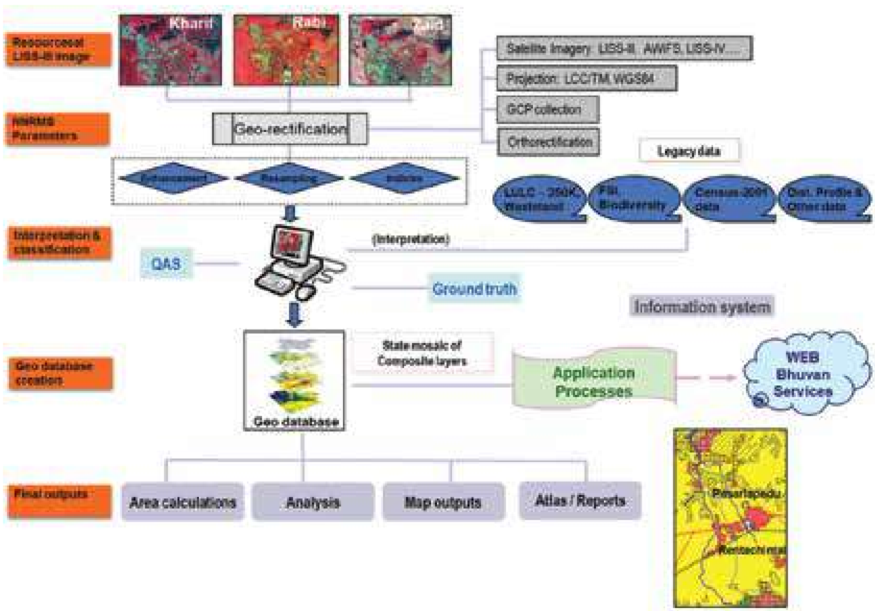

Figure 2 Broad steps involved in the generation of LULC database (Courtesy : Reference 3)

The detailed steps in the generation of Land Use / land Cover are explained below.

- Use of multi temporal satellite data (AWiFS for 1:25000, LISS-III for 1:50000, LISS-IV Mx for 1:10000) data, covering to address spatial and temporal variability in land cover classes. In the event of clouds and lack of good quality of data the multi-sensor data is used.
- Ortho rectification of multi-temporal datasets are used to correct the effect of relief and geo-referencing.

- The land cover classes from the satellite data are interpreted using standard classification system and a preliminary interpretation map is prepared.
- Statistically sound sample grids are identified and verified on the ground. This assures a good statistical representation of the land cover classes.
- Fieldwork is carried out by the interpreters using a fully standardized methodology.
- Establishing the relationship between image elements and the tentatively identified LULC categories during preliminary interpretation. An interpretation accuracy is done using field data.
- The interpreted LULC categories made earlier phase is modified based on information collected during the fieldwork, existing maps such as wasteland, biodiversity, LULC data, etc. During this phase the accuracies are ascertained.
- In digital database the steps involved are the finalization of land cover layer through editing, digitization, reclassification, coding and geographic referencing of land cover to facilitate their follow-up GIS processing.

e. Area Coverage: National / State / District

The area covered for Land Use and Land Cover (LULC) using space based services is the whole Country and it encompasses all states and union territories of the Country.

f. Results Obtained: (compare with item c above)

National Remote Sensing Centre (NRSC) has been preparing Land Use and Land Cover (LULC) maps for all states and union territories of the Country. LULC maps of particular area/s provide information and help the users to understand the current landscape. Annual LULC information on national spatial databases enables the monitoring of temporal dynamics of agricultural ecosystems, forest conversions, surface water bodies, etc. on annual basis. Annual Land use / Land cover mapping is carried out since year 2004-05 at 1: 250000 scale and net sown area is estimated apart from generation of the Land Use / Land Cover information. Under this exercise satellite data from AWiFS sensor is being classified using digital classification methods and final integration of individual classes are being done through rule based approach. Integrated year wise Land Use / Land Cover data are available till year 2018-19. Land Use / Land Cover information is generated once in 5 years at 1: 50000 scale. Land use / Land cover is generated at 1: 10000 scale, useful for water land resources planning at village / taluk level. Wasteland mapping and monitoring has been carried out at 1: 50000 and 1: 25000 scales. The data generated at 1: 10000 scale is used for planning at Panchyat and Taluka level.

Nationwide land use/land cover analysis for planning based on agro-climatic Zones was carried out for all the 15 agro-climatic zones, in 15 districts using the 22 fold LULC classification system. The Remote Sending - LISS-II data of kharif (July-October) and Rabi (November- March) were used to generate details on crop land in Kharif (July- October) and Rabi seasons, the area under double crop, fallow lands, different types of forests, degradation status, wasteland, water bodies, etc using hybrid methodology. National Remote Sensing Centre (erstwhile NRSA) along with Regional Remote Sensing Service Centres (RRSSC's), State Remote Sensing Centres and other institutions completed this task. Out of 442 districts in the country, 274 districts were analyzed using visual techniques and remaining the 168 districts by digital techniques. The Planning Commission of India was the main user for this project.

Wasteland mapping by NRSA/NRSC was first time taken up in year 1984 on 1:1 million scale to tackle the challenge and need for treating such wastelands across the country. As precursor to this and request by Government of India Wastelands at 1:50000 were made available for the country at district level to plan the reclamation measures spreading across the years 1986-2000, 2003 and 2005-06. However, for the first time, wastelands change analysis was attempted between 2005-06 and 2008-09 time followed by another change mapping between 2008-09 and 2015-16 to bring comparison of wastelands across the country. Both Landsat Thematic Mapper (TM) and the RS (LISS-2 and LISS-3) data were used for mapping purposes in exercise till 1986-2000 and thereafter IRS LISS-III were utilised to map 23 classes of wastelands. Hybrid methodology was used to derive information on the wastelands. About 55.77 million ha (16.96 per cent) have been estimated as wastelands during 2015-16 exercise which saw reduction of about 0.88 million ha from 2008-09 exercise. The total area of wastelands in the country is being estimated periodically and the data on the per cent of the geographical area of the country is generated for use by the concerned departments.

Forest Survey of India (FSI) is carrying out forest cover surveys using satellite data since 1981-83, at every 2 years of interval. Based on the latest estimates for year 2021 by FSI the total forest cover has been estimated at 21.71 per cent of the geographical area of the country. As part of landscape level biodiversity characterization project of the DOS-DBT supported programme, the vegetation type mapping of NE regions and Western Ghats with 1 : 250,000 scale was carried out using RS- LISS- satellite data. The mapping of Central India, Eastern Ghats and East coast in 1 : 50,000 scale are carried out using IRS P6, LISS- satellite data.

For drought mitigation, 'Integrated Study to Combat Drought' was carried out by Department of Space(DOS), Govt. of India. Different thematic maps viz., LULC, Hydro geomorphology, Soils, Slope etc. were generated on 1 : 50,000 scale and integrated to derive locale specific prescriptions or action plans for sustainable development of land and water resources on watershed basis. The work comprised three phases covering 175 districts in different agro-climatic zones covering about 84 million ha. or 25% of the total geographical area of the country (NRSA,2002).

Net sown crop area was generated, for the Ministry of Agriculture & Farmer Welfare, GOI. Seasonal crop area information is utilised by State agricultural departments for assessing the performance of various agriculture scenario at district and sub district level. Land Use / Land Cover information generated in different scales are used for planning effective utilisation of natural resources. Identification of hotspots with major land cover changes in landuse is also done to identify the drivers of these changes. Several hydrologic models utilise this information for estimation of run off coefficients while estimating water balance components.

g. Users' Perspective

The users for LULC data and maps are from government (central and state) departments, research organisations, academia, NGOs, as well as from private sectors. Different departments of Government, dealing with built up lands in urban, rural and mining areas, agricultural land, forest, grass and grazing land, wastelands, wetlands, and snows and glaciers are active users and using it in the preparation of regional plans. Department dealing with rural management, utilises the data for the human settlement (generally of smaller agriculture, allied sectors and non-commercial activities). In mining areas the data is used to assess the recognizable impacts of mining activities on the landscape. With regard to agricultural lands the data is used in several applications. For example, to assess the cropland area, the area which is primarily used for farming and for production of food, fiber, and other commercial and horticultural crops. The data is also utilised to identify the kharif, rabi and zaid crop lands along with areas under double or triple crops. The plantations are another application, where it is used widely; the area under agricultural tree crops like agricultural plantation (like tea, coffee, rubber etc.) horticultural plantation (like coconut, arecanut, citrus fruits, orchards, fruits, ornamental shrubs and trees, vegetable gardens etc). Further the Departments related to forest, grass/grazing land, wastelands, water bodies etc., are also effectively utilising the LULC data to record the details and also to assess the changes occurring over a period.

Academic and research oriented organisations are using Land Use / Land Cover data for understanding interaction between land cover and atmosphere which ultimately leads to regulation of hydrologic cycle and energy budget. These data are regularly being used in various models involving Land Surface Parameterisation, database preparation on Albedo, understanding evapo-transpiration and carbon sequestering.

The project outputs have been very useful and effectively used by the User Departments.

a. Generated a spatial database on net sown area for different seasons. Facilitated the monitoring and assessment of total cropped area under rain fed and irrigated conditions.

b. Helped in monitoring of dynamic land covers like surface water, forest and waste lands etc.

c. Serving as a primary database for regional authorities in planning and developmental activities and for addressing global environmental issues related to biodiversity, climate change, land cover atmosphere interactions, carbon sinks, etc.

d. Created as a useful database for different Ministries and Departments like Agriculture, Rural Development, Environment and Forest, Jal Shakti, Social Statistic Division of MoSPI, National Bureau of Soil Survey and Land Use Planning, All India Soil and Land Use Survey etc.

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5. SOIL AND LAND DEGRADATION

a. Objectives:

The soil and land are essentially a life supporting system from the time immemorial. Remotely sensing data is used to generate the comprehensive information on soil resources and also track land degradation as a process. On the soil front one can assess its potential, limitations and also generate information about its capabilities, which are needed for a variety of applications under sustainable agriculture. Some of the important and essential activities for sustainable development and food security are soil conservation, reclamation of degraded lands, command area development, watershed management, etc. For effective in-season monitoring it is essential to conduct Soil moisture studies, use remote sensing based soil fertility analysis, adopt GIS techniques for online tracking, conduct soil resources studies for effective planning, like, crop suitability studies, land irrigability assessment, land productivity assessment, soil erosion modelling and prioritization of watershed. Space data plays an important role in all these studies, particularly when they are taken as part of geospatial analysis on GIS platforms.

b. Expected Benefit to Society:

The remote sensing technologies and data so generated on regular basis have contributed vastly for mapping and monitoring soils / degraded lands at different scales. GIS based models are utilised for automatic land evaluation. Better utilization of soil information has helped in taking suitable measures at field level, particularly the establishment of digital soil database has been extremely beneficial for varieties of studies. Ground Penetrating Radars (GPRs) have been playing a major role in assessing the moisture content and other soil related investigations. Study of the presence, depth and lateral extent of soil horizons can be effectively utilised for classifying the soils and estimate the taxonomic composition of soil units. Polarimetric SAR data can be effectively explored for studying the spatial-temporal variations in soil moisture. The hyper spectral remote sensing data is utilised to establish quantitative relationship between spectral reflectance and soil properties. The remote sensing satellites data with very high spatial, spectral and radiometric resolutions can be gainfully used for micro-level (1:4000 to 1: 8000 scales) management of soil resources for sustained agricultural production.

The extent and spatial distribution of various kinds of degraded lands are very important for strategic planning of reclamation and development of such lands, which are essential for the sustained food production to meet the needs of Indian population and also to restore the fragile ecosystem. Decline in land productivity, reduced agricultural or forestry resources, siltation of rivers and drainage systems, decline in agricultural income are leading to increased poverty, rural-urban migration, and increased frequency of natural disasters, such as, floods and landslides and loss of biodiversity, which are closely linked to land degradation. Remote sensing provides a rapid and inexpensive means to gather land information in terms of exact delineation of boundaries, for repetitive, annual or seasonal multi-spectral examination and for this the satellite imageries could be used at several levels of intensity / scales. Repetitive nature of space data helps to monitor land degradation over a period of time and in multiple geographical locations.

c. Implementation mechanism:

Application of geospatial technology (Remote Sensing, GIS, GPS) are effectively used in many studies that use spectral reflectance of soils, land degradation information, monitoring of degraded lands, soil moisture along with highlights on issues and prospects. While using remote sensing tools, the soil reflectance characteristics are obtained over a large area and reflectance are studied in the spatial domain with sample ground validation data. Low signal to noise ratio and atmospheric attenuations are to be appropriately factored in these measurements. Passive remote sensing instruments can provide valuable information about soils from reflectance spectra in the visible (0.4 µm to 0.7 µm), near infrared (NIR – 0.7 to 1.1 µm) and short wave infrared (SWIR- 1.1 to 2.5 µm) regions of electromagnetic spectrum (EMS). The thermal infrared regions (3 to 5 µm and 8 to 12 μm) provide diagnostic information about soils that are very important. Instruments like Spectrometers, radiometers and polarimeters are able to generate much required quantitative measurements of reflected energy from soil and have specific applications in studying various aspects of soils. When the Satellite Data is used with minimum crop/ vegetation cover, it helps better in the identification of soil patterns. For better extraction of information, the summer months are good and under certain terrain conditions the data of monsoon in association with summer season is required.

Table 1. Soil scales, sensors and levels of soil mapping

Scale	Sensors	Classification	Application
1:250,000	LANDSAT-MSS IRS-LISS-I, WIFS	Subgroups/ Families and their association	Resource Inventory at Regional Levels
1:50,000	IRS-LISS-II/III LANDSAT-TM SPOT	Soil Series and their association	District/Sub-district levels
1:25,000	IRS-IC/ID (PAN+LISS-III merged Data)	Soil Series and their association	Block/Taluk/Mandal levels
1:8000	IKONOS / LISS-4/ Cartosat-2S (MX+PAN)	Types and Phases	Village Level

The scale of soil map determines the sensor that has to be employed. The remote sensing data and the utility of soil mapping at different scales and their applications are given in the table 1. The identification, description and delineation of soils based on physiography forms the soil mapping. This has to be confirmed through field work and laboratory data. Further, they are classified as number of groups based on the different soils observed within an area. Once this is done the delineated units on a map are given a specific symbol, colour and name. The soil maps are prepared on different scales varying from 1:1 million to 1:4,000 to meet the requirements of planning at various levels. The approach used for soil mapping using satellite details given in Fig 1. The ancillary data used in soil map preparation are topographical maps, geological maps, reports, published soil maps, and climatic data particularly rain fall and temperature.

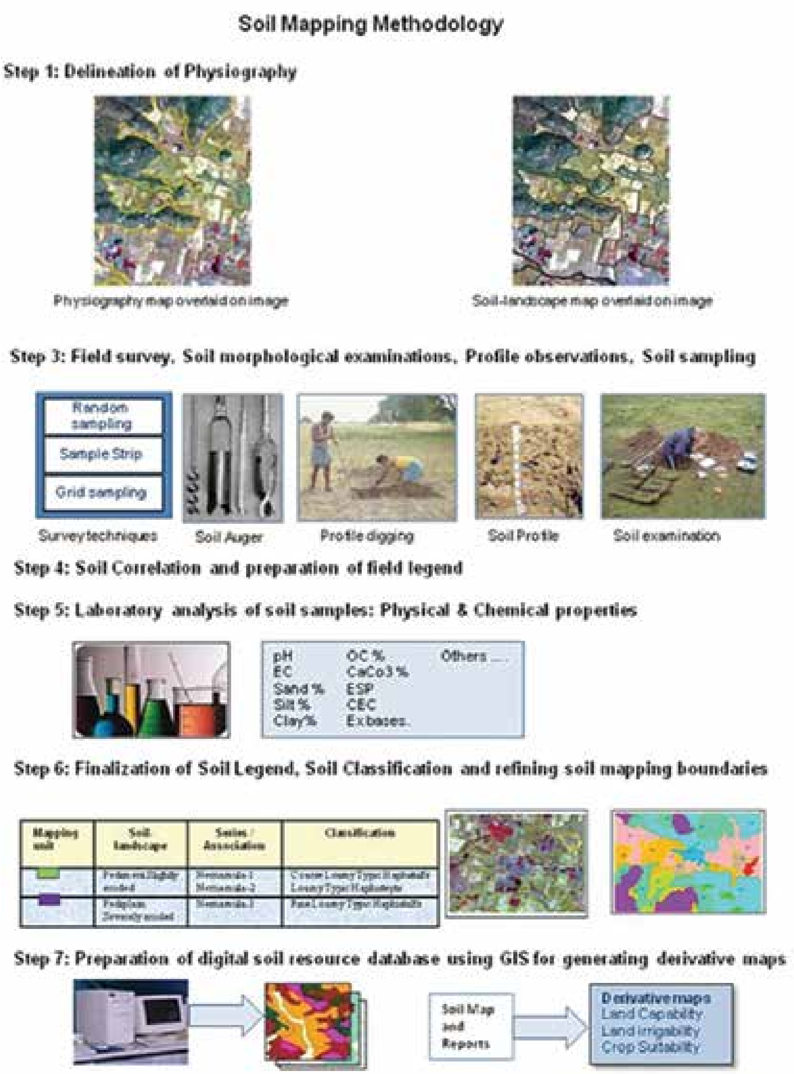


Figure 1. Schematic diagram of soil mapping methodology

The size of sample strip chosen for soil mapping is generally of the order 2 x 5 km and will have at least 2 or more mapping units. The variability in lithology, physiography, vegetation cover etc. determine the number of sample strips and a minimum of 10 per cent of total study area are covered in a topo-sequence. It is possible to increase sampling intensity depending upon the heterogeneity in the terrain conditions. Random observations in each sample strip are taken to account for variability in the soils within the mapping unit. The selected sample strips have to be transferred on to the base map for getting the field sample collection. Satellite data is of repetitive nature and enables monitoring of land degradation process over a period of time in any geographical location

d. Area Coverage: National / State / District

Soil and land degradation mapping are carried out broadly at National or State levels. National levels mapping helps to assess the resources for broad level planning purposes and for understanding the gross conditions of degradation. At state level, the mapping helps for developing management action plans. Further detailed mapping (village / block level) is required for ground level implementation of actions.

e) Results obtained (Compared to b above)

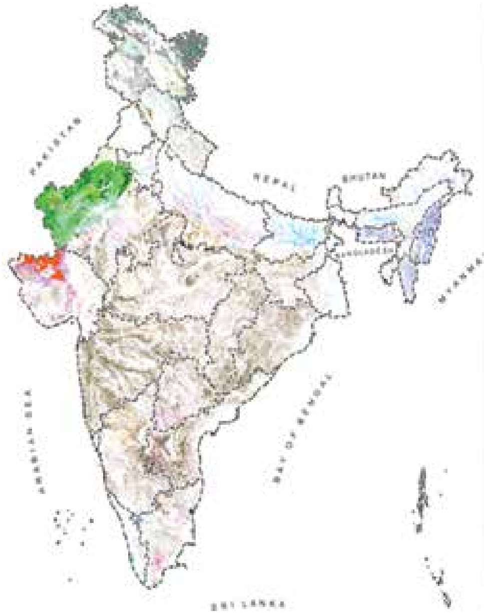
In the Country, soil survey is carried out both by central and state level organizations. Report of the Task Force (1984) says that the total areas surveyed in the country up to 1983 was 33.5 million hectares and reconnaissance soil surveys was 115.0 million hectares. NBSS & LUP prepared soil map of the entire country at 1:250,000 scale using satellite imagery and published them at 1:500,000. The report of Department of Space (DOS, 1999), presents the status of soil mapping at 1:50,000 scale and it was 119.37 million hectares for the whole country. Finer scale information may be available for very limited area.

Decadal changes in land degradation status of India:

The nationwide land degradation mapping has been taken up by ISRO along with partner institutions from State remote sensing centres, ISRO/ DOS centres and academia. The project has been taken up under Natural Resources Census (NRC) program of ISRO for generating information on land degradation at 1:50,000 scale using multi-temporal Resourcesat-1/2

LISS-III data. The endeavour of this magnitude called for adaptation of uniform classification as well as database scheme along with usage of common spatial database for deriving land degradation information. The first cycle of mapping was carried out using Resourcesat-1 multi-temporal LISS-III data of 2005-06 and the second cycle of land degradation mapping on 1:50,000 scales was now carried out using Resourcesat-2 multi-temporal LISS-III data for 2015-16. The overall approach to map land degradation on 1:50,000 scales is based on visual interpretation using the multi-temporal LISS-III data.

Classification system along with visual interpretation cues, developed during 1st cycle LD mapping (2005-6), was used for visual interpretation of multi-temporal LISS-III data. This was supported by adequate field checks, soil chemical analysis and internal as well as external quality checks at various stages of project execution. The land degradation processes addressed in this project are water erosion, wind erosion, water logging, salinisation / alkalization, acidification, glacial, anthropogenic and others. For mapping land degradation, nearly 900 LISS-III images acquired during Kharif, Rabi and summer seasons were used. Visual interpretation of multi-season data was supported with knowledge from historic thematic bases like waste lands and land use land cover as well as Cartosat DEM. The maps were finalized with adequate ground truth and soil analytical results of nearly 2900 soil samples collected exclusively under this project. Quality check was carried out for co-registration, cloud cover and radiometry during data generation stage



S.No	Process	Code	Land Degradation Class	Symbol	Area Ha.
1	Water Erosion	A1	Sheet erosion - Slight		9244007
2		A2	Sheet erosion - Moderate		24001733
3		A3	Sheet erosion - Severe		14064059
4		A4	Rills		3145902
5		A5	Gullies		1818395
6		A6	Ravines-Shallow		419440
7		A7	Ravines-Deep		302764
8	Wind Erosion	B1	Sheet erosion - Slight		5555988
9		B2	Sheet erosion - Moderate		3069226
10		B3	Sheet erosion - Severe		1046831
11		B4	Stabilized Dunes		2980597
12		B5	Partially Stabilized Dunes		3610287
13		B6	Un Stabilized Dunes		407917
14	Water logging	C1/C2	Surface ponding - Seasonal/Permanent		5689202
15		C3	Subsurface waterlogged		132593
16	Salinisation / Alkalisation	D1-D3	Saline - Slight/Moderate/Severe		2668404
17		D4-D6	Sodic - Slight/Moderate/Severe		1085456
18		D7-D9	Saline Sodic - Slight/Moderate/Severe		976047
19		D10	Rann		1734701
20	Acidification	E1/E2	Acidic - Moderate/Severe		3043478
21	Glacial	F1	Frost heaving		325129
22		F2	Frost Shattering		2558729
23	Anthropogenic	G1	Industrial effluent affected areas		53125
24		G2	Mining and dump areas		518030
25		G3	Brick kiln		85627
26	Others	H1	Mass movement / mass wastage		475211
27		H2	Barren rocky / Stony waste		10124507
28		H3	Riverine Sands/Sea Ingress etc		474355

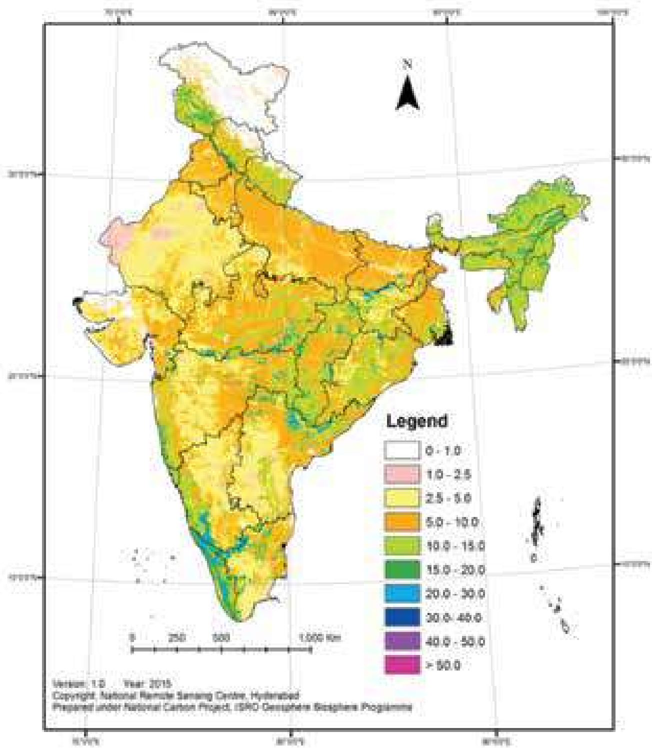
Figure 2. Land degradation status in India on 2015-16 using IRS LISS data.

Results indicate that the total land degradation of country was 91.2 M ha (27.77% of geographical extent of India) during 2015-16 against 91.3 M ha during 2005-06 (Figure 2). During the ten year period, there is an overall decrease of around 0.1 M ha. However, noticeable extent of intra and inter class changes were observed in land degradation status during the ten year period. Major reclamation was noticed in sand dunes which were converted into crop lands by levelling the dunes. Substantial decrease in severity and extent of salt-affected soils was noticed in Uttar Pradesh.

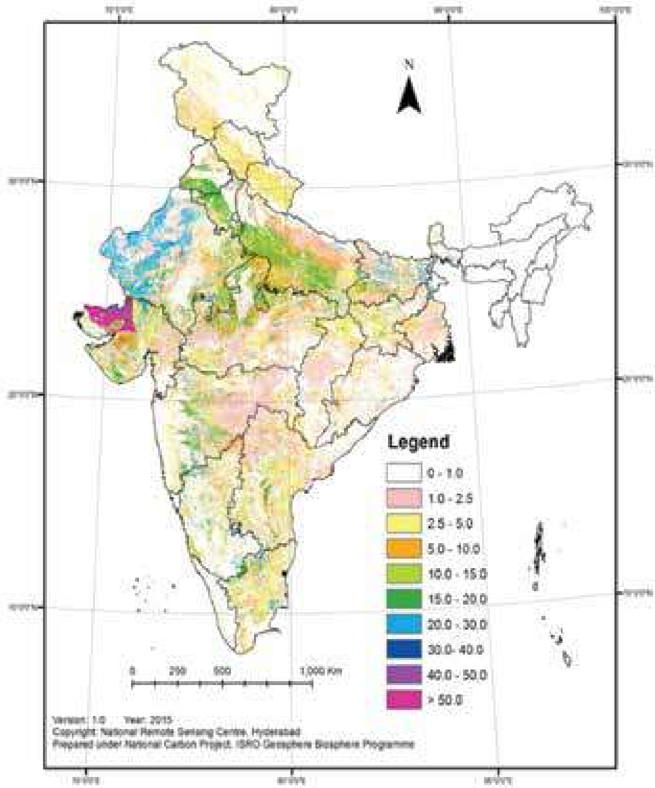
Digital Mapping of Soil Carbon in India:

Reliable mapping of soil organic carbon (SOC) and Soil Inorganic Carbon (SIC) densities and estimates of their pool size are important from global warming perspective to understand the sequestration potential and losses. In this study, first spatially explicit mapping of SOC and SIC at 250 m resolution and an estimate of their pool size in India was undertaken using a large number of remote sensing derived data layers and data mining approach

(Figure 3). The SOC and SIC densities up to 100 cm depth or paralithic contact (whichever is shallower) were estimated for 1198 soil samples located across India using a stratified random sampling that integrated land use, soil, topography and agro-ecological regions. Using Random forests (RF) based spatial prediction procedure with climatic, land cover, rock type, soil type, multi-year NDVI, irrigation status as independent input variables, models for predicting carbon density at 250 m spatial resolution were developed. For modelling with RF algorithm, about 898 soil profile observations (75% observations) were used, while the rest of 300 (25% of total observations) were used for validation.



(a)



(b)

Fig 3. Digital soil organic (a) and Inorganic Carbon (b) density (Kg/ m²) maps of India

It was observed that the data distribution of sample points don't have significant influence on RF model predictions. The relationship between observed and predicted values was characterized by Mean Squared Deviation (MSD) and Root Mean Squared Error (RMSE) parameters. The SOC, SIC and total soil carbon pool size of India has been estimated at 22.72 ± 0.93 Pg,12.83 ± 1.35 Pg and 35.55 ± 1.87 Pg, respectively, which are comparable to previous studies while providing first spatially explicit 250m map of their distribution. The spatial distribution indicates that majority of the carbon stock resides in the northern part of India. The soil carbon stock of eastern India has contribution from organic carbon while the western portion has contribution mainly from inorganic carbon.

d. Users' Perspective

The data on Decadal assessment of land degradation at 1:50K scale (2005-06 and 2015-16, using IRS LISS-III data) and Digital soil carbon stock maps(250m) are periodically provided to the MoEFCC, which in turn is submitting necessary reports to the UNCCD. The users from various State and Central government and NGO's have been utilising the data very effectively for various developmental, soil conservation and reclamation planning related applications and the efforts on usage of this data is being continued.

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6. WATER RESOURCES MANAGEMENT

a. Objectives:

The objective is to use the space technologies for sustainable water management by carrying out the resource assessment& monitoring, generation of inputs & DSS tools for conservation, development and management of water resources supporting sustainable development goals (SDG). Water is one of the fundamental elements in sustaining the integrity of the natural environment, which is a key driver for economic and social development. Some of the aspects of water management, which pose concerns are lower precipitation coupled with higher evaporation in many regions causing the alterations in flow regimes in rivers, lakes and groundwater storage, increased pollution damaging ecosystems and lack of safe drinking water and basic sanitation affecting the health, lives and livelihoods of people. Space technologies have been gainfully utilised, for the conservation and optimal utilization of this dynamic resource and ISRO has developed various products &services of satellite remote sensing towards improved management of water resources in the Country.

b. Expected Benefit to Society:

Agriculture sector in India is the largest consumer of fresh water resources and estimated to be around 90% of total water use. The demand has to be met with by both surface and groundwater resources. To meet the increased food requirements by 2050, a quantum jump in water demand &utilization is inevitable. Similarly, there would be increased demand for both drinking water and water for industrial usage. At the same time, the dependence on Indian groundwater is quite high thus placing very high risks on food and livelihood security. There is also a significant gap between the ultimate irrigation potential, creation and the utilization. The efficiency of the water-usage in the country is estimated to be only 30-40 percent. While India has about 16% of the global population and it has only 4% of total water resources, thus driving many parts of India under water scarcity.

The problems related with the water resources development are not only multi-fold but are quite complex too. The problems associated with water management are: a) large variations in spatial and temporal availability, b) reducing per capita availability c) inefficient irrigation practices d) loss of reservoir storage due to sedimentation e)frequent floods severely affecting the flood prone areas f) recurring drought g) over-exploitation and depletion of the ground water resources h) deteriorating water quality and environment and i) climate change impact adversaries .

The possible solutions to these problems are efficient use of available water resources through surface water harvesting, adoption of newer irrigation practices, inter-basin transfer, effective watershed management and sustainable use of surface and ground water. The real-time information on various aspects of water, which control and influence the supply & utilization is generated by satellite remote sensing data to manage the resources effectively, to attain the maximum efficiency in water usage. Therefore the satellite remote sensing and geo-spatial techniques play a crucial role and provide vital information to aid water management decisions. Systematic approaches of utilising the satellite remote sensing data and techniques have helped vastly in having efficient water management in the country.

c. Implementation mechanism:

Remote sensing satellite measurements enable clear identification of geographical space and also their temporal description. They capture electromagnetic radiation from earth surface which is either reflected or emitted. Active microwave radars obtain backscattered / returned microwave signals from the satellite sensor itself. The surface reflectance is used for snow & glaciers, surface water features, geologic & geomorphologic features, water quality, etc. The thermal emission in the infrared is used for surface temperature and microwave radiation for soil moisture, snow & glacier, flood, etc. The advantage of the satellite data is that the information derived is systematic, allowing time series, covers a wide area such as entire river basin and can be disaggregated to very fine scales to provide more detailed information related to spatial variability. It is also necessary to have the judicious combination of conventional ground measurements and remote sensing techniques for achieving the optimum results.

The data from Earth Observation Satellites (EOS) is used extensively for better management of water resources in the Country. The overall applications of RS & GIS in water resources sector are categorized into a) Water resources assessment& monitoring, b) Watershed development & management c) Flood disaster support d) Environmental impact assessment & management e) Water infrastructure planning & development and f)Water resources information & decision support systems. The satellite data is utilised to observe surface water bodies, to understand their surface spread dynamics and also to estimate its volume. Satellite data is extensively used to study the snow & glaciers, surface water resources, like water bodies and wetlands, irrigation water management, reservoir sedimentation, and environmental Impact assessment and management. The Indian Remote Sensing (IRS 1A/1B) series satellites, developed during the initial period provided the much needed fillip to RS applications for water resources sector through availability of multi-spectral information at various resolutions and at affordable prices. The services of various remote sensing satellites starting from IRS series (IRS 1C/1D/P2) further to Resourcesat-1, 2, 2A Cartosat-1 & Cartosat-2, Cartosat-2S, Cartosat-3 etc., were improved in a progressive manner to provide a variety of applications like near real time monitoring, hydrological modelling, infrastructure planning, mapping & monitoring, information systems, and decision support systems and so on. IRS-P6/Resourcesat-1 was utilised for better discrimination of snow and cloud, besides delineating the transition and patch in snow covered areas. The SWIR band of AWIFS sensor of IRS P6 was used for Snow-melt runoff forecasts. These forecasts enabled better planning of water resources by the respective water management organisations. Monitoring of reservoir water spread through seasons are carried out to assess the storage loss due to sedimentation, updating of reservoir capacity tables. In the last three decades several applications have been developed, and Remote Sensing satellite data have been used extensively to generate the quantitative and reliable information, to improve water resources management.

d. Area Coverage: National / State / District

The area covered is for the entire Country including Indian river catchment in transboundary region and the area to be studied are selected depending on the need generated time to time from various user agencies.

e. Results Obtained: (compare with item b above)

Exhaustive studies have been carried out for improving the water resource management in the Country using Indian remote sensing satellites to provide solutions to a range of problems explained in section b) above. While the satellite applications in India have been very widely used for tackling many of the water resource issues, only a few results have been highlighted here to give a flavour of RS applications with respect to the efficient use of water resources. Snow-cover mapping of entire Himalayas was carried out at the request of Ministry of Environment using IRS AWiFS data. Ten daily snow cover products and area-altitude distribution products were generated to observe the snow cover variability for 28 basins of the Western Himalayan region. National Remote Sensing Centre, (NRSC), Hyderabad has provided the forecast of snowmelt runoff into Bhakra reservoir to Bhakra Beas Management Board. The forecast helped to allocate the water for different sectors and to share among five northern States. Additionally, snow cover in Sutlej basin is monitored from October to June next year to understand the accumulation and depletion pattern of the snow pack in the season using NOAA/AVHRR satellite data. National Institute of Hydrology (NIH) used water balance approach to estimate the average contribution of snow and glacier-melt runoff in the annual flow of the Beas River at Pandoh Dam. The meltwater from the glaciers and snow and ice from the Himalayas, form the water inflow to the rivers such as Ganges, Brahmaputra and Indus. The Glacier lakes have potential to cause outburst flood which may in turn can cause disaster, downstream. Therefore, satellite monitoring is effectively utilised to provide the vital data on their status to safeguard downstream utilities.

Snow and Avalanche Study Establishment in the Country has been utilising the satellite data for avalanche hazard zonation in parts of J&K, Uttaranchal and HP. Under avalanche mapping, a number of highways and lateral road axes in J&K, HP and Uttaranchal have been carried out. The Water bodies have been mapped up to 0.9 ha surface area in Jodhpur district, Rajasthan state using Landsat TM images. The Landsat TM data facilitated reliable and reasonable accuracy of ±10%. The comparison with Survey of India topographical maps of the year 1958 revealed reductions in the water surface and drainage basin areas up to 1.8 to 2.4 and 6.0 to 8.0 times, respectively, over a period of 28 years (1958-1986). This has happened due to the biotic interference like cultivation and urbanization resulting in desertification in the large adjoining areas. The surface waterspread is updated at frequencies ranging from weekly (for waterbodies of (> 50Ha area) to seasonal (> 0.25 Ha area).

As part of inland wetland mapping, integrated land use, turbidity and aquatic vegetation maps were generated using multi-season IRS LISS III data. Wetland statistics were generated for all the 65 districts in Gujarat, Bihar, J&K, MP, Rajasthan, UP, Karnataka, Tamil Nadu and AP. Field data was integrated for prioritization of wetlands towards conservation planning as part of MoEF/UNDP sponsored project.

National Wetland Inventory and Assessment (NWIA, 2007-2011) project was carried out by SAC/ ISRO at 1: 50,000 scale at the behest of MoEFCC using pre and post monsoon IRS LISS III data. A seamless database of the states and country was generated in GIS environment. The development of query shell for information retrieval as well as state-wise wetland atlases were prepared in 2011. Total wetland area estimated was 15.26 Mha, which is around 4.63 per cent of the geographic area of the country.

Performance assessment & monitoring of irrigation command area was carried put through mapping of cropping pattern and crop condition assessment using satellite remote sensing data. In addition, NRSC has also executed several projects for various State Irrigation and Command Area Departments. The conventional approach of monitoring the progress of irrigation infrastructure creation involved field inspection of selected locations and also the use of the inputs provided by implementing state agencies. ISRO developed a methodology for using Very High Resolution Satellite data for monitoring irrigation infrastructure creation progress in the country. NRSC, at the request of Ministry of Water Resources, GOI, carried outassessment of irrigation infrastructure creation progress using high resolution satellite data. The pilot projects in Teesta command area, West Bengal state and Upper Krishna project, Karnataka state led to National level activity for 103 AIBP (Accelerated Irrigation Benefit Programme) projects. With these projects, spread over 21 statescovering 6.45 million hectare (Mha) irrigation potential was demonstrated. Bhuvan-AIBP web application, simplifying the satellite data usage for monitoring irrigation infrastructure creation status was also developed. Identification of critical gaps in irrigation networks helped to assess the actual irrigation potential created for its comparison to the potential targeted. Capacity building, enabled the Central Water Commission (CWC) to carry out the monitoring of irrigation projects internally.The high resolution satellite data from the Indian satellite sensors (Cartosat-1& Cartosat-2 & 2S) are extensively used for this activity. The information regarding the status of completion of irrigation infrastructure helped in estimating the irrigation potential created and for its comparison to the planned irrigation potential creation.

Fig 1 given below provides the details of the monitoring of irrigation infrastructure creation. The methodology for monitoring irrigation infrastructure creation using Geospatial tools and Very High Resolution satellite data has been internalized within the Ministry.

At present, evapotranspiration from satellite data is confined to regional level assessment, providing basin level water balance appraisal. Satellite data has been used to derive crop-wise monthly crop coefficient data for estimation of crop evapotranspiration.

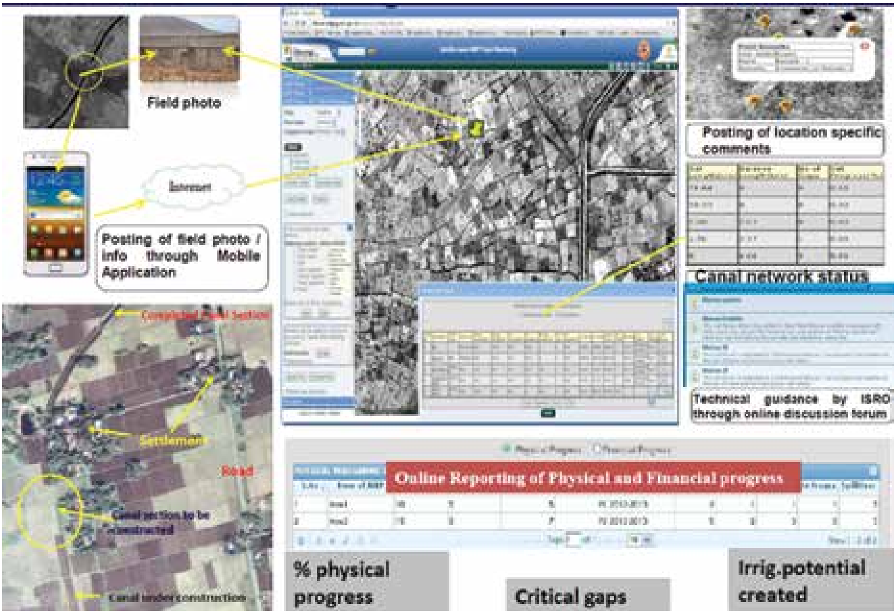

Figure 1 Monitoring of irrigation infrastructure creation

Since the reservoirs are generally losing capacity at the rate of 0.30 to 0.92 per cent annually, it is essential to carry out the periodic assessment of sedimentation rates to estimate the reservoir live storage capacity for efficient and productive management of water resources. The reduction in storage volume results from the decrease in water spread area due to sedimentation at different elevations. Therefore, capturing the water spread at various reservoir operating levels helps in estimating the current reservoir storage and a comparison with previous or original storages would provide the loss in storage due to sedimentation. Multi-spectral satellite data facilitates distinct separation between water bodies and the surrounding landuse/landcover. The water spread boundary captured by the satellite data has been providing the water spread contour at that particular reservoir water level.

Watershed characterization is done using the measurement of related parameters, such as geological, hydrogeological, geomorphological, and hydrological, soil, land cover/land use etc. Remote sensing data is effectively used for watershed characterization and assessing watershed priority, evaluating problems, potentials, management requirements and periodic monitoring. Further RS data is utilised effectively for mapping of forest, vegetation cover, geology and soils over watershed, in order to assist in the study of land use, soil & water conservation potential, degradation etc.

RS data is a reliable and cost-effective tool for managing extreme water conditions such as flood and drought. The timeliness of satellite data has proved to be very critical in flood management, rescue operations, damage assessment, planning the flood plains and to formulate long term strategies. Under the conditions of water scarcity, satellite data is useful for monitoring and assessing the drought severity and consequent impact on agricultural production. Integration of newer technologies such as Remote Sensing & GIS in conjunction with traditional knowledge is necessary to assess the extreme water availability conditions.

During monsoon season, a constant watch is kept on the flood situation in the country and all possible satellite data are procured over flood affected areas. The satellite data is analyzed for delineation of flood inundation layer. The flood inundation layer was integrated with district boundaries and district-wise flood inundation area statistics are generated. Apart from providing flood inundation information, based on the historic flood inundation observed from the satellite data is used for generation of flood hazard zone maps for planning non-structural flood management measures.

ISRO and Central Water Commission (CWC) jointly developed methodology for using space based geo-spatial inputs to estimate basin-level mean annual water resources, through pilot studies in Godavari and Brahmani-Baitarani river basins. The methodology was adopted for re-assessment of basin-wise water resources of the country, to provide latest update on country's water resources potential and impact of land use/land cover changes on water resources availability.

A comprehensive spatial database on water resources of the country has been generated and an information system called India Water Resources Information System -WRIS is implemented and now institutionalized under the National Water Informatics Centre (NWIC) within Ministry of Jal Shakti. Similarly, many State-level Water Resources Information systems such as Telangana Water Resources Information System (TWRIS), Andhra Pradesh Water Resources Information & Management System (APWRIMS) etc. have been implemented utilising Earth Observation derived inputs.

Geospatial products and services are being developed by ISRO as part of the National Hydrology Project (NHP) on behalf of Ministry of Jal Shakti. The major components being developed by ISRO are (i) Spatial Flood Early warning system for predicted flood levels and inundation in Tapi and Godavari river basins (ii) Daily actual evapotranspiration product for entire India at approximately 5 km resolution (iii) Systematic database of glacial lakes in the Himalayan Region of India (size > 0.25 ha) (iv) Daily information on the Himalayan Snow cover, for use in the estimation of snow-melt runoff (v) 3-day snowmelt rate forecast (vi) National daily gridded water balance components (vii) Hydrological drought indices maps using satellite data & hydrological model inputs, and (viii) capacity building to the stakeholders. In order to disseminate this among National Hydrology Project, NHP stakeholders, a web portal on Bhuvan Geoplatform, called Bhuvan-NHP is also developed. Surface water spread information derived using multi-sensor; multi-satellite data is hosted on Bhuvan for visualization and analysis of water availability at national level. Sensor-specific automated water body extraction algorithms are developed at NRSC / ISRO for enabling this application. The frequency of updation of the information varies from weekly (for waterbodies of area >50ha) to seasonal (for waterbodies of area >0.25ha). Fig 2 gives the web-enabled waterbody information system.

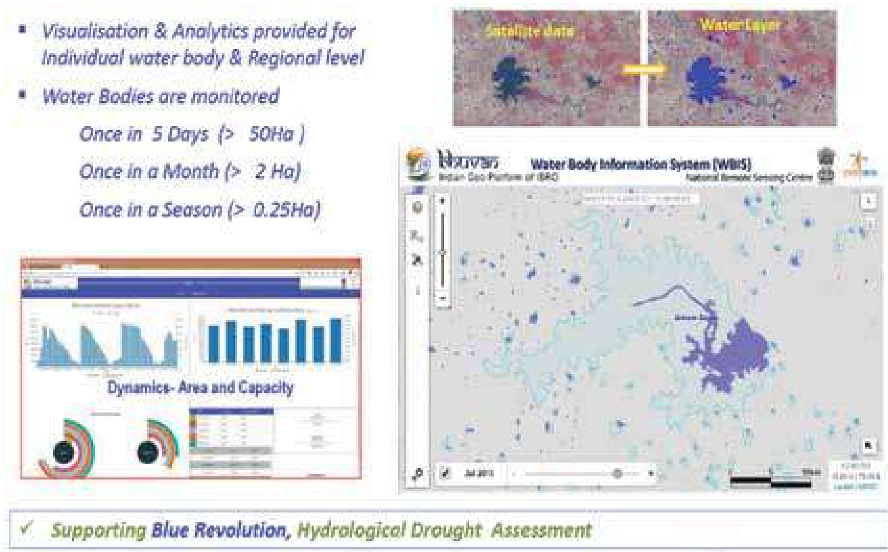

Figure 2 Web-enabled Waterbody Information System (WBIS)

f. Users' Perspective

The users are the Water Resources Departments of State and Central Governments, Central water commission, and Departments concerned with flood management in both State and Centre and State Disaster Management Authorities (SDMAs) and NDMA. Users have been utilising the space services effectively to assess, conserve, and initiate necessary actions for the overall management of water resources in the Country to meet the sustainable development goals (SDG). The flood inundation maps along with affected area statistics are furnished to - NDMA, Min of Home affairs, Govt. of India, New Delhi, Chairman, Central Water Commission, Govt. of India, New Delhi, Relief Commissioner of the concerned States and other Departments connected with flood management in the States & Central Government. Using multi-date satellite data maps pertaining to river configuration, bank erosion and flood control works are prepared and furnished to user for planning structural flood control measures. NRSC is also contributing towards generation of National Database for Emergency Management which would help in planning suitable flood control measures, relief and rescue management and to formulate long term strategies.

The satellite data products and services on a range of issues are being provided on a continuous basis to several user agencies all over the Country and they are effectively used for sustainable water resource management

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7. GROUND WATER IN INDIA

a. Back ground

The quantity of water present beneath the earth's surface within pore spaces of soil/unconsolidated rocks and in the fractures/fissures of crystalline rock formations etc is called ground water. Fresh water comprises of about 2.5 percent of the total volume of water available on Earth. Of these freshwater resources, 70 percent is in the form of ice and permanent snow cover in mountainous regions; the Antarctic and Arctic regions. Around 27 percent of the world's freshwater is stored underground in the form of groundwater. Ground water is heterogeneously distributed throughout our planet earth both spatially and temporally. Varied hydrogeological condition coupled with uneven precipitation type is one of the prime reasons for this. Secondary porosity like fracture/lineament distribution in combination with lithology, geomorphology and other hydrological characteristics produces heterogeneous and inconsistent yield as well as the depth of groundwater resources. This finite source of water serves as a dependable resource for various purposes like agriculture, domestic and industrial uses. Due to ever increasing human population the fresh water supply is critically stressed. It is estimated that by 2030 approximately 47% of the population would face critical shortage of water and hence the effective management of water resources is of paramount importance. It is essential that sustainable water resources plan to be adopted by the global community, to ensure fresh water availability for sustainable future. This calls for detailed assessment and monitoring of all water resources and hence the need for reliable data collection and analysis. However, having only field data collection is quite difficult and time consuming particularly in remote areas. As these conventional methods are very laborious, costly and time consuming, geospatial techniques plays meaningful role in this aspect. Remote sensing (RS) and geographical information systems (GIS) are very useful to extract information on groundwater regime. With the modernization and sophistication in RS-GIS, allowing integration of data collected from various sources and methods, complex analysis of data is possible. Undoubtedly RS_GIS are cost-effective means of data collection and analysis with complimentary field data calibration and validation. In addition the Earth Observation (EO) data provides wider and synoptic coverage over large areas, including and remote and inaccessible ones, areas with systematic, repetitive and accurate coverage, making it very advantageous. EO data are always integrated with the field collected data to generate useful value-added products and services. Groundwater due to its dynamic and interdisciplinary nature needs, an integrated synergetic approach of RS-GIS which can provide diverse datasets over a large inaccessible area that can be efficiently handled and analyse groundwater regime for sustainable management.

b. Objectives

The main objective is to carry out a systematic evaluation of the groundwater resources spatio-temporally using advanced space based techniques for sustainable groundwater management. Therefore,it is essential to assess and meet the water demand, for drinking as well as irrigation, industries and domestic usage etc., with the needed required quality. Furthermore, also to ensure that quantity needed is met with the available water resources. Any strategy for scientific management of groundwater resources should involve a groundwater recharge measure, draft estimation, prospective groundwater zones mapping, identification of over- exploited, critical, semi-critical and safe zones etc. depending on the regional setting which need a detailed analysis. With the modernization and sophistication in Geographic Information Systems (GIS), allowing integration of data collected from various sources and methods, complex analysis of data is possible, thus attempt have been made to delineate the groundwater recharge zones. Groundwater is dynamic and interdisciplinary in nature, an integrated synergetic approach of remote sensing (RS), geohydrology, geomorphology and GIS technique is very useful in various groundwater security-management-plans. Remote sensing can provide diverse datasets over a large inaccessible area that can be efficiently handled and analysed in a GIS framework. Integrated synergetic use of satellite data with field based information in GIS platform is significantly potent for groundwater studies. The space based groundwater studies are utilised for systematic planning, development and management of precious groundwater resources on a sustainable basis. These studies further assist in identifying data gaps and develop approaches for improving the hydrogeological understanding of the aquifers to support future plans related to sustainability of groundwater.

c. Expected Benefit to Society:

The space based technologies offer wide spectrum of advantages in terms of synoptic coverage, larger area coverage, faster timely information, systematic repeat cycles, measurement frequency and usage of advanced sensors etc. The techniques are being applied successfully in the important field of water science for improved water management. The technologies are helping to carry out detailed assessment towards development of well-informed plans for groundwater conservation and to arrest the regular decline of groundwater levels. Proper data collection and necessary precaution for ensuring that shallow wells sustainability, thus avoiding the loss and replenishment of drinking water. The stoppage of groundwater depletion along the sea coast helps to avoid the sea water intruding into the fresh water aquifers which has the potential to cause irreversible damage and also long time environmental degradation. The systematic groundwater prospects studies are therefore necessary in planning, development and its sustainability, and hence in contributing significantly for national development.

d. Implementation mechanism:

The groundwater regime is dynamic in nature. Understanding the groundwater scenario of a particular area is complex, as it involves the study of large number of controlling variables. Broadly, the variables that influence the groundwater regime are grouped under four categories namely a) Lithology b) Geological Structures c) Geomorphology / Landforms and d) Hydrology/ Recharge conditions. Once, we are able to gather the information on these four factors, it is easier to define the groundwater regime by visualizing the gross aquifer characteristics of each unit. These data can be generated primarily by systematic knowledge guided interpretation of satellite imagery. Once we analyse these space based data, in conjunction with the existing geological, hydrogeological and geomorphological maps, along with limited field checks / observations, the information related to the four major controlling factors can be generated. This will facilitate to integrate the lithological, structural, landform and hydrological information to prepare the groundwater prospects map. It helps in better understanding of groundwater regime as compared to the conventional hydrogeological map.

In order to generate the groundwater prospects and to define the output parameters like a) aquifer material (lith-geom i.e combination of lithology and geomorphology) b) type and depth range of wells c) yield factor d) heterogeneity of the aquifer/the failure rate of wells e) planning recharge structure and types and f) quality, the inputs like lithology, landform, geological structures, recharge conditions, depth to water table, and yield information were utilised. These maps have been quite useful in arriving at the target zones for ground hydrogeological studies for selection of sites for the purpose of drilling and for planning recharge structures.

The methodology for preparing groundwater prospects involves using the remote sensing data, i.e., aerial photographs and satellite images to update the conventional hydrogeological maps prepared from ground surveys. Today in the Country many organizations like National Remote Sensing Centre (NRSC/DOS), Central Groundwater Board (CGWB), State Remote Sensing Application Centres, Groundwater Departments of different states, research laboratories and academic institutions have expertise in preparing the groundwater prospects maps using satellite data in conjunction with limited field checks. Depth information of groundwater levels are generated by Central Groundwater Board (CGWB), Ministry of- Jal Shakti, GoI, for pre- and post-monsoon seasons every year for the Country. One typical data giving groundwater levels in India (January 2020) is given in Fig 1.

The mapping and updating of lithological, geomorphological and structural features using the optical sensors' data started with the launch of Earth Resources Technology Satellite (ERTS-1) by USA, later known as Landsat-1. In India with the launch of IRS-1A in 1988, Linear Imaging Self-scanning Sensor

(LISS II) sensor data was initially used to prepare groundwater prospects maps at 1:250,000 scale. The LISS-III multispectral sensors in IRS- 1C and 1D satellites were later used for preparing the groundwater prospects maps at 1:50,000 scale. In addition to optical sensors data, microwave data have also been used.

Imaging radar data is useful in discrimination of surface lithology, buried palaeo-channels; dykes, sand-covered bed rock etc. to a depth ranging from 1.5 to 6.0 m, particularly in arid conditions. Thermal infrared sensor data are also useful in groundwater targeting, but more work requires to be done. Although they have given encouraging results, insufficient spatial resolution and lack of repetitive global calibrated thermal data have been limiting the usage of thermal infrared data for groundwater studies.

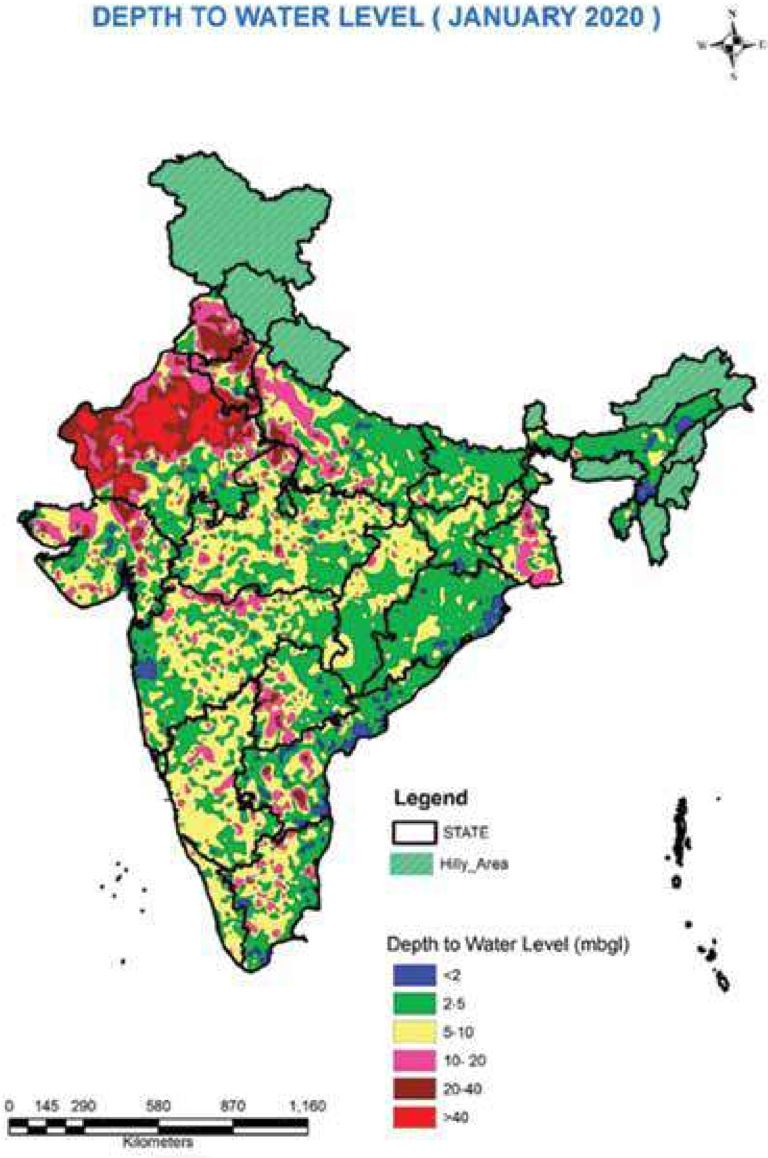

Figure 1 : Groundwater Levels in India (January 2020) : (Courtesy: CGWB. GoI)

In groundwater prospects mapping, firstly the lithological mapping is done using the spectral contrast of satellite images in conjunction with the knowledge available from the general geological setting of the area and published geological maps. A typical lithological map prepared through interpretation of satellite imagery is given in Figure 2.

The synoptic coverage through the satellite imagery helps in generating the maps of regional geological structures which is otherwise quite difficult through conventional ground surveys due to limited rock exposures, soil cover, lack of continuous observations, camouflage of landforms to landuse etc. The information on geological structures play significant role in the groundwater exploration.

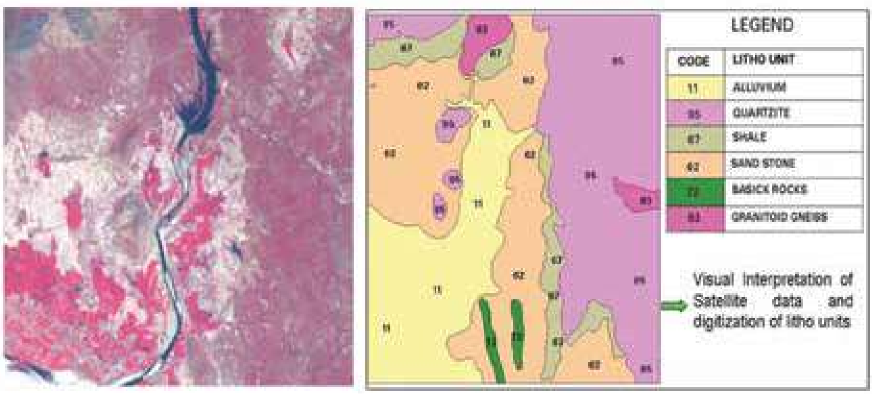

Figure 2. A Typical lithological map prepared through satellite imagery interpretation

In hard rock areas where the rocks are devoid of primary porosity, the geological structures primarily govern the occurrence and movement of groundwater. Satellite remote sensing data are used for preparation of geological structural maps, depicting the presence of structures like faults, fractures, joints etc. These features appear as linear to curvilinear elements in the satellite data. Information on the bedding, folding, schistosity etc. pertaining to the sedimentary and metamorphic rocks is derived with the help of satellite data and field inputs.

For better understanding of geomorphology, it is essential to map different landforms and their assemblage using interpretation criteria, such as tone, texture, shape, size, location, association, physiography, genesis of the landforms, nature of rocks, and associated geological structures. These data so derived through the images are used for identification of different landforms / geomorphic units, through field validation.

The hydrological information is derived from the satellite data by interpreting the drainage/ river network, waterbodies, irrigation canals, irrigated areas (by canals and groundwater) etc. Observation well data (depth & yield), meteorological data etc. collected from field and from relevant sources also become part of the hydrological map.

An example of such a map prepared from satellite imagery and ancillary data sources is shown in Figure 3.

Once these data on the lithological, structural, geomorphological and hydrological parameters for a region are generated, the groundwater prospects maps are prepared by integrating the lithological and geomorphological maps and evaluating the litho-geom units in terms of expected yield, suggested depth of suitable wells, etc. The prospects information is derived based on observations on wells existing in these homogenous units.

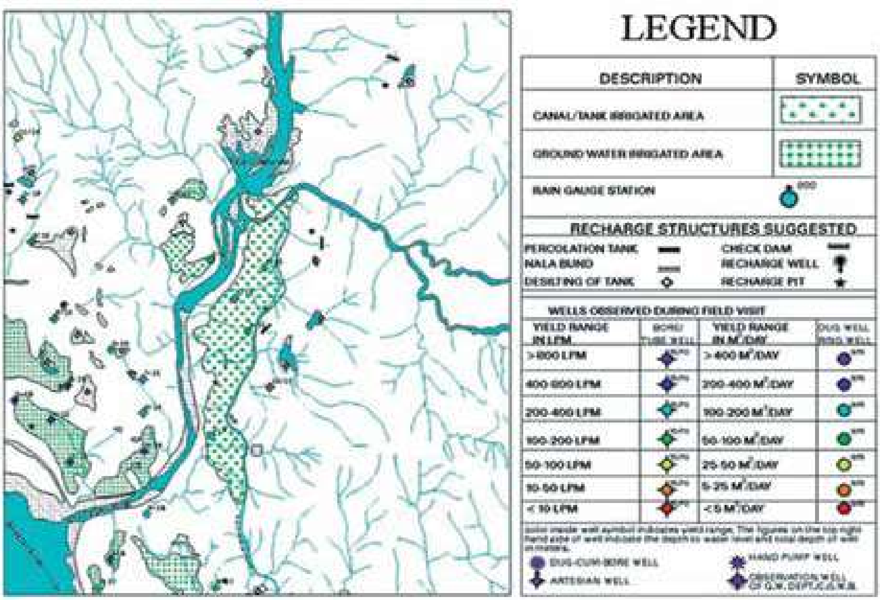

Figure 3: An example of hydrological map from satellite imagery and other datasources

ISRO-NRSC has successfully completed the nationwide systematic groundwater prospects (GWP) (Figure 4) and groundwater quality (GWQ) mapping for sustainable groundwater scenario development.

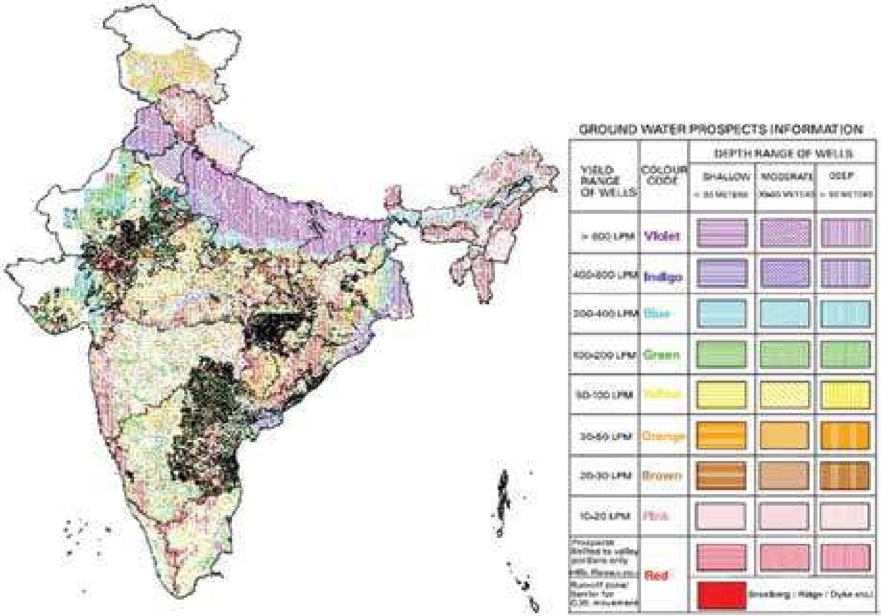

Figure 4. Groundwater prospects map of India showing probable groundwater yield and depth range.

The groundwater prospects of a typical hydrogeomorphic unit is evaluated by considering the lithological, structural, geomorphological and hydrological information is given in Figure 5. The probable locations for planning suitable recharge structures are also identified and indicated on the prospects maps, based on the information generated.

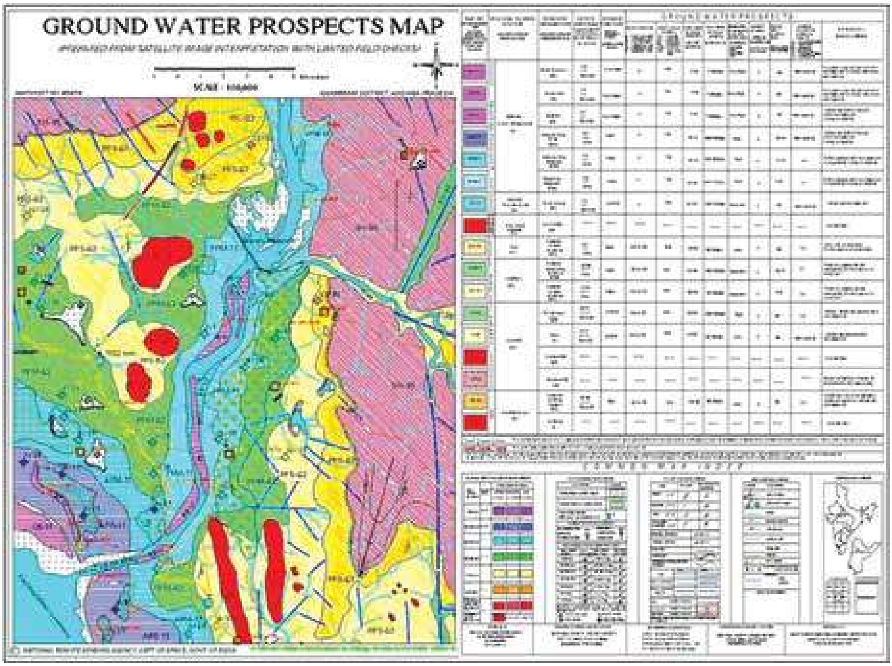

Figure 5. The groundwater prospects map depicting the hydrogeomorphic units, alongwith structural and hydrological information

The satellite data also provides useful information for groundwater recharge & draft estimation, its forecast, mapping of prospective groundwater zones, identification of over exploited, critical, semi-critical and safe zones.

a. Area Coverage: National / State / District

The satellite provides a systematic synoptic coverage of the entire country and beyond and hence it is very much possible to do national level mapping. While doing so, specific maps could be produced upto Block level with village boundary overlay to enable grass-root usage of such important maps. Accordingly, the groundwater assessment was carried out for the whole Country and the satellite data was effectively used through systematic full coverage for all parts of the country. The area/s to be studied were planned and selected depending on the need, from time to time, through the help of various user agencies. National Remote Sensing Centre (NRSC) of ISRO has prepared the scientific database on the prospective groundwater zones for the entire Nation geospatial data processing approaches. They are generated over a period of one and half decade and made available through Bhuvan-Bhujal portal located at NRSC, Hyderabad.

Currently, the efforts are going on for generating groundwater prospects information at village level, for sustainable development of the groundwater resources. Methodology is developed for village level groundwater prospects mapping across various aquifer systems in the country.

b. Results Obtained: (compare with item c above)

The operational utilization of satellite data for groundwater studies in India started in the year 1985 to prepare the groundwater potential zone maps at 1:250,000 scale for two states, namely Maharashtra and Karnataka. Subsequently a nation-wide mapping of groundwater potential zone for entire country (447 districts) at 1:250,000 scale using the Landsat-TM and the Indian Remote Sensing Satellite - IRS-1A Linear Imaging Self-scanning Sensor (LISS-II) data under National Drinking Water Technology Mission during the period 1987 to 1992 was carried out.

In order to provide drinking water to the non-covered and partly covered (in terms of drinking water source) habitations in the country, National Rural Drinking Water Programme (previously known as Rajiv Gandhi National Drinking Water Mission) was implemented by Government of India. One of the objectives of the programme was to identify potable groundwater sources which are sustainable for longer periods in the supply of drinking water to the rural habitations in the country. As part of this, using IRS-1C/-1D LISS-III geo-coded images in conjunction with the existing geological, hydrogeological and hydrological information, the groundwater prospects maps on 1:50,000 scale was prepared for the entire nation. This database facilitated identification of groundwater sources for drinking within the radius of 1.5 km of the habitations, to tackle the drinking water problem in rural water supply.

NRSC/ISRO has displayed the scientific database on prospective groundwater for the entire nation through groundwater prospects maps generated over a period of one and half decades in its Bhuvan-Bhujal portal. Users from authorised agencies utilise the data for sustainable development of groundwater.

c. Users' Perspective

ISRO in collaboration with State Remote Sensing Application Centres had generated groundwater prospects maps of the country. The groundwater prospects maps were provided to all the state groundwater departments, for Groundwater developmental activities. The required information connected to groundwater exploration and recharges are being used by the respective states for selection of a) sites for drilling and b) for planning recharge structures. The studies on groundwater fluctuations by the concerned agencies and necessary actions for annual groundwater recharge have been helpful in replenishing the depletion of the precious groundwater.

The groundwater prospects maps have helped the states planners and line departments for identifying the locations of detailed ground geophysical surveys for pin-pointing the bore well locations. This was utilised in drilling more than 3.5 lakh wells with success rate of more than 85% in the country. These maps were also helpful to augment the drinking water supply during the drought seasons in many States. The suggested locations of recharge structures were also used by states for developing the groundwater resources on a sustainable basis. ISRO has provided these inputs (prospects, recharge locations etc.) to the field teams which implemented water conservation/ recharge measures as part of Jal Jeevan Mission (M/o Jal Shakti). The groundwater prospects database generated by NRSC/ ISRO has also been shared with Central Groundwater Board (CGWB) for its National Aquifer Mapping programme.

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8. WATER BODIES AND GLACIER LAKES IN THE HIMALAYAN REGION

a. Back ground

The Himalayan region contains a large mountain system and has a great influence on the interaction between climate, hydrology and environment. The total spread of Himalayas is between latitude 25° and 35° N and longitude 60° to 105° E and it covers an area of 84.4 lakh sq. km.The Himalayan region encompasses about 3500 km from Afghanistan in the west to Myanmar and China in the east, and runs through Pakistan, Nepal, India, Bangladesh and Bhutan. The glaciers of this region are no doubt one of the greatest renewable storehouses of fresh water. In the high elevation of glacierised basin the glacial lakes are common. They are formed when glacial ice or moraines impound water. There are varieties of such lakes, ranging from melt water ponds on the surface of glacier to large lakes in side valleys dammed by a glacier in the main valley. The melt water is generally accumulated in the topographic depression created by moraine, leading to formation of glacial lake. The lake sometimes may be unstable, leading to sudden release of large quantities of stored water. Failure of these ice or moraine dams can be very destructive causing the flash floods and termed as Glacial Lake Outburst Flood (GLOF). Flash floods caused by the outburst of glacial lakes, called as Glacial Lake Outburst Flood (GLOF), are well known in Himalayan terrain, where such lakes are formed due to landslides. Therefore it is important to carry out the satellite remote sensing based mapping, inventory and monitoring of the glacial lakes and water bodies, covering Indian river basins of Himalayan region. Accordingly the Planning & Development Directorate of Central Water Commission (CWC) in association with National Remote Sensing Centre, (NRSC) Hyderabad have been using the satellite remote sensing techniques to map, to carry out inventory and to monitor the glacial lakes & water bodies in Himalayan region. The inventory of glacial lakes and water bodies in the Himalayan region prepared by NRSC in 2014 indicates the presence of 2028 glacial lakes and water bodies. NRSC identified a total of 477 glacial lakes/water bodies as important for monitoring and for future study.

b. Objectives

The Himalayan region has the largest snow and ice deposits outside the two poles and hence it is one of the important water resources providing food, energy and ecosystem services to a large section of population. Climate change and socio-economic and demographic changes have brought tremendous pressure on these water resources. This is causing uncertain supplies, increased demands and increased occurrence of floods and droughts. Therefore the objective is to carry out the inventory of glacial lakes/water bodies in the Himalayan region using satellite data every year for the last few years. For this purpose Glacial lakes with spatial extent greater than 50 ha are considered and inventoried. The extent of changes happening on annually the glacial lakes/water bodies are also to be monitored and inventoried on monthly basis during June to October months for 5 years, succeeding the inventorying year.

Using the base year as 2009, the inventory of glacial lakes & water bodies in the Indian Himalayan region using satellite remote sensing has been carried out and monitoring is being done every year for the years 2011-2021. The changes in the corresponding year are analysed with respect to the year 2009.

c. Expected Benefit to Society:

A comprehensive understanding of the challenges and opportunities offered by the Himalayan glacial lakes and water bodies using the satellite based data and subsequent analysis and assessment helps to initiate appropriate actions to benefit the society. Towards this clear knowledge of changes in glaciers, natural hazards associated with floods and GLOFs are necessary. Regular monitoring and inventorying the data enables to carry out a detailed analysis of various aspects ranging from the physical to the socio-economic and institutional-policy dimensions of glacial lakes in the region. Glaciers are widely recognized as key indicators of climate change. The melt water from them is an important source of fresh water and also aids in hydropower generation. Glacial lakes have the potential to give rise to Glacial Lake Outburst Flood (GLOF), and the regular monitoring helps to reduce the risk of GLOF through the implementation of proper mitigation measures. In order to carry out the tasks space technologies are very useful for the collection of the data and also the subsequent assessment of the hazard of GLOP, risk and vulnerability in a comprehensive manner.

d. Implementation mechanism:

To monitor the glacial lakes and water bodies from satellite images, it is important to have the cloud free satellite images during monitoring. But unfortunately the monitoring is carried out during monsoon period and this brings down the probability of cloud free data. Therefore, it becomes necessary to browse all possible data and check for their coverage of the study area and cloud cover.

Indian remote sensing satellite Resourcesat-2 satellite with images of the Advanced Wide Field Sensor (AWiFS) is used to carry out the inventory of glacial lakes and water bodies and also their monitoring. The specifications of AWIFS used for monitoring is given in Table 1.

The AWiFS data is available in four spectral bands, three in the visible and in NIR (VNIR B2, B3 and B4) and one in the short wave infrared (SWIR B5). The AWiFS camera has two electro-optic modules viz. AWiFS-A and AWiFS-B, and provides a combined swath of 740 Km. Each camera consists of four lens assemblies, detectors and associated electronics pertaining to the four spectral bands B2, B3, B4 and B5. The Table 1 given below specification of AWiFS.

Table 1. Specifications of AWIFS

Specification	AWiFS
Resolution	56m
Swath	740km
Revisit	5days
No. of Bands	4

The important steps in monitoring of glacial lakes and water bodies in the Himalayan region are:

Orthorectification of Satellite Data;In orthorectification the geometric distortions of the image are modelled and accounted for, to generate a planimetrically correct image. 3D world is created by the imaged generated by most sensors in 2D and orthorectification is used to correctthe anomalies caused during the conversion. Orthorectified imagery is useful in areas with terrain features such as mountains, plateaus, etc. The orthorectification process gives map-accurate images and can be highly useful as base maps and it is possible to incorporate into a GIS. The success of the orthorectification process depends on the accuracy of the DEM and the correction method.

Monitoring of Glacial Lakes & Water Bodies : The delineation of glacial lakes & water bodies are done based on the visual interpretation of satellite images of Resourcesat AWiFS sensor. Different image enhancement techniques are needed to improve the visual interpretation. This method is complimented with the knowledge and experience of the Himalayan terrain conditions for inventorying glacial lakes and water bodies.

The studies are carried out essentially to monitor the glacial lakes & water bodies having the area larger than 50 ha. The boundary of glacial lakes and water bodies are digitized as polygon feature using on-screen digitisation techniques. The polygons are geoprocessed and the water spread area of glacial lakes & water bodies are computed digitally. These steps are repeated for each date of satellite data and water spread area is computed. The maximum water spread area for each water body among the different dates of satellite in the month has been considered for the final analysis of the change in water spread. The criteria followed while monitoring the water bodies are a) change in water spread area within +/- 5% is considered as no change and partly or fully cloud covered or frozen water bodies are not considered.

e. Area Coverage: National / State / District

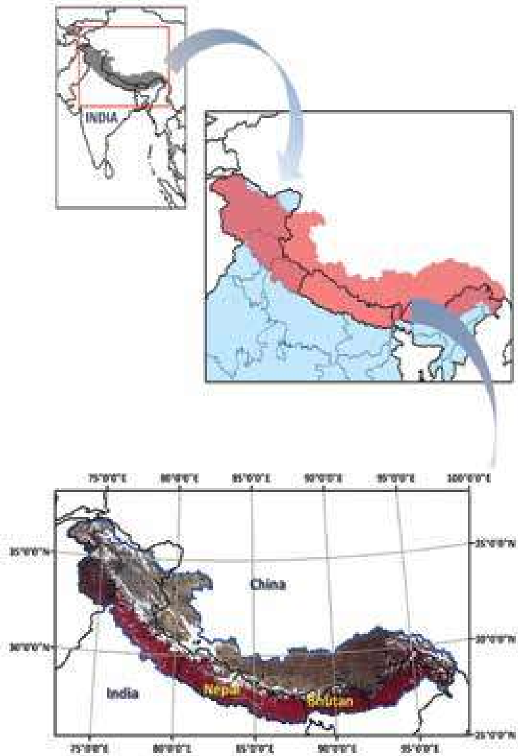

Fig. 1 the Map of the Study Area
(Courtesy: NRSC document on status in 2014)

The interest of region is covering Himalayas under the major river basins of Indus, Ganga and Brahmaputra. Since the region selected is Himalayas the study area includes beyond India, and includes Nepal, Bhutan and China. The study area encompasses the areas as shown in the Figure 1.

f. Results Obtained: (compare with item c above)

Cloud free satellite images during the time of monitoring are essential for the purpose of monitoring glacial lakes and water bodies. For example the list of satellite data used for monitoring during June 2021 is given in Table 2 below. (Ref: Monitoring of Glacial Lakes & Water Bodies in the Himalayan

Region of Indian River Basins for the Year 2021;June to October, Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of jal Shakti, New Delhi). Similar browsing is done for the months from June to October 2021 and the days of satellite data are accordingly chosen.

Table 2. List of satellite data used in 2021

June-2021 Satellite data			
S. No.	Path	Row	Date
1	115	51	21- June -2021
2	113	49	11- June -2021
3	93	44	07- June -2021
4	97	44	27- June -2021
5	102	50	04- June -2021
6	97	49	27- June -2021
7	93	49	07- June -2021
8	108	52	10- June -2021
9	98	49	08- June -2021

The typical monitoring results obtained in the year 2021 from June 21 to October 21 and the subsequent analysis are given in brief below.

The analysis of water spread area of glacial lakes & water bodies monitored in June 2021 was done for only 209 glacial lakes & water bodies using cloud free satellite data. The observations are ; a) 70 glacial lakes & water bodies have shown decrease in water spread area, 75 have shown increase, 64 have not shown any significant change (± 5%), b) 28 out of 70 have decreased by more than 20% and 28 out of 75 have shown increase in area by more than 20%. Similar analysis of water spread area of glacial lakes & water bodies are in remaining months from July to October 2021. Glacial lakes also could be different depending on the visibility using cloud free satellite data. Based on this, decrease in water spread area, increase, and significant change (± 5%) are assessed as given in Table 3.

Table 3 Changes seen in glacial lakes & water bodies monitored during the year 2021 (Same ref as in Table 1)

Month	Monitored No. of lakes	Increased			Decreased			No Change
		> 20%	< 20%	Total	> 20%	< 20%	Total	
Jun-2021	209	28	47	75	28	42	70	64
Jul-2021	169	27	32	59	24	36	60	50
Aug-2021	114	11	26	37	26	34	60	17
Sep-2021	398	39	53	92	78	122	200	106
Oct-2021	367	31	48	79	99	118	217	71

Figure 2 gives the changes in Glacial Lakes/Water Bodies as assessed through the satellite based monitoring during the year 2021

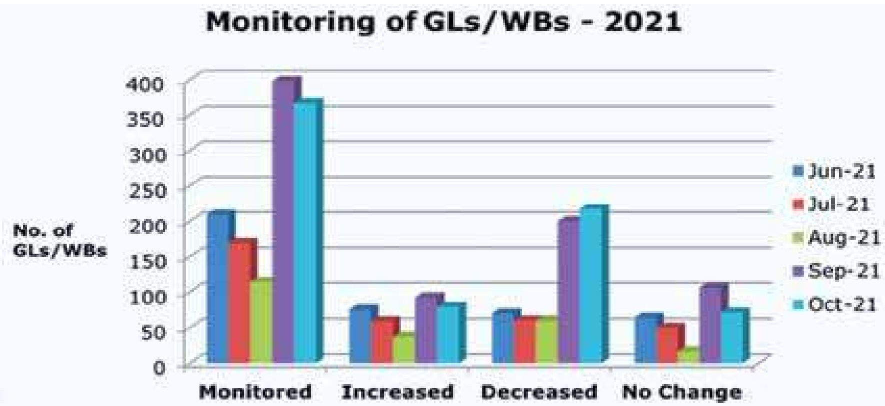

Figure 2: Glacial Lakes/Water Bodies Monitored during the year 2021 (Ref : Same as in Table 1)

Results indicate the increase in water spread area in certain water bodies by 40%. The necessary alerts wherever essential are issued for the corresponding regions. It is also informed that all such identified Glacial Lakes/Water Bodies require vigorous future monitoring in order to avoid any future disaster.

NRSCas one of the Central Implementing Agency under National Hydrology Project (NHP) has taken up GLOF risk assessment of glacial lakes in the

Himalayan Region of Indian River Basins in 2017. The study is sponsored by Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Govt. of India with funding from World Bank. Glacial lakes with water spread area greater than 0.25 ha have been mapped for entire catchment areas of Indian Himalayan rivers (~9.8 lakh sq.km) using Resourcesat-2 using Linear Imaging Self Scanning Sensor-IV (LISS-IV) satellite data using visual interpretation techniques. Based on the data on lake formation, location, and type of damming material, glacial lakes are identified. The entire database of glacial lakes in the Indian Himalayan rivers have been brought into three atlases (Indus, Ganga and Brahmaputra river basins) and it is estimated that the total lake water spread area is of the order of 1,31,071 ha. The atlas provides a comprehensive and systematic glacial lake database for each River basin with size > 0.25 ha. The atlas is utilised as reference data for change analysis, both with respect to historical and future time periods. It also provides authentic database for regular changes in spatial extent (expansion/shrinkage), and formation of new lakes. The atlas in conjunction with glacier information is used to understand the retreat of glacial lakes and also the climate impact studies. The information on glacial lakes like their type, hydrological, topographical, and associated glaciers have been in identifying the potential critical glacial lakes and consequent GLOF risk. Central and State Disaster Management Authorities are encouraged to make use of the atlas for disaster mitigation planning and related program.

g. Users' Perspective

The alerts and imminent problems emanating from this expanding water bodies are being utilised by Jammu & Kashmir including Ladakh, Himachal Pradesh, Bihar, Sikkim, Uttarakand, Arunachal Pradesh & Assam. All these States have proper mechanism to utilise this data and initiate appropriate action with all concerned stakeholders in the Country.Glacial Lakes & Water Bodies are mapped and updated in all these states every year. A typical map plotted for the region in Arunachala Pradesh for the year 2021 is shown in Fig 3.

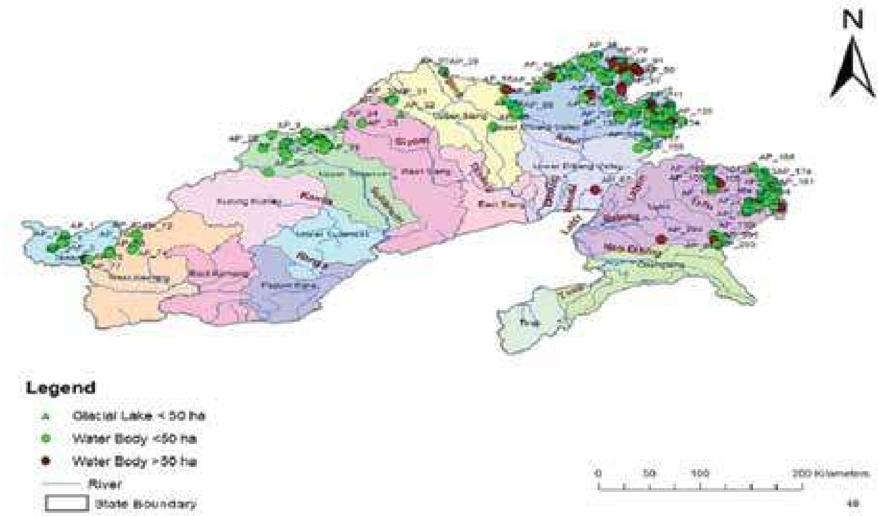

Figure 3 : Glacial Lakes & Water Bodies in Arunachal Pradesh

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9. WATERSHED PROGRAMME FOR SUSTAINABLE DEVELOPMENT

a. Objectives:

Scientific methods for conserving Land and Water are by adopting the development strategy in tune with the terrain characteristics and their properties. So, it is necessary to use the concept of watersheds for any developmental aspects, particularly in rural areas for soil and water conservation. Watershed is nothing but the drainage area on the surface of the earth, wherein the runoff resulting from rainfall flows through a designated path to a stream/ river/ or an outlet point like a lake. Optimal management of water, through such a flow, while also considering appropriate conservation measures helps in sustainable development of resources of the area. Space technology plays a crucial role in watershed development and help in addressing sustainable development due to the synoptic coverage and multi-time data acquisition, particularly with regard to the Agricultural activities

b. Expected Benefit to Society:

Adoption of watershed based activities at field level helps in many ways, particularly in developmental planning of any given area. The approach helps in deriving many benefits, such as, (a) protecting the soil from erosion (particularly in high slopes), (b) retaining moisture for longer time in the soil and allow percolation, (c) improve soil moisture status, (d) ground water replenishment (due to better infiltration of water, it takes place), (e) Improved water availability to crops and other vegetation, (f) improved agricultural produce, (g) better preparedness against possible drought conditions as proper watershed management results in drought-proofing effects on the ground. On other fronts such as socio-economic front, the benefits are:

I. The farmers who own the land are bound to get improved produce due to the improved health of the land and water availability.

II. Those who are land-less are bound to get employment opportunities due to increase in agricultural activities

III. Self Help Groups (SHG) which works at the local level, especially the ladies groups, would experience improved micro-credits activities with increase in savings and hence SHGS get strengthened.

IV. Better economic returns per unit area, leading improved lifestyle.

V. Younger generation get the opportunity to pursue their education/ go to schools or colleges, due to improved economic conditions of the local farmers.

These are the typical benefits that the rural areas derive, with proper implementation of watershed development activities..

c. Implementation mechanism:

The conventional methods that were earlier being used were highly cumbersome and time consuming, as every measurement has to be done on the ground. Comprehensive Planning for watershed development for a 500 Ha area would take days and weeks, but with the GIS and space based initiatives, this is done in two stages in a very scientific manner. Desktop planning using GIS, space based images and understanding the entire watershed, its neighbourhood due to synoptic views from satellite images made it efficient. This understanding followed by field based planning resulted in better action preparation and at much lesser time frame. This has served as a big advantage when large number of watersheds are to be planned for development in a country like India. Use of space data has enabled better and accurate planning for development; bring about right kind of interventions at the right place. Actual implementation of watershed development on the ground still uses, to a large extent, the conventional methods. But, the inputs for planning could effectively be done using space data and also monitoring of the implementation. Earlier, there were not standard methods for monitoring and evaluation during plan implementation, but now space and ICT tools have proved effective methods for monitoring and evaluation (M&E) which always used to fail earlier. Sujala project has been able to uniquely demonstrate the efficacy of technology usage. Similarly, impacts due to watershed implementation used to be a difficult proposition as no proper measurements could be done. However, space data has shown that one can visualize how was the ground situation before implementation and after. This has been a big boon, as visible changes can be captured with multi-temporal satellite images. Both positive and negative impacts could be clearly established with such imaging capabilities.

It is quite well-known that Indian villages face multitude of problems in the form of incessant droughts or floods, large tracts of wastelands, poor rainfall, poor land productivity, poor living conditions, large number of un-employed people, hosting very poor people and so on. It is observed that about 60% of the arable land in India is rain-fed, which is characterized by low productivity, very fragile land, poverty, low income, low employment etc. The rainfall pattern in most of these areas is high variable which often leads to moisture stress at crucial stages of plant growth that results in poor production.

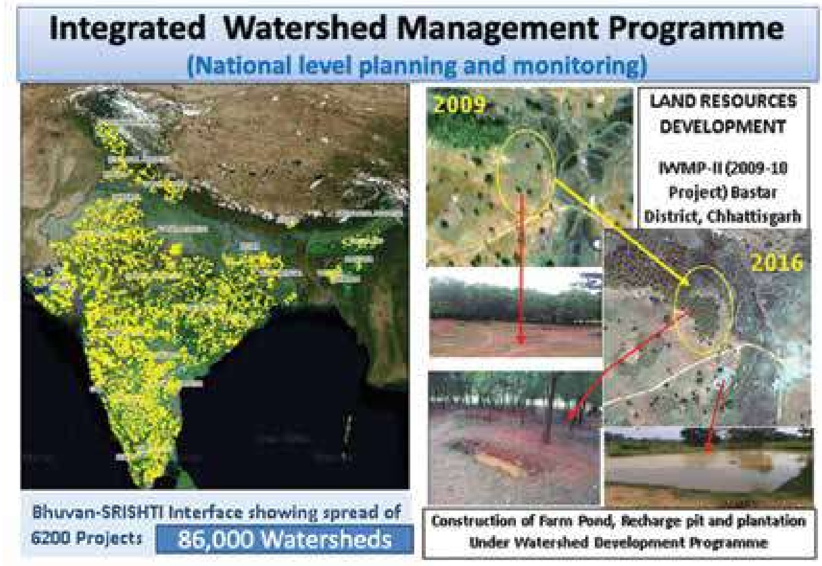
The watershed development programs for many decades are implemented under Drought Prone Area Program (DPAP) and later as National Watershed Development Project for Rain-fed Areas (NWDPRA) and recently as Integrated Watershed Management Program (IWMP). While in earlier stages, conventional techniques were used, NWDPRA program made the initial beginning by using space data for impact assessment and also to some extent for planning. On a sample basis more than 100 watersheds were analysed for their impacts using multi-temporal satellite data to study the impacts. However, IWMP program recently adapted Space based techniques at a different levels. The program initially started by tracking the asset creation using GPS based Geotagging and also high resolution satellite image based assessments. Very large number of watersheds were selected at national level (86,000 micro watersheds) for monitoring in all States /

UT of our country. This has given an interesting and very useful input to the Government, wherein all assets created under the program were captured using Geotagging and space images. In a recent development, the Ministry of Rural Development has further enhanced this program by incorporating the use of space data for planning, monitoring and impact assessment.

Watershed development ensures that, over a period of time, the area would experience sustainable growth and would perform well even under drought conditions. Visible change in soil and water conditions which in turn helps the local people with better living conditions. Hence, such programs need to be implemented in a well-planned manner, so that, the poor people could enjoy the fruits of success in the form of sustainable livelihood. The implementation is done by following a series of simple steps that would help in implementing watershed development in a selected area.

The first step is watershed prioritization and drawing implementation strategies. This calls for using a multi-criteria-based evaluation of a given area before earmarking for development. Judicious selection of parameters across a given area is important. The prioritization of watersheds is normally done on the basis of the status of natural resources, socio-economic conditions, biophysical parameters and so on. Multi-parametric criteria are applied by taking a holistic view of all aspects, including living conditions and historical perspectives, to choose a set of watersheds that need immediate development. Once the watersheds are prioritized, actions related to developmental activities are taken up, such as, setting up baseline database, historical data analysis, soil and water condition, socio-economic conditions of the locals, weather and rainfall data analysis, historical pattern of farming practices etc.

All these are carefully analysed to arrive at an action plan for implementation, which involves several land-based activities, socio-economic development strategies, implementation of the plans, monitoring and evaluation and so on.



More than 17.0 lakh assets have been geotagged

Fig 1. A Typical watershed management programme

A typical integrated watershed management programme (IWMP) implemented and monitored at National level is given in Figure 1. The IWMP program, under Ministry for Rural Development, has done the watershed development across the country in a phased manner. ISRO/DOS provided a very good mechanism, using Remote Sensing and Geospatial technologies, to do monitoring and evaluation (M&E) of the program using space technology. The design was interesting wherein IRS images from multiple satellites and GPS measurements on the ground were used to give geospatial updates on the assets created in the field and also the efficacy of implementation. About 86,000micro watersheds were initially taken up for the task covering the entire nation.

d. Area Coverage: National / State / District.

Watershed development, in India, has been done both from Central and State schemes for decades and gives coverage for the entire Indian region. Collective use of watershed based development helps all farmers in a given region and hence such developments always emphasize on collective planning and implementation.

This monitoring and evaluation (M&E) mechanism was adopted from the experience gained from SUJALA project in Karnataka State. Further to the M&E of watershed development at national level, the rural development ministry has further requested for enhancement of the project objectives that involves detailed planning of watershed development followed by arriving at action plan at micro-watershed level, so that the same is implemented with M&E from space data.

e. Results Obtained: (compare with item b above)

ISRO/DOS initially started working with Ministry of Rural Development in implementation of Watershed impact assessments of NWDPRA projects, as part of 5-year plan outcomes, during late 1990s. Here the focus was to take satellite images before and after implementation to establish the changes that have taken place over a span of 3 to 5 years and make assessment reports, which were submitted to the ministry for further analysis. The reports submitted in late 1990s and also early 2000 helped in establishing the efficacy of using optical remote sensing data for such impact analysis. However, with better technologies and possibilities ISRO/DOS developed end to end solutions for watershed development programs. Sujala project is a typical example wherein the project started in 2002 and went on upto 2010 and remote sensing and ICT were used through out the project period, right from planning, development, monitoring, management and ultimate impacts. The use of technology was found to be most effective and adoptable elsewhere in the country. As Sujala project was funded by World bank, it got a big popularity at global level and got special recognition for the innovative methods used in the project. The same was emulated in many African countries, including Bangladesh and Sri Lanka by the World bank. Looking at such success stories, Ministry of Rural Development, GOI wanted the Monitoring and Evaluation (M&E) portion of the project to be implemented across the country under the IWMP scheme. ISRO/DOS took up this requirement with a new design from 2015 onwards and was successfully implemented for 86,000 watersheds across the country – project continues to provide the vital inputs to the Ministry even now. This was recently further enhanced by incorporating space inputs at all stages of the project, such as, planning, implementation and impact assessment stages. Hence, the techniques developed over a period of time is now fully operational at national level. ISRO/DOS carries out the data processing and provides the reports to the Minisstry of Rural Development (MoRD) on a regular basis. SUJALA watershed development, Govt. of Karnataka, through worldbank funding, took up watershed development of dryland areas in 5 Districts covering an area of about 5,00,000 Ha with a plan to benefit 4,00,000 families. There were more than 725 micro-watersheds that was developed over a span of about 9 years and this was a comprehensive development program that addressed all aspects of development and ISRO's technology played a pivotal role in achieving success. The project profile of Sujala Watershed Development programme along with constrains are given in Figure 2.

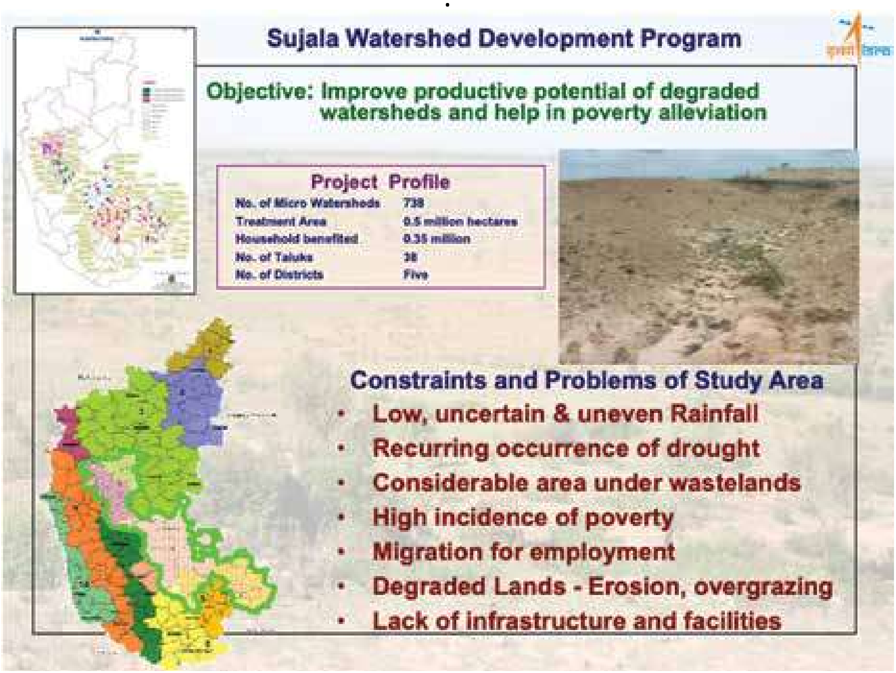


Figure 2. Project profile of Sujala Watershed Development programme

These kind of systems were used in the field for the first time and this made the entire project implementation most efficient. Added to this, multi-temporal satellite images were procured and analysed to showcase exact implementation and their impacts on the ground. SUJALA turned out to be a big success due to multiple interventions done by ISRO/DOS with judicious use of technology to ensure that the decision makers are able to take informed-decisions at various stages of the program implementation. The Sujala watershed development utilising the technology based planning, development and concurrent monitoring is explained in Fig 3.

Initially it was only impact assessments which culminated in providing impact assessment reports to the ministry that helped the ministry in assessing the efficacy of carrying out watershed development in the country. Subsequently, the Sujala project demonstrated the use of space technology and ICT solution at various stages of the entire project, such as, watershed prioritization, watershed planning, action plan preparation, near real-time monitoring of implementation, impact analysis and socio-economic benefits to the villagers.

Figure3. Planning and Development for Sujala watershed development programme

The results for all the watersheds in 5 districts of Karnataka were continuously being provided on weekly/fortnightly/monthly/quarterly basis depending on type of actions that helped the project to continuously watch the pulse of the project all through its lifetime. The results of the project was widely publicized and also published in many forums at all levels. Many villages, particularly in dryland areas like Chitradurga, were transformed into productive areas over a span of 5 to 7 years. The result of such a project paved the way for Karnataka state to take up followup projects of Sujala with more innovation. Presently, Sujala-3 is in the final stages and next version of Sujala is already being planned for implementation. Results showed many positives, such as, improvement in ground water conditions, better moisture holding in soils, improved productivity, improved socio-economic conditions in many villages and ultimately better value for money spent in development. Similarly, the subsequent watershed development projects being implemented by MORD under IWMP scheme has taken the same technology, as used in Sujala, for implementation across the country. The assets being created under the program is being geotagged and put on Bhuvan for the public to see and the same has even been discussed in the parliament as part of good practices of the Government. The IWMP project has been largely successful as it provides the satellite images based impact assessment due to watershed development and also geotags all the assets created in the field that helps in bringing in the much-needed transparency of public money being spent. The approach and innovations done as part of watershed development by ISRO/DOS using space technology has enabled the country to adopt and sustain the same at all levels, resulting in a big success for technology usage at national level.

f. Users' Perspective

The users in watershed development programs have been of different kind ever since the program was initially taken up under NWDPRA program of MORD. In this program the space inputs were used as part of impact assessment reports that were used for assessing the performance of 5 year plans during 90s and early 2000. This gave a lot of confidence in the user ministry that the result of having spent money for development was in the right direction or not. So, the ministry continued to invest on space technology to assess impacts of watershed development across the country on a regular basis in successive 5 year plans.

Sujala project and the newer methods and innovative techniques that were used in the project, through out the project lifetime of more than 7 years took the space technology and its use to a different level. The Government of Karnataka found the technology usage of great value as the number of watersheds to be developed were very large and only a combination of Space tech and ICT would have given such a solution. Efficiency of the Government improved by leaps and bounds due to near real-time data gathering mechanism from the field and effective weekly monitoring of the entire project. Government as a user of technology got rich benefits and could implement the project more efficiently at even District and Block levels. Due to space technology there was total transparency in the project and hence the money spent on the ground showed rich dividends that could be seen across the project areas in terms of productivity and yields. Due to this the farming community also enjoyed the benefits, as they were able to earn better, their living conditions changed and the entire socio-economic conditions of many villages changed to better levels. So, the popular say was “improve the health of land and automatically the health of the humans and livestock also improves”, that got proved in the process.

The IWMP scheme of MORD quickly adopted the positive outcomes from Sujala project and ISRO/DOS helped the ministry in implementing the same for the entire country with space based impacts and also geotagging the assets created on the ground. Through the interventions done under the IWMP program, ISRO/DOS could prove that earth observation data can be used for large number of micro watersheds (86,000) in regular impact assessments and also mobile applications usage on the ground for geotagging all assets. The results are highly appreciated by the Government for bringing about transparency and the people at large are able to enjoy the benefit of such interventions by the government that is helping in soil and water conservation across the country.

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10. URBAN AND REGIONAL PLANNING

a. Background

Urban areas are always hard-pressed for their infrastructure, environmental quality, water supply and other important resources due to ever-increasing urban populations and continuous expansion of cities. Cities are often the growth foci while measuring the development and prosperity of any country.

b. Objectives

Urban planning is done in hierarchical manner, starting with perspective plans to regional plans at the macro level to sub regional plans to city development plans / master plans at city or town level to local area plans / planning schemes at ward level (micro level). Each successive plan in a lower stratum, should ideally factor in and adhere to the broad guideline set in its next higher-level plan. Structured plans at urban and regional levels are vital for infrastructure development, improving health and hygiene, industrial growth and creating employment for the growing urban populations. These plans are based on the area under consideration, number of people inhabiting it, infrastructure available within, accessibility to other areas, and the potential growth engines which can be nurtured over a nearly two-decade horizon (plan period).Every urban plan starting at the city level to higher order is a legal document and is enforceable by statute.

Plan formulation used to start with data collection, followed by analyses, identify growth trends and potential growth drivers, draw up future land use proposals and scenarios, which would then be put up for feedback by the stakeholders and general public; before firming it up, budget estimation, document it and get the legislative enactment.

Urban Planning in India

India is having about 8,000 towns and cities with nearly 31% of its population inhabiting them (2011 Census). Urban development in India is archaic and many of the cities have grown up naturally. Given the fact that urban plan formulation is time-consuming, data-intensive and highly technical job; it is understandable that only about 20% of Indian cities have proper plans available for them. By 2036, the proportion of urban population is expected to rise to about 50% of Indian Population. Taking cognizance of this humongous task, Ministry of Housing and Urban Affairs (MoHUA, Govt of India) nodal ministry for planned urban development in India, is making concerted efforts to improve the living standards across urban India.

Traditionally, collection and collation of data including field surveys required for plan formulation used to take from few months to a year or two.

With the advent of improvements in the geospatial technologies, mainly remote sensing and Geographic Information Systems, the paradigm of urban planning also witnessed considerable changes over last three decades.

Urban Mapping Scheme (1992): It was one of the earliest efforts, wherein the capability of aerial photography was explored for creating large scale urban maps at the scale of1:2500 for 53 towns on pilot basis. These outputs could not be used for further analysis in the absence suitable GIS tools. Developing technical capabilities of the Town & Country Planning Departments at Central and State level have helped for further analysis.

Regional Plan - 2021 of NCR (RP-2021): This is one of pioneering tasks wherein both satellite remote sensing and GIS were used to create urban GIS database of National Capital Region at 1:50,000 scale. National Remote Sensing Centre (NRSC / ISRO) mapped the Existing Regional land Use of NCR using IRS-1C / IRS-1D LISS-III + PAN data of 1999. This information was used by National Capital Region Planning Board (NCRPB), a Regulatory Body under MoHUA to prepare the RP-2021 of NCR. Subsequently, NRSC has updated this database during 2012-15 for the purpose of revising the RP-2021.

National Urban Information System (NUIS) (2006): This Scheme was launched during the Tenth Five Year Plan on the recommendation of Planning Commission with the objective of developing database standards, create spatial and attribute databases using modern data sources adhering to the standards, develop urban indices, and build capacity at State & local body Level. NRSC/ISRO created multi-thematic urban GIS database at 1:10000 for scale 152 cities using Resources at + Cartosat merged data and GIS technologies, besides providing aerial photography support to Survey of India (SOI) for the creation of 1:2000 scale database covering core urban areas for 126 cities. NRSC web-hosted this database through Bhuvan-NUIS and gave secure access-based support for preparation of GIS based Master Plans. In all, NRSC has trained about 3,500 Town Planners across India on Bhuvan-NUIS operations. In addition to the formulation of GIS based Master Plans, which were prepared for 23 cities, this data was helpful for disaster management, environmental planning etc.

State Initiatives: Parallelly, many a state in India have started using remote sensing and GIS technologies for urban planning activities on their own. Cities of Delhi, Mumbai, Kolkata, Bangalore, Hyderabad, Ahmadabad, Chennai (with the initiative of Planning Commission and more than 200 corporation/councils in Karnataka (27), Punjab (16), Rajasthan (10), Tamil Nadu (8), Uttar Pradesh (7), Kerala (7) etc., have prepared GIS based Master Plans during 2000-2015.

Taking note of the success of remote sensing and GIS technologies' utility in NUIS project, and the feedback of town planners for need of larger scale database for Master Plans, MoHUA has revised the Urban and Regional Development Plans Formulation and Implementation Guidelines, 2014 (URDPFI, 2014) mandating the use both these technologies in the domain of urban planning.

Atal Mission for Rejuvenation and Urban Transformation (AMRUT 1.0) (2015): Launched as a National Mission by Govt of India, this programme targeted uplifting 500 Class-I cities across India with proper urban development with their Master plans driving their progress. To address this formulation of GIS based Master Plans is taken up as reform, under which, NRSC/ISRO is contributing to the geospatial database creation of 238 cities at 1:4,000 scale using Very High-Resolution Satellite (VHRS) data. Town and Country Planning Organization (TCPO/MoHUA) along with NRSC have designed a set of uniform Design and Standards for creating GIS databases at city level. Unique model adopted for this effort brought both NRSC (database creator), Urban Local Bodies (Database owner) and TCPO (funding agency) onto a common platform, while creating the GIS database itself, so that the ULBs are familiarised with the GIS technologies besides being the owners of the data. This is subsequently leveraged to smoothen the process of GIS based Master Plan formulation by the ULBs. This project resulted in establishing procedures for very large-scale urban GIS database preparation using VHRS data with uniform classification and GIS Standards, and generating a comprehensive, updatable Large-scale urban GIS database at city level for planning its future development. Besides, it also helped in reducing the turnaround time (TAT) for Master Plan preparation, facilitating State/UT specific changes to Geospatial data content. Noteworthy feature of this effort at NRSC was the set-up of a dedicated cloud based geospatial database creation facility with open source software at NRSC and capacity building of the Private Geospatial Industry with large scale urban database generation capability. So far, Master Plan generation is in advanced stage for about 165 cities. Its spin-offs includediverse value-added services like – estimation of roof-top solar power generation potential, building level rainwater harvesting capability, taxation, liveability condition assessment etc. The project is nearing completion.

AMRUT 2.0 (2022): Similar to AMRUT 1.0, MoHUA is planning to focus on another 650 Class-II cities (population <1 lakh) during the next three years. Here, the source of the geospatial database is expanded to cover Unmanned Aerial Vehicle (UAV) data also. NRSC/ISRO is having a significant role in this project also.

c. Expected Benefits to Society

Perspective plans define a vision for a given region, which is essential for policy framework. It develops spatio-economic framework based on its urbanization and land utilization. Its scope encompasses social, economic, environmental and spatial development goals, policies etc that have both spatial and financial implications. It has an overarching effect for all plans listed below.

Regional plans for metro regions, cities, towns and Special Economic Zones (SEZ) provide statutory framework for development direction,for polices of land use regulation and land use zoning for future development within the overall national / local polices. Existing land use / land cover spatial information will be used in preparation of these plans. Its coverage can include administrative regions, investment regions and special regions, and these Regional Plans can be formulated under a variety of acts and laws.

It has to be comprehensive plan at an appropriate scale for integrating its urban nodes like towns / cities with neighbouring hinterlands.

Some other important benefits are mapping urban sprawl and land use/ land cover, creation of GIS layers and preparation of land use mosaic, study of land use changes over a period for monitoring the urban growth and land use patterns, generation of image atlas for regional and towns planning and creation of GIS database for Regional plan proposals. Infrastructure facility mapping is prepared within the frame work of national / local development polices with an aim to optimize the infrastructure and facility network. Capturing information on existing infrastructure and location of facilities is possible through high resolution satellite imagery and aerial photos whereas route alignment of infrastructure and facility location analysis are carried out through spatial analysis in a Geographic Information Systems (GIS) environment.

Additionally, the requirements of industries and the needed infrastructure for their growth are also to be taken care. Geospatial technologies, primarily remote sensing and Geographic Information Systems (GIS) are widely used for urban and regional planning,to identify urban growth, and for the formal planning. Further, space-based data is utilised for undertaking the overall control and timely implementation of remedial actions to provide necessary basic infrastructure and also measures to improve health and hygiene.

City Development Plans also some times referred to as Master Plans that focus primarily on the development of aforesaid urban node in a detailed manner with a perspective year of two to three decades or so. It needs to provide proposals, which definitive in nature, supported by suitable strategies and measurable progress. The targeted development should be monitored in a phased manner (every 5 years or so) for facilitative reviews and mid-term corrections.

Local Area Plans are prepared at the grass root level of this hierarchy, which focus on development and redevelopment of land, conservation of buildings and physical features, providing infrastructure and amenities, measures for improving health and safety of the public, environment etc. The prescriptions of Local Area Plans should be as per extant higher plan guidelines.

d. Implementation Mechanism

Conventional source data was the major input for generation of base maps for a long time for preparation of development plans. Presently, many new techniques like aerial photography and remote sensing have emerged and they are used for generation of base maps. The updating is further done by utilising the conventional collateral data and limited field survey. Conventional aerial photography, photogramme try, digital photo grammetry, high-resolution satellite image data, use of global positioning systems and GIS are some of the important techniques used for survey.

Spatial maps prepared using High Resolution Satellite (such as the Cartos at Series) data is utilised in urban planning and development. Regional perspective plans, master plans/development plans and Infrastructure plan are prepared using the resources information derived from remote sensing data. Further the remote sensing data is also utilised in the identification of archaeology sites for excavation. The available conventional/ground-based data in a GIS environment when integrated with satellite data helps vastly for urban studies.

The use of remote sensing & GIS technology in urban applications has immense advantages in terms of reduced time, reduced cost and high reliability over the traditional ground methods. For bigger citieslike Delhi, Bombay, Hyderabad, Bangalore etc., preparation of maps/geospatial databases required formaster plans / zonal plans using satellite data is far easier compared to ground surveys whichare impractical for such large areas. But at the same time the other essential house hold data, utility data are to be collected by ground surveys.

The preparation of a development plan of a town and its urbanisable area is carried out based on the geographical location, spatial distribution pattern and composition of present land use and socio-economic data. Remote sensing data of different resolutions are utilised for urban and regional planning, including urban sprawl mapping, land use inventory, utilities, infrastructure etc. With increase in spatial resolution of the satellite data, the extractable information content also increases many-fold.

IRS 1A/1Bdata was widely used in our country for resource mapping and land use mapping.IRS-1C/1D satellite provided 5.8 m data, which was used in preparation/revision of development plan. Urban sprawl and land use/ land cover mapping are also doneusing IRS-1C/1D (LISS III + PAN) data on 1:50,000 scale, to create relevant GIS layers as input in the planning process. It was used in revision of development plans of several Urban Development Authorities, Municipal Corporations etc. For example, this data was used in the preparation of regional plans of BMRDA and as well mapping of land use of National Capital Territory (NCT), Delhi for 1993. With the availability of SPOT satellite data, the resolution was further improved to 10 mts and this data was used in urban planning as well in regional planning to update the land use and base details. Data from Resources at LISS-IV (5.8-meter resolution), Cartosat-1 (2.5 m resolution), Cartosat-2 (1 m resolution) and Cartosat2 Series (0.65m PAN & 2m MX) are used for base & land use thematic mapping of metropolitan areas and union territories on 1:10,000 and 1:5,000 scales.

Cartosat-1 (PAN) ortho corrected data was useful for preparation of geospatial database at 1:10000 scale, for development plan generation of urban areas. Subsequently, Cartosat-2 data helped in updating the details on 1:5000 scale. IRS Cartosat-2 satellite provided 1-mresolution panchromatic data and enabled planners to distinguish ground features as small as 2-3 m.This data was used for up to class-1 towns towards generating thematic information under National Urban Information System (NUIS) on behalf of Ministry of Housing and Urban Affairs (MoHUA).

A few of the planning agencies in the Urban Development sector, such as Town & Country Planning Organisation (TCPO, MoHUA) have capabilities for remote sensing data processing and its interpretation.

e. Area Coverage: National / State / District

Remote sensing and GIS technologies have been widely used all over the Country to resolve some of the urban issues and also use best approaches for urban planning, governance and management. The studies can be done for any region depending on the requirement. It can be effectively utilised for the identified urban areas. Considerable amount of mapping of urban areas have been done in different parts of India which include many metropolitan cities and union territories. In the Country, the Class I urban agglomerations/cities account for more than 60% of the urban population. Further breakup of the population of cities indicates that the majority (around 42%) of the population of Class 1 urban agglomerations/ cities live in 27 metropolitan cities with a population of more than a million each. With this kind of urbanization, it is important tostudy the urbanization process and its associated problems.

f. Results (As compared to c above)

It is evident that considerable economic benefits have been derived by the use remote sensing & GIS in urban applications. The use of remote sensing & GIS technology in urban applications are being operationalised due its advantages inreduced time, cost benefit, and reliability of data over the traditional ground methods. For any urban application such as urban planning including infrastructure, municipal applications (tax, water supply etc.,) up-to-date maps and geospatial data are used. These maps are widely used for timely updation in 153 cities including cities like Delhi, Bombay, Hyderabad, Bangalore etc. Preparation of maps/geospatial databases are utilised for preparing master plans and zonal plans because the ground surveys are not practical for such large areas. But necessary data such as house hold data, utility data are collected by ground based methods. The economic benefits like indicative cost and approximate time requirements for preparation of Urban thematic maps in various scales by using remote sensing and GIS technology are given in the following table.

Sl. No.	Project Activity	RS and GIS Methods	RS and GIS Methods	Ground Methods	Ground Methods
		Cost/sq,m (Rs)	Time required	Cost/sq,m (Rs)	Time required
1	Thematic quality Urban Landuse / Land cover mapping and GIS database creation for Delhi NRC region (34,000 sq.km) on a scale of 1:50,000. (for regional plans)	1000	1 year	10000	More than 2 years
2	Cartographic quality Large Scale mapping on 1:10 K using high resolution satellite data. 5000 sq.km covering 40 towns	10000	2 years	25000	More than 3 years
3	Thematic quality Urban Landuse / Land cover mapping and GIS database sq.km creation for Hyderabad, HUDA region on 5,000 scale using high resolution satellite data. (for master/zonal plans and infrastructure plans.)	5000	For 2000 sq.km 6 months	20000	More than 2 years

Under the AMRUT programme, ISRO established methodology for generating the urban geospatial database using very high-resolution satellite data and executed the project through industry partners. The resultant database would be used for development/zonal/utility planning, accurate land & natural resources management; analyzing settlement patterns/slums;

addressing environment concerns; tools for modeling redevelopment/re-densification; real time land use monitoring;value addition in various planning processes like disaster management planning, environmental planning, city sanitation planning, heritage management planning etc. The geospatial database for 238 cities has been provided to the ULBs, and the ground verification and attribute information tagging process is going on at the ULBs.

Figure 1. Typical Cartosat -2 data showing part of Kerala

TypicalCartosat-2 Series data showing Part of Thrissur (Kerala), AMRUT City is given Figure 1.

g. Users' Perspective

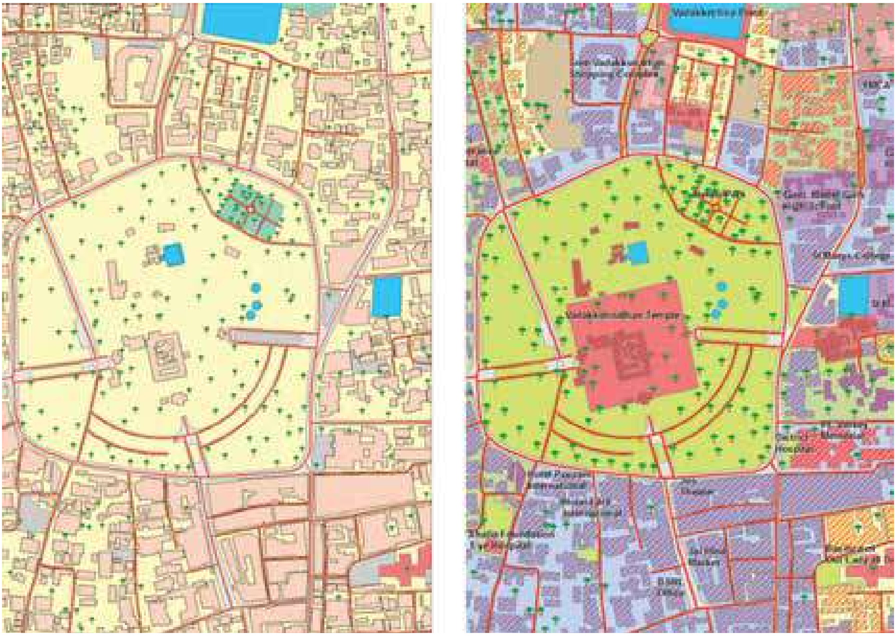

Figure 2. ***The base Layers, building footprints & urban land use***

With necessary maps and diagrams the Perspective Plan for a long-term plan spanning 20 to 25 years is prepared and it has been providing the required inputs to state government with the goals, policies,strategies and the general programmes for the urban local authority regarding spatio-economic development for the settlement under its governance.

(Road, Rail, Water bodies, Bridges/Flyovers, Broad Land use/land cover, building footprints) - ~140 features (Left: Before field inputs. Right: With field data and attached attributes).

The development plan is generated within the framework of the approved perspective plan, as a medium-term plan, spread over five years has been providing the comprehensive proposals for socio-economic and spatial development of the urban centre. This has helped for the use of land and development actions by the local authority and other agencies. Further the annual Plan, again generated within the framework of a development plan, has been providing the details of new and ongoing projects slated for implementation bythe local authorities. This is helping them to mobilise the necessary fiscal resources through plan funds and other sources. It also enables for the projects identified to detail with working layouts,thesupporting infrastructure,cost of development, source of finance and various plans for their execution either by a public or private agency.

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11. ATAL MISSION FOR REJUVENATION AND URBAN TRANSFORMATION (AMRUT) PROJECT

a. Background

India, is the second most populous country in the globe and has a population of around 1.3+ billion people (as per 2011 Census). About 31.8% of them have been living in 4041 towns and cities and it is expected to increase to 40% by 2026 and to about 50% by 2051. This, no doubt, brings in a lot of pressure on available land and also puts stress on the available resources in the urban cities. To alleviate these problems, it is necessary to prepare the requisite infrastructure for sustainable development of these cities through proper planning, adopting state-of-art geospatial tools and technologies like remote sensing and GIS.

Traditionally, urban plans were prepared manually and the entire process was time-consuming and cumbersome, in terms of preparations of inputs as well as plan formulation. With the advent of modern geospatial tools and technologies, satellite remote sensing and GIS techniques also have forayed into the domain of urban planning. Because of the advantages like synoptic coverage, time series comparison, finer details etc. Satellite images and aerial photographs have found their use in mapping of spatial distribution of settlements, their connectivity through transportation corridors, land utilization, infrastructure and monitoring the growth (urban sprawl) and dynamics of land use / cover changes. Likewise, the GIS tools offer numerous analytics and visualisation with overlay capabilities in spatial domain.

Multi-thematic urban GIS database was generated for 152 cities at 1:10,000 scale using the merged data of PAN (Cartosat-1) + LISS-IV (Resourcesat) sensors under the National Urban Information System (NUIS) Scheme during 2007-10, as input for GIS based Urban Master Plan preparation. This GIS database is hosted on ISRO's geo-spatial platform Bhuvan and a web-based GIS (Bhuvan-NUIS) is utilised for accessing, editing and managing the database. NUIS Scheme is used for understanding and experiencing the utilisation of remote sensing & GIS technologies for urban base, thematic mapping and GIS database creation. Preparation of base maps from Very High-Resolution Satellite (VHRS) Images and Geographic Information System (GIS) technology are cost effective solutions.

Noting the importance of these two technologies in the field of urban planning, Govt of India vide its document 'Urban and Regional Development Planning Formulation in India (URDPFI) Guidelines – 2015' has mandated the use of Remote Sensing and GIS technologies for urban Planning activities in India.

b. Objectives

Atal Mission for Rejuvenation and Urban Transformation (AMRUT), a major national programme launched by Government of India in June 2015, envisages to establish infrastructure to ensure availability of potable drinking water and sewage connections to every household, with increased emphasis on developing greenery and well-maintained open spaces (e.g. parks); and to reduce pollution by switching to public transport or constructing facilities for non-motorized transport. Town and Country Planning Organisation (TCPO) is the Nodal Agency from Ministry of Housing and Urban Affairs (MoHUA), Government of India.

The Mission attempts to achieve these goals through a set of eleven (11) reforms, of which, the city level planning reform aims to achieve planned urban and infrastructure development by preparing GIS based Master Plans for 500 Class-1 cities (Population greater than 1,00,000).

Master Plans are statutory documents, which indicate detailed land use allocation for future development of city / town (say over next 20 years or so) based on existing demography, land use, infrastructure and socio-economic conditions. This becomes very important as they help to avoid haphazard development, ensure proper growth and efficient utilization of resources. At the time of the launch of this project, such Master plans were available only for about 20% of Indian cities.

c. Expected Benefit to Society

AMRUT is envisaged to give a greater thrust for the economic development of Cities in India as they are engines of economic growth. Currently, India is under immense pressure, due to population increase and the consequent urbanization. In the situation of rapid pace of Indian Urbanization, AMRUT project is timely and has helped to enhance the basic planning processes towards better household services and amenities (e.g. water supply, sewerage, urban transport etc.) in many cities of India.

AMRUT project offers several benefits for city/ township planning, like, the capacity building, reform implementation, water supply management, sewage and septage management, storm water drainage, urban transport and development of green spaces and parks. During the process of planning, the Urban Local Bodies* (ULBs) have freedom to include some smart features in the physical infrastructure components, due to the geospatial maps of high resolution that facilitates planning in advance.

* [Urban Local Bodies (ULBs) are small local bodies that govern a city or a town of specified population. Urban Local Bodies are vested with functions like public health, welfare, regulatory functions, public safety, infrastructure works, and development activities. Urban Local bodies in India can be Municipal Corporation, Municipality, Town Area Committee, Township, Cantonment Board etc.]

Such base maps are generated on a scale of 1:4,000 using Very High-Resolution Satellite (VHRS) data as per the requirement of state town planning departments. In addition, the design and standards for the Geospatial Database have been standardised and used across all 500 AMRUT cities in the country.

d. Implementation mechanism

AMRUT programme implementation is carried out in a structured way by Government of India. To start with, 500 Class-1 cities (Population >1 lakh) were shortlisted by states for Master Plan formulation. Activities under this reform mainly comprise of: (i) urban geospatial database creation at

1:4,000 scale from VHRS data (by NRSC and others), (ii) formulation of GIS based Master Plans (by the Urban Local Bodies), and (iii) training and capacity building.

Urban Geospatial database creation from VHRS data

Based on the experience gained from NUIS, under the AMRUT programme, Urban Geospatial base maps are prepared at 1:4,000 scale using on-screen visual interpretation techniques from Very High-Resolution Satellite (VHRS) data. Common Design and Standards were evolved for creation of Geospatial database and uniform database schema was adopted for generating the database with the help of National Remote Sensing Centre (NRSC), ISRO. NRSC has been entrusted with the responsibility for generating urban geospatial database for 238 AMRUT cities.

NRSC/ISRO has developed a set of Private Geospatial Industry partners for the purpose of geospatial database creation under its guidance as 2-D feature extraction work from VHRS data is manual, intensive, time-consuming and repetitive job.

Besides, it has established a state-of-the-art GIS database Creation Facility in one of its campuses with 300 thin clients using a secure cloud-based access providing data, system and software (open source) as services.

To reduce city-wise turn-around times, the appropriate methodologies have been developed along with Standard Operating procedures (SOP) for both – (i) 2-D feature extraction from VHRS data using GIS software tools, (ii) field verification & attribute data collection by ULBs and (iii) Incorporation of field and attribute data and city-wise GIS database finalization. A series of four (4) National meets were organized for the benefit of Urban Local Bodies (ULBs) by both NRSC and TCPO for smooth execution of project tasks.

This activity is executed in three different phases, viz. pre-field, field, and post-field.

Pre-field Phase (NRSC): Main tasks executed comprise of finalisation of city-wise mapping area, ordering, procurement and rectification of the satellite data, 2-D feature extraction and pre-field GIS base map generation for field verification.

The pre-field base map for a given city normally has seven (7) GIS layers, viz. road, rail, bridges, flyovers and water bodies, building footprints and urban land use. After quality checks of the data, base maps are generated in PDF (½ km X ½ km tiles) with unique numbering scheme for the purpose of field verification and attribute data collection. Along with excel files corresponding to these tiles to record attributes in tabular form, which otherwise is not possible from satellite data alone. Respective ULBs were provided with these inputs to facilitate field verification and attribute data collection.

Field Phase (ULBs): As part of AMRUT cities' GIS database creation, ULBs are responsible for carrying out the ground truth and attribute data collection. It is the responsibility of the ULBs to examine the PDFs in the field for their feature correctness and consistency.

ULBs collect all the attributes related to road width, road name, railway gauge, etc. and also use of the building, address, number of floors, land use, etc., as feature updates. Unique IDs are provided for each of this data and they are updated in the excel (Tabular data) tables. This process takes about a month or two.

Offices of the ULBs responsible for the project were given the Standard Operating Procedure (SOP) for field verification and attribute data collection. Parallelly, their teams were trained by TCPO on the SOP execution. NRSC have provided them the pre-field GIS database as well as the PDFs of pre-field GIS base maps for field verification along with corresponding Excel files for collection of attribute data.

ULBs compile the information collected in field (verified field maps & attribute data) and pass on to NRSC for Urban GIS database finalization.

Post-field Phase (NRSC): On receiving the filed data from ULBs, NRSC, then updates the pre-field base maps with the field derived information. Doubts, if any, shall be clarified in consultation with the ULBs. Pre-field GIS Base Maps Generation Sequence is explained in Fig. 1. The final database comprising of about 7 spatial layers (88 spatial features, 415 number of classes after classification) are checked for both its content and topology before it is finalized. The final GIS database shall be checked for its quality before submission to the ULBs once again for further use. Delivery of standard products is carried out while meeting the quality control parameters, including standards, formats, and use of appropriate software tools.

It has also been conducting periodic Training of Trainers (ToT) to TCPO officials of MoHUA, on the use of Geospatial technology for Urban Master plan generation. Once the officials get trained they in turn impart further training to respective ULBs on need basis. Based on this updated database, GIS based master plans are generated.

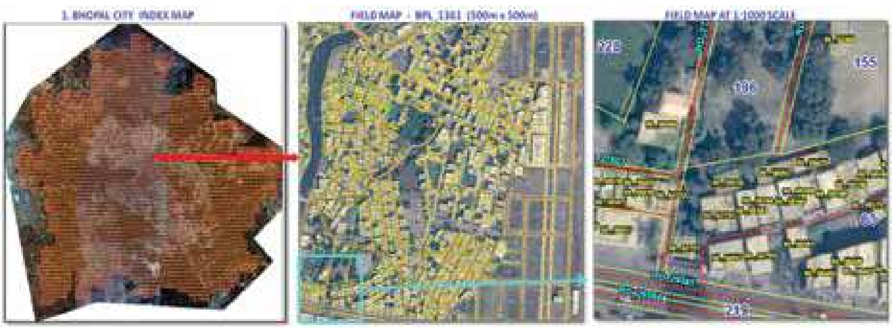

Figure 1. Amrut-Pre-field GIS base maps generation sequence

AMRUT Geospatial database is effectively used in several urban applications, like, the urban planning, monitoring land use change dynamics at regular intervals, identification of potential sites for rooftop solar energy harvesting, preservation and conservation of urban green areas, governance application, such as, property tax etc. The database is also used as a base for preparing sectoral plans and town planning schemes at larger scales.

In summary, the total sequence of AMRUT Geospatial database creation involves 1) preparation of base maps using VHRS data, 2) Delivery of base maps to State/ULBs for field data verification and attribute data collection and 3) GIS database finalization after integration of field data. This process helps in the generation of reliable database for formulation of the GIS based Master Plan. The Fig 2, summarises the Master plan preparation under AMRUT program that highlights parts of Bhopal, Madhya Pradesh.

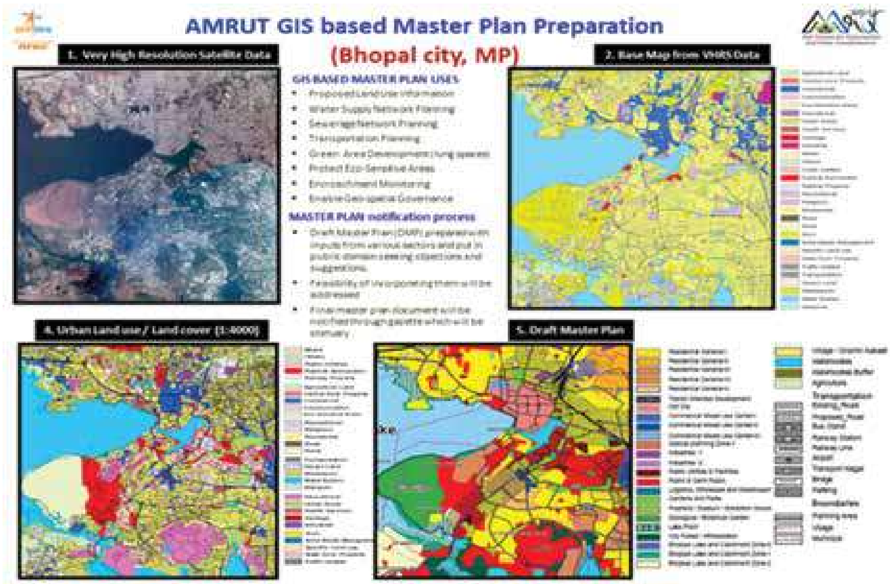

Figure 2: Process flow of AMRUT GIS Database Creation

e. Area Coverage: National / State

The AMRUT project is implemented all over India in almost all States of India. Initially 500 cities have been identified for the implementation of AMRUT spread all over India.

f. Results Obtained: (compare with item c above)

The project is well received both by MoHUA and the State Governments. The outcome from AMRUT project serves as inputs for providing basic services to households and building amenities in cities, towards improving the quality of life in our cities/ towns. The Missions implemented so far have demonstrated that proper planning for infrastructure creation has a direct impact on the needs of people, such as providing taps, toilets and many other amenities to households. The focus has been to carry out detailed planning with a view to identify specific gaps and cater to the required infrastructure with the main aim of providing better services to people.

So far, under AMRUT, more than 500 projects have taken off. These include water supply connections to households, besides enabling adequate water needs in a number of cities. Similarly, a good number of projects on sewerage management system and on augmentation of water supply have also been carried out. Development of open and green spaces is presently in progress in almost all the 500 mission cities. Considerable investments have been initiated under Atal Mission during 2016 for improving infrastructure related to several amenities like water supply, sewerage networks, storm water drains, urban transport with focus on non-motorized transport including open and green spaces.

g. Users' Perspective

AMRUT is being implemented in several States in India and to name a few;

1. West Bengal, at Jangipur in Murshidabad,
2. Andhra Pradesh at Amaravati,
3. Haryana at 18 ULBs (Urban Local Bodies),
4. Jammu and Kashmir at Srinagar Municipal Corporation (SMC),
5. Maharashtra at 44 towns and cities
6. Madhya Pradesh in 34 mission towns and cities and
7. Telangana to enhance water supply in 12 AMRUT cities.

In addition, a number of initiatives have already been taken by various states in the direction of implementing various segments of project in different States as given below

12 cities in Andhra Pradesh, 2 cities in Madhya Pradesh, 7 cities in Odisha, and 29 cities in Rajasthan

Considerable number of projects for achieving energy efficiency in street lighting and water pumping have been taken up in Public-Private partnership (PPP) mode in number of cities of Rajasthan, Gujarat and Punjab.

Sixth Anniversary was organised by Ministry of Housing & Urban Affairs on 25th June 2021 to commemorate the launch of several initiatives on urban transformation like AMRUT and Smart Cities. As per the details provided in the report, as on that date, 105 lakh household water tap connections and 78 lakh sewer/ sewerage connections have been provided under AMRUT Mission. In addition, 88 lakh streetlights are replaced with energy efficient LED lights leading to energy savings of 193 crore units and 84.6 lakh tons carbon footprint is reduced through various initiatives under AMRUT, as per TERI. The work done so far is very encouraging. The implementation of these projects has brought in improvement in service delivery, in mobilization of resources and in making municipal functioning more transparent and accountable. The whole project has been helping in transforming Urban India to help in meeting the aspiration of its citizens as envisaged.

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12. SPACE BASED SUPPORT FOR GOVERNANCE

a. Background

At national level, the good governance is a very essential tool for enhancing the economic activities and also for accelerating the development. The Government has to play a facilitator's role with proper processes in place involving the procedures, policies and conventions with appropriate decisions and accountability. Governance also encompasses wider section of society like citizens, businessmen, NGO's, government and media. There are a lot of overlapping of the interests amongst these stakeholders. Governance has to set the directions and goals with the main objective of achieving welfare of the society. Therefore, in all these governance matters, space based inputs play a major role towards improving efficiency and effectiveness of existing policies, schemes and programmes by utilising the geospatial technologies, which encompass remote sensing (RS), geographic information system (GIS), satellite based navigation along with enabling information & communication technologies (ICT). These technologies ensure smooth last mile connectivity of government services by enabling the much needed seamless automation in administrative and development processes. The natural resources management, public health, education, infrastructure development and many more are able to derive the benefits of digital technologies in governance, enabling wider participation of multiple stakeholders.

b. Objectives:

In India Vikram Sarabhai, the founding father of space programme, envisioned that India could leap frog in development by adopting advanced space technologies in several applications of relevance for national development benefiting the common man. Therefore, the objectives have been to utilise space based inputs for delivering the public services to enable the governance at Central and State Governments in order to accelerate National development. Various space-related services include communication, broadcasting, weather advisories, resources mapping, disaster management support, navigation and surveillance. Presently, there is a big thrust in using such inputs for governance. The prime aim is to provide good governance, thus empowering the local populace by bringing together the voluntary groups, local governmental agencies, entrepreneurs, service industry and the academic institutions.

c. Expected Benefits to Society:

Maximum benefits can be derived by utilizing the Informed decision making, better planning & monitoring, enhanced transparency, good governance, and sound policy making with reliable data and analytical tools based on spatial and non-spatial data-centric technologies. The space based inputs are being used in the Governance system over a period by offering host of datasets, information products, services and planning tools, benefitting all section of society. Many citizen-centric services have improved drastically by utilising the new forms of knowledge and tools through digitalisation and datafication. The vital contents are derived in the demand-supply chain of a Governance system. The benefits include bringing in the rural transformation by expanding the outreach of Sat Com and EO applications in the remote and rural India. The various governance issues addressed and being implemented in India are eradication of illiteracy, improving healthcare, training & capacity building, enhancing agricultural productivity and ensuring drinking water management, affordable housing, crop insurance support, infrastructure development, disaster management, building Natural resources Assets and many other related areas.

d. Implementation methodology:

The high technology space inputs have been effectively integrated in operational system to provide important services in the prioritized sectors for the Governance in the country, as given below;

I. Ensuring socio-economic security: food water, energy etc,

II. Building natural resources assets,

III. Improving physical and social infrastructure,

IV. Supporting disaster management,

V. Improving services through weather & climate studies, and

VI. Reaching the local community for their livelihood applications.

Typical operational applications using remote sensing towards Governance and Development in the country are:

I. Mapping of the land-use / land-cover,

II. Mapping of the command area in the irrigated agricultural areas to monitor efficiency of water use,

III. Land and water resources management for watershed development in the rain-fed agricultural areas,

IV. Irrigation infrastructure and reservoir sedimentation assessment,

V. Estimation of the agricultural crop acreage and the potential yield for major crops,

VI. Mapping of the wastelands to enable appropriate reclamation strategies for useful land usage,

VII. Micro-watershed development in a participatory manner in rural areas,

VIII. Identifying the ground water prospect zones in rural villages,

IX. Mapping of the flood affected areas as well as providing periodic input for agricultural drought assessment,

X. Space based inputs for Urban Master Plan Preparation and developmental planning at Gram Panchayat level,

XI. Geospatial monitoring of Rural Employment Guarentee Programme,

XII. Space based detection & monitoring of forest fire and agriculture residue burning,

XIII. Space technology inputs for Crop Insurance Programme (smart sampling for Crop Cutting Experiments, Damage estimation, crop yield proxies etc.),

XIV. Mapping of potential fishery zones, etc.

The space technology based services are being implemented in the rural sector to utilize the spatial information like geo-referenced land record, wastelands for reclamation, managing natural resources, locating suitable sites for drinking water wells &groundwater recharge, rural employment creation, and infrastructure development for good governance.

Satellite Communication (SatCom) technologies encompassing the telecommunications, TV broadcasting, business communications, DTH services, rural area connectivity, search and rescue operations and emergency communication are judiciously used during the implementation. Some of the space based services effectively used by State governments are universities for distance education, rural development, panchayat raj, women & child welfare, agriculture, forestry, healthcare etc.

Strategies adopted are geospatial policy, NSDI implementation, centralised governance model etc. The various efforts in this direction are briefly given here. The affordable and actionable products & services derived using space technology inputs are disseminated through web services such as BHUVAN, BHOONIDHI, Meteorological and oceanographic satellites Data Archival Centre (MOSDAC), and Geoportals/ information systems such as India Water Resources Information System (India-WRIS), GeoMGNREGA, Bhuvan-IWMP, Bhuvan-NHP, Space based Information system for decentralised planning (SIS-DP), National Database for Emergency Management (NDEM), Flood Early Warning System (FLEWS), North Eastern Spatial Data Repository (NESDR) etc. BHUVAN has been providing visualization products of satellite remote sensing data, and also the vector layers of many operational applications carried out in the country. It is also supporting State Governments in their governance in various sectors. ISRO's disaster management support programme (DMSP) has operationally integrated the location-aware hand-held devices into the decision support system. In addition, many such innovative applications are being implemented utilizing the cloud computing and crowdsourcing. (Reference 3).

From 2006 onwards, the active forest fire monitoring is carried out using satellite data. The information on forest fires is provided on real time basis to Forest Survey of India (FSI) and state forest department users (by SMS and emails) across India. The satellite data used are from the MODIS flying on the TERRA and AQUA spacecraft and Visible Infrared Imaging Radiometer Suite data from the Suomi National Polar-orbiting Partnership (SNPP-VIIRS).

The satellite data is received and processed at National Remote Sensing Centre, Shadnagar campus, Telangana in near real-time using Science Process Algorithms (SPAs) obtained from the Direct Readout Portal (https://directreadout.sci.gsfc.nasa.gov). The forest fire product dissemination is through Bhuvan.

As a futuristic requirement and to provide much better governance in the country, advanced technologies like deployment of high power, high throughput Communication satellites (HTS), sub-resolution remote sensing satellites, and spatial positioning systems through IRNSS appropriately linked with cloud computing, crowd sourcing, broadband social networking and smart mobiles are needed and the technology growth in these directions opens up newer and newer applications in the coming years.

e. Area Coverage: National / State / District

Space based inputs for addressing Governance aspects covering its various sectors are being utilised across all states and union territories of India. India has several space assets for earth observations, communication and navigation applications, and these assets have been providing the space based inputs to the benefits of all parts of the Country.Utilised with a need for panchayat level development,constitution directions, strengthening people and direct benefits etc. A calibrated approach and implementation enhance the governance issues, in several areas thus helping to accelerate the national development.

f. Results Obtained: (Compared to c above)

Different tools have been used to effectively address the Governance issues, in a wide variety of application areas like agriculture, crop insurance, forest cover, forest biomass, bioenergy (towards renewable energy solutions), biodiversity characterization at landscape & community level, property tax mapping application, master plan formulation of AMRUT cities, rural development, watershed monitoring, water resources assessment & management, irrigation infrastructure creation, assessing river linking potential etc. Bhuvan (https://bhuvan.nrsc.gov.in), a Geoportal platform of Indian Space Research Organisation (ISRO) launched in 2009, has a wide variety of tools to provide the services ranging from visualization of multi-date, multi-platform, multi-sensor satellite data, thematic map display, query and analysis, free data downloads, products, near real-time disaster services and Apps for crowdsourcing and diverse geospatial applications. The details and description of the tools used is beyond the scope of this document. The Bhuvan has a versatile viewing platform with capabilities of providing 2D/2.5D/3D photo-realistic textured pictures draped on image-based footprints providing a unique viewing/animation experience. This Geo-platform has been supporting more than 43 state/central ministries departments in India with more than 200 applications and more than 75 android-based mobile applications. Android apps are available for downloading the field data for various national/state flagship programmes.

In order to support the decision making, monitoring and evaluation, various domain specific applications are built in collaboration with partner organizations and ministries. Some of the important Bhuvan applications are:

Election GIS: To monitor the vehicles movement carrying EVMs and incident reporting from the field during Loks Sabha and state elections enabling the officials to make right decisions and provide appropriate instructions as and when required.

Health GIS: Extended its services in tracking, identifying hotspots, vegetable markets, and home isolation during pandemic. Geoportal and analytics are enabled for National Health Resources Repository (NHRR) programme of Ministry of Health and Family Welfare. A geospatial solution is used by Govt. of AP to collect & visualize entire health facility details under NTR Vaidya Seva program including blood bank, hospitals, medical facilities. It also enabled Punjab Remote Sensing Centre to host its health facility & infrastructure for public and end users visualization.

Municipal GIS: It geotagged more than 12 Lakhs properties across 72 ULBs in Telangana in phase 1 and extended in phase 2 to all new ULBs to identify many properties which helped Govt. of Telangana in proper tax assessments. In Ludhiana, Municipal GIS is used to provide complete information from ward to house level.

Post Office: To collect all information related to the post offices using simple mobile app and host it on Bhuvan with various value added tools & services for public visualization. Tools are also provided to capture delivery zone mapping.

Bhuvan has been increasingly used to provide solutions to support many of the governance programmes / schemes by utilizing the Remote Sensing & GIS data. In agriculture domain,Pradhan Mantri Fasal Bima Yojana (PMFBY) is being implemented in the country. Remote sensing, mobile application and data analytics technologies are used for providing inputs for effective and efficient implementation of the scheme. Maha-Agritech is a collaborative effort of NRSC, Department of Agriculture, Govt. of Maharashtra and State Remote Sensing Applications Centre, Maharashtra. Innovative mapping and data analysis techniques are used to provide quantitative in-season parameters related to agriculture. The project has supported both farmer-centric and planning-centric activities in agriculture decision-making in crop insurance, drought management, agro-advisory etc.

Monitoring of biodiversity at high resolution was taken up towards conservation of biodiversity in India. It was initiated in 2018 as a joint effort of Department of Biotechnology and Department of Space (with the support of National Natural Resources Management System (NNRMS) of the Department of Space), with the aim of developing an Earth Observation based strategy for characterizing biodiversity at the vegetation community level in India.

As part of urban application, support for local governance is carried out at the level of the municipality or urban local body which includes planning for economic and social development of the town, its plan, its physical infrastructure such as, roads, bridges, culverts, sanitation conservancy, solid waste management water supply for domestic, industrial and commercial purposes and public health. In Remote Sensing and GIS applications, Very High-Resolution Satellite (VHRS) Data is utlised in diverse applications for municipal governance. Commissioner and Directorate of Municipal Administration (CDMA) is the apex authority of Municipal Administration of any state/UT in India. In an integrated application, the CDMA of Government of Telangana carried out geo-tagging, visualization and moderation of all assessments, trades, advertisements and cell towers in Telangana for 30 Districts comprising of more than 134 Urban Local Bodies under Phase-II. Aim of this project is to obtain the location information of all assets with measurements and trade details.

In the rural development programme, Geospatial technologies are used in various Government Flagship Programmes in India like Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), watershed development component (WDC) of Pradhan Mantri Krishi Sinchayi Yojana (PMKSY, erstwhile Integrated Watershed Management Programme), monitoring rural roads under Pradhan Mantri Grameen Sadak Yojana (PMGSY), Pradhan Mantri Fasal Bima Yojona (PMFBY) etc. to bring in required transparency and accountability in monitoring the programmes at minimal cost. Bhuvan provides range of geo-information based products and services for various natural resource management and rural development needs. A large repository of geotagged data has been created under several of programmes. These schemes have made important contributions towards rural development and productivity.

Monitoring and evaluation of the watershed development (WDC-PMKSY) are being done with the help of Bhuvan Geo-Web portal (SRISHTI; https:// bhuvan-app1.nrsc.gov.in/iwmp/). Also, android based smart phone Application named DRISHTI is implemented for collecting field information (including geotagged photos) on watershed development interventions. Till date, several lakh geotagged points have been uploaded using Drishti App. More than 24000 high resolution satellite images of different time series have been hosted on Srishti portal for evaluating the changes due to the interventions (Fig 1).

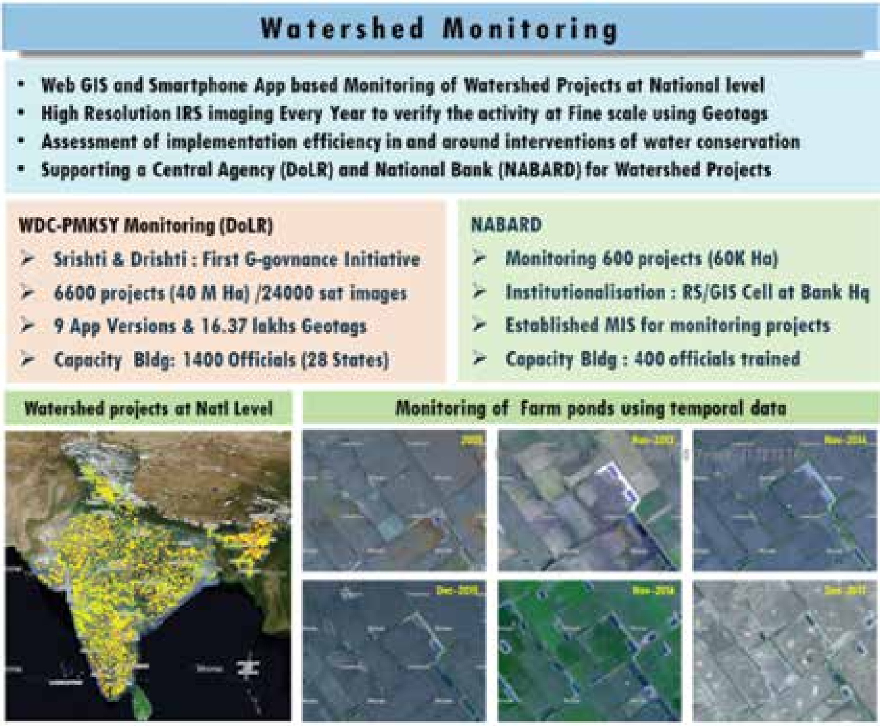

Figure 1 Support to Governance: Watershed monitoring using Geospatial approach

g. Outcomes of different programmes

A National Meet on promoting Space Technology based Tools and Applications for Governance and Development, was conducted at Vigyan Bhavan, New Delhi on September 7, 2015. Nine themes on Agriculture, Energy & Environment, Infrastructure Planning, Water Resources, Technology Diffusion, Developmental Planning, Communication & Navigation, Weather & Disaster Management and Health & Education were selected. More than 150 newprojects were identified where improved and extensive space technology inputs were envisaged. Additionally, quite a few areas which benefit the common man were also identified such as empowering panchayats in planning the land & water resources, automated warnings at unmanned level crossings; programmes for tribal districts like potential fishing pond, identification tracking of illegal mining; enabling Geo-fencing etc. Many flagship programmes of the Government were also identified like, Atal Mission for Rejuvenation & Urban Transformation (AMRUT); Pradhan Mantri Awas Yojana; Pradhan Mantri Krishi Sinchayee Yojana; National Mission for Clean Ganga and Digital India, for utilizing enhanced Space based inputs.

At the request of Central Water Commission, NRSC, ISRO developed India-Water Resources Information System(WRIS) as a 'Single Window' solution for comprehensive, authoritative and consistent data & information of India's water resources. This led to formation of National Water Informatics Centre (NWIC) at Ministry of Jal Shakti, Govt. of India enabling internalisation of geospatial technology in the Ministry. This initiative is intended to develop and adopt improved methodological framework for measuring/monitoring the progress of the country's water sector towards a sustainable development, management and governance.

Another important application is to map the parks and green spaces in big cities since they play an important role in promoting public health, arts, tourism and economy. They are essential facilities for the citizens. Around 760 parks of various shapes and sizes are spread over the city of Kolkata, under the ownership of the Kolkata Municipal Corporation (KMC). These neighborhood Parks of the city of Kolkata are to be continuously monitored for their conservation, management and development. Geospatial technology is used to bring these widely scattered 760 parks in the city of Kolkata in a single window to disseminate the Park information of the city. This effort has helped to conserve the green area by keeping an inventory of green parks along with its location and area extent.

Heavy and persistent rains during third week of July 2021 led to flooding in large areas of Raigad, Ratnagiri, Satara and Kolhapur districts of Maharashtra. The flood inundation mapping in these areas was carried out using the microwave Synthetic Aperture Radar data from Global missions through the 'International Charter Space and Major Disasters' for the peak flood period. The impact of flood inundation on the agricultural areas was also assessed. The analysis on the village-wise flood inundation showed that Satara district has 222 villages inundated by floods with greater than 25 ha area and 155 villages are inundated in Ratnagiri district. In case of Kolhapur and Raigad districts, 174 villages and 64 villages are inundated respectively. The studies using the near real time satellite data helped to assess the more realistic analysis of the impact of the floods which in turn helped Government in initiating further post-flood response and recovery action.

Haryana Government in association with ISRO has effectively implemented a GIS & ICT based citizen centric application "HARPATH," named "CM Digital Haryana Mission." This has enabled the citizens to report the road conditions like damaged road and accident blackspot along with location based information. It also has helped to photograph and to monitor the progress of the work carried for the reported issues of the roads. Technology was also transferred to Govt. of Haryana for further enhancements & operationalization.

Use of space technology applications have been internalized or institutionalized in more than 20 Ministries. For example, agriculture/ horticulture applications (Mahalanobis National Crop Forecasting Centre; MNCFC in MoA&FW), forestry related applications (FSI, MoEF&CC), Water resources applications (NWIC, MoJS), urban related applications (TCPO, MoH&UA), fishery applications (INCOIS/ MoES), weather/ disaster management applications (IMD, MoES; GSI, MoMines, FSI, MoEF&CC, CWC, MoJS, NDMA, MHA etc.) are some of the examples of internalization/ institutionalization of space technology applications by the stakeholder Ministries. Hence, space based geospatial data infrastructure becomes invaluable information tool and need to be included in institutional and socio-economic framework of good governance for dynamic and sustainable decision making.

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13. SPACE BASED FLOOD DISASTER MANAGEMENT:

a. Background

India, is considered as the worst affected Country for disasters in the South Asian region. It is highly vulnerable to several natural hazards including floods and associated landslides. After Bangladesh, India is the second most flood affected Country in the globe and as per the data available, India accounts for one fifth of global death due to floods. According to National Flood Commission around 40 million hectares of land in the country are subject to floods, and an average of 18.6 million hectares of land is affected annually. The annual average cropped area affected is approximately 3.7 million hectares. The Brahmaputra and Ganga River basins are the most flood-prone areas in India . They are in the Indo-Gangetic- Brahmaputra plains in North and Northeast India, which carry 60 per cent of the nation's total river flow. The other flood prone areas are in the north-west region of west flowing rivers such as the Narmada and Tapti, Central India and the Deccan region with major east flowing rivers like Mahanadi, Krishna and Cauvery. Although the floods cannot be stopped, the damages due to flood can be minimized by proper Disaster Management measures particularly in reducing the probable losses from hazards and in providing fast support to the victims. Satellite based systems involving telecommunication, Remote Sensing and Navigation Systems provide effective inputs to implement the efficient disaster risk management and emergency response. The space-based information are used effectively in all stages of disaster management like preparedness, early warning, response and reconstruction.

Maximum Indian rainfall is received over a short monsoon season of four months (June-September). During this period the rivers will have heavy discharges leading to widespread floods in almost all states, particularly in states like Uttar Pradesh, Bihar, West Bengal and Assam. Drainage problems also arise if the floods continue for a longer period. The massive indiscriminate deforestation, has been causing large amounts of topsoil becoming loose during the heavy rains and the loose soil flows down into the river streams causing the riverbeds and its tributaries to rise.

Space technologies offer significant advantages in addressing the important issues related to disaster management. Continuous monitoring of atmospheric as well as surface parameters attributing to the phenomena are possible by Earth observation satellites. The other space technologies which are very vital for supporting disaster management are satellite communications viz., satellite phones, point-to-point networking solutions routed through the arrays of Very Small Aperture Terminals (VSATs) deployment in remote and inaccessible areas. In addition, the Cyclone Warning and Dissemination Systems (CWDS), Data Collection Platforms (DCP) and Satellite Aided Search & Rescue (SAS&R) are very critical during a disaster. Satellite remote sensing provides the crucial data to estimate the spatial flood extent, flood damage statistics and also to carry out the river engineering studies in a cost effective manner.

b. Objectives:

The major objectives of space-based technologies are essentially to contribute in all phases of the disaster management cycle, including preparedness, early warning, response and reconstruction. It is possible to provide early warnings for disaster such as floods, cyclones etc., based on remotely sensed data which gives the information for systems and models. Other objectives are to provide relief & rehabilitation based on the quick assessment of damages and also to organize the needed relief operations based on the maps prepared for the inundated areas.

c. Expected Benefit to Society:

Use of Satellite remote sensing data for generation of spatial flood extent, flood damage statistics and also in river engineering activities are highly beneficial and cost effective towards flood disaster management. The utilisation of data on flood maps, flood damages, flood control, river bank erosion and flood prone areas under flood disaster management activities and the corresponding benefits are given in the Table 1 below. (Reference 2)

Table 1. Utilization of the flood products and their benefits

	Deliverables	Utilization
1	Flood map	To map inundated areas for organizing relief operations
2	Flood damages – Extent of inundation – Crop area submerged – Number of Villages marooned – Length of Road/ railway network affected/submerged	Quick assessment of flood damages, for providing relief & rehabilitation
3	Flood control works and River configuration	Strengthening of existing & planning of future flood control works
4	River Bank erosion	Planning bank erosion protection measures
5	Identification of chronic flood prone areas and Floodplain zoning	Hazard zonation & floodplain regulation, planning flood control works

d. Implementation mechanism

The Disaster Management Support Programme (DMSP) of DOS operationally integrates the space technology inputs and services on a reliable and timely basis to provide support to disaster management activities by nodal Ministries/ Departments in the country. DMSP covers majors disasters such as flood, cyclones, landslides, earthquakes and forest fire. To meet the demands of flood disaster management, Department Of Space (DOS) has developed techniques and methodologies by integrating space based systems and services. Specific areas of DMS initiatives for Flood disaster are:

(i) Creation of digital databases at appropriate scales for facilitating hazard zonation, damage assessment etc. for the flood-prone areas.

(ii) Development of appropriate Remote Sensing & Geographical Information System (GIS) based decision support tools and techniques.

(iii) Generation of very high resolution digital elevation models with centimetre-level vertical accuracy and elevation contours at close interval for priority areas

(iv) Strengthening the communications backbone for addressing the real time / near real time information transfer and networking of scientific institutions for exchange of data, information and knowledge.

Towards enabling the operational services under Disaster Management, a Decision Support Centre (DSC) is established at National Remote Sensing Centre, (NRSC) as a single window service provision mechanism, benefiting the National / State disaster management authorities/ agencies. Satellite & aerial data acquisition strategy; information & formats, output generation, dissemination of information, support functions such as digital database, hazard zonation, network modelling, query shells, etc. are the essential components of DSC.

National Remote Sensing Centre (NRSC) is the nodal agency for providing satellite data based information related to floods on timely basis to Central Water Commission (CWC) / Ministry of Jal Shakti, which is responsible for flood disaster management in India. Optical satellite data from Indian Remote Sensing satellites (IRS) and microwave data from Indian (EOS-04) as well as foreign satellites (RADARSAT/ SENTINEL-1A) to monitor and map flood inundation. Table 2 gives the details of the Satellites used for Disaster Management Applications are given below (Reference 3)

Table 2. The details of satellites used for Disaster Management Applications. (Reference3)

	Launch Date	Launch Mass	Launch Vehicle	Orbit Type	Application
EOS-04	February 14, 2022	1710 kg	PSLV-C52	LEO	Disaster Management Support, Natural Resources management
EOS-01	Nov 07, 2020		PSLV-C49	LEO	Disaster Management Support, Earth Observation
RISAT-2BR1	Dec 11, 2019	628 Kg	PSLV-C48	LEO	Disaster Management Support, Earth Observation
RISAT-2B	May 22, 2019	615 Kg	PSLV-C46	LEO	Disaster Management System, Earth Observation
INSAT-3DR	Sep 08, 2016	2211 Kg	GSLV-F05	GSO	Climate & Environment, Disaster Management Support
INSAT-3D	Jul 26, 2013	2060 Kg	Ariane-5 VA-214	GSO	Climate & Environment, Disaster Management Support

Table 3 shows various sensors used for flood mapping activity (Reference 2)

Table 3. The Sensors used for flood mapping (Reference 2)

Sl. No	Satellite	Sensor/ Mode	Spatial Res(m)	Spectral Res(µm)	Swath (km)	Used For
1	IRS-P6	AWiFS	56	B2:0.52-0.59 B3:0.62-0.68 B4:0.77-0.86 B5:1.55-1.70	740	Regional level flood mapping
2	IRS-P6	LISS-III	23.5	B2:0.52-0.59 B3:0.62-0.68 B4:0.77-0.86 B5:1.55-1.70	141	District-level flood mapping

3	IRS-P6	LISS-IV	5.8 atnadir	B2:0.52-0.59 B3:0.62-0.68 B4:0.77-0.86	23.9	Detailed level Mapping
4	IRS-1D	WiFS	188	B3:0.62-0.68 B4:0.77-0.86	810	Regional level flood mapping
5	IRS-1D	LISS-III	23.5	B2:0.52-0.59 B3:0.62-0.68 B4:0.77-0.86 B5:1.55-1.70	141	Detailed level Mapping
6	Aqua/Terra	MODIS	250	36 in visible, NIR & thermal	2330	Regional level Mapping
7	IRS-P4	OCM	360	Eight narrow bands invisible & NIR	1420	Regional level Mapping
8	Cartosat-1	PAN	2.5	0.5-0.85	30	Detailed level Mapping
9	Cartosat-2	PAN	1	0.45-0.85	9.6	Detailed level Mapping
10	Radarsat-1/2	SAR/ Scan SAR Wide	100	C-band(5.3cm) HH Polarization	500	Regional level mapping
11	Radarsat-1/2	SAR/ Scan SAR Narrow	50	C-band (5.3cm)	300	District- level mapping
12	Radarsat-1/2	Standard	25	C-band	100	District- level mapping
13	Radarsat-1/2	Finebeam	8	C-band (5.3cm)	50	Detailed level mapping
14	ERS	SAR	25	C-band VV Polarization	100	District-level mapping
15	EOS-04	CRS	50	C-band SAR	223	Regional level mapping
16	EOS-04	MRS	33	C-band SAR	160	District-level mapping
17	Sentinel-1A/1B/1C	EW	40	C-band SAR	410	Regional level mapping
18	Sentinel-1A/1B/1C	IW	20	C-band SAR	250	District-level mapping

If the satellite coverage is not adequate due to longer revisit periods, complete mapping of a flood event can be missed at times. Therefore, to cover the entire flood affected areas, particularly in India, where the rivers are mostly aligned in the East-West direction, wide swath imaging are essential. One of the solutions is possibly to have a constellation of Low Earth Orbiting satellites (LEOs) covering an area at regular intervals with different resolutions and swath.

ISRO has also implemented a multi-resolution database for disaster management (National Database for Emergency Management; NDEM) in 2017 with user friendly features essentially to serve the stakeholders. ISRO has also developed (in association with IMD), indigenous Doppler Weather Radars which are installed at Cherrapunji, Thiruvananthapuram, Gopalpur (Odisha), Kochi and Sriharikota to improve the weather monitoring, monsoon studies, and rainfall forecasting.

e. Area Coverage: National / State / District

The area coverage is whole of India encompassing all states including the North Eastern states. The capabilities of IRS class of Satellites to provide synoptic, multi-temporal coverage of large areas at regular intervals and with a very quick turnaround time in a comprehensive manner have been very useful in providing the data on flood prone regions.

f. Results Obtained: (compare with item c above)

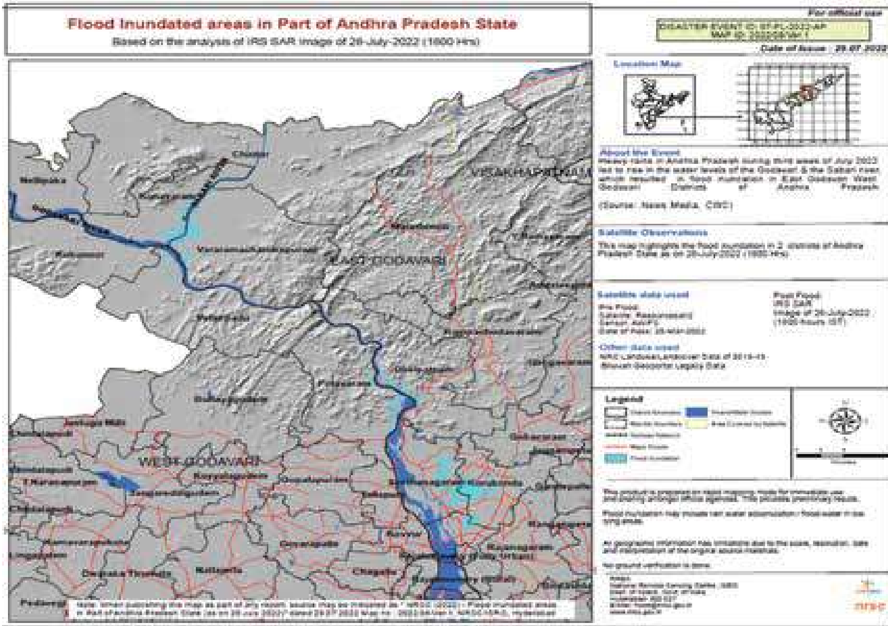

Figure 1: A typical flood map showing the inundation around East & West Godawari Districts in July 2022.

The flood maps and damage statistics are provided to central and concerned state government agencies by digital and as hard-copy inputs. The flood maps provides the spatial extent of flood inundation. This is useful to identify the flood-affected areas and helps in better planning of rescue operations and allocation of resources for relief. Figure 1 shows a typical flood map highlighting the flood inundation in 2 districts (East & West Godawari) of Andhra Pradesh State as on 28-July-2022.

Figure 2 shows the floods in part of Bagmati river basin during June to Oct 2006. This monitoring of floods at regular interval of time was possible through meticulous planning and acquisition of satellite data. All the flood inundation layers acquired during 2006 were integrated and the maximum extent of flooding observed from these datasets was extracted. During 2006 flood season, about 11, 28,902 hectares of area was inundated in

Bihar. Figure 2 shows the maximum flood inundation in Bihar during 2006 in the periods of June to October 2006. Each Fig represents different date in the months of June to Oct 2006.

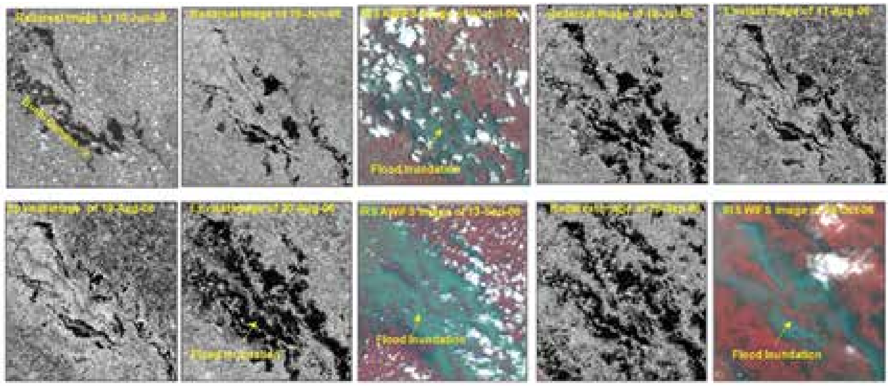

Figure 2: Continuous monitoring on different dates from June to Oct., 2006

Figure-3 shows flood inundation during the major flood in Assam in July 2022, as visible in IRS Resoucesat-2 AWiFS data.

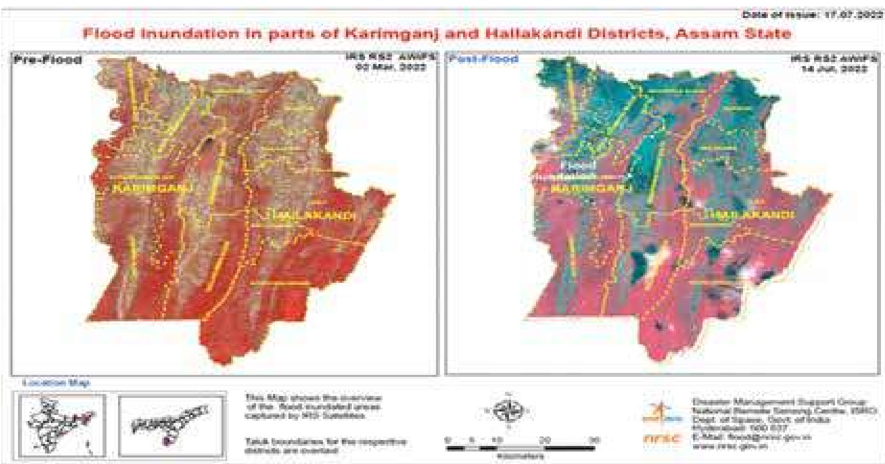

Figure 3. Flood inundation during the major flood in Assam in July 2022

Flood Hazard Atlases

The flood hazard atlases provide a snapshot of the areas which are classified as homogenous zones based on the degree of flooding in space and time, using long term satellite data derived information on flood inundation. These maps are useful as inputs for planning developmental activities in floodplains, construction of relief; rescue and health centres, construction of flood control structures etc. Satellite data provide synoptic observations of flooded areas and are the primary inputs in the preparation of flood hazard atlases that help in disaster risk reduction. The historical flood maps, generated by NRSC/ISRO, are used for preparation and prioritization of flood hazard areas in the country.

Flood Hazard Atlases are prepared for major flood-prone states in the country such as Assam, Odisha, Bihar, West Bengal, Andhra Pradesh and Uttar Pradesh. Aggregated flood maps for Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Arunachal Pradesh and J&K are also prepared using available historic satellite data of 2003 to 2020. These atlases and aggregated flood maps are provided to the concerned states and NDMA.

g. Users' Perspective

NESAC had taken up a study with application of space based numerical rainfall prediction and a physics based distributed hydrological model in GIS platform, after a devastating flood event in Lakhimpur district of upper Assam in June 2008. This was requested by the Government of Assam, after 8 years, the activity has been extended to 33 districts of Assam with 40 major tributaries and around 108 minor tributaries, rivulets etc., under its ambit. This system generates flood alerts in district and revenue circle level with an average actionable lead time of 24 to 48 hours. An average year on year success score of 75% to 80% has been achieved.

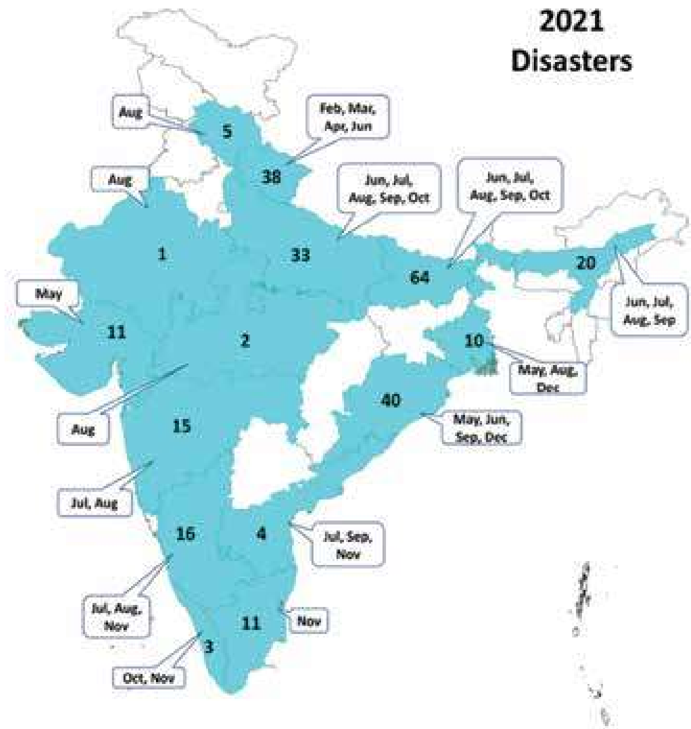

Figure 4 Major Flood and Cyclone addressed by ISRO for various States in 2021

In 2021, about 270 flood maps and value added products have been provided covering major floods/cyclones in 15 States as given in the Figure 4. The data is provided to the state and central disaster management departments (MHA, NDMA, State SDMAs, CWC, etc), relief commissioners, state remote sensing centres and disaster relief forces to augment the rescue & relief operations during the times of crisis.

Geospatial database is essential for flood management since it provides timely inputs meeting the user needs in terms of information content, format and multiple thematic layers integration and analysis. Therefore, it is essential to have a related Geo-spatial data with proper data standards formats and data access mechanism. To achieve flood preparedness, mitigation, relief and rescue, Decision Support Systems (DSS) are very effective tools for decision-making on flood preparedness, mitigation and relief and rescue using available geospatial data sets in centralized data server. DSS is an intelligent information system for flood management and relief. It requires active participation of users end spatial datasets. The correspondence system and report generation are also designed based on the consultation with the user.

Spatial Flood Early Warning Systems Development and its Operational Use

Early warning for floods is generated utilising the inputs from rainfall forecast, flood inundation simulations using the digital elevation models, DEM's, obtained from laser terrain mapping and space borne stereo data and real-time discharge data. An example of spatial flood forecast generated for Godawari river (flood condition at Perur Station) is give in Figure 5 and the associated flood inundation in Figure 6.

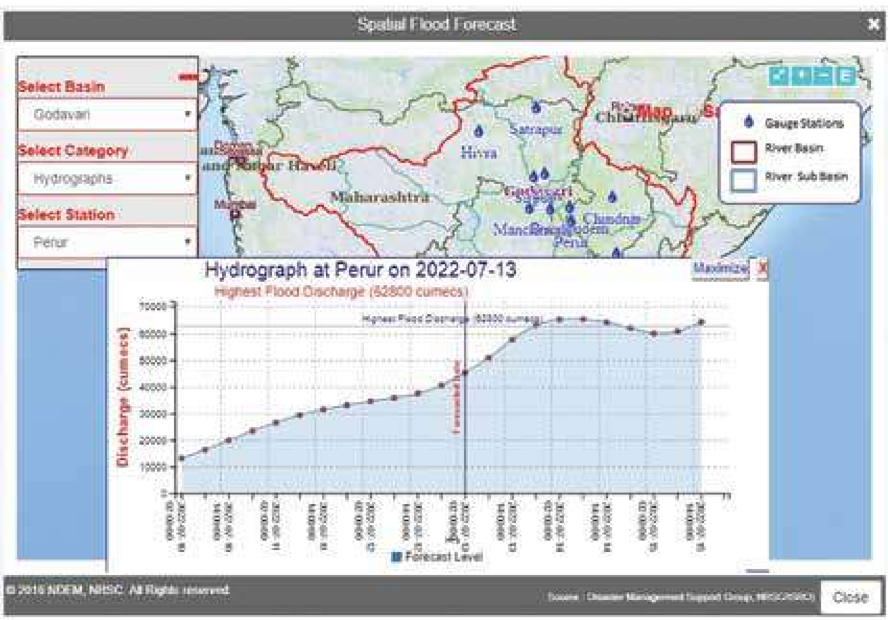

Figure 5. Forecast Flood condition at Perur Station, Godawari catchment

Figure 6. Simulated flood inundation at 08:00 hours on 14 July, for Godawari river

The flood forecast model is developed under National Hydrology project (NHP) in association with CWC and real-time data support from IMD. Daily point observed rainfall data and WRF rainfall data obtained from IMD are used in the real-time runs (error may be +15%,). The model is in the calibration/ validation phase.

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14. CYCLONE TRACKING AND MONITORING

a. Back ground:

Indian subcontinent has a long coastal line of around 7500 km and these coastlines are vulnerable to tropical cyclone and Tsunami. Cyclones occur frequently on both the coasts of India (the west coast Arabian Sea and the east coast Bay of Bengal). More cyclones occur in the Bay of Bengal than in the Arabian Sea and the ratio is approximately 4:1. In Bay of Bengal, average five or six tropical cyclones form in a year and strike the east coast of India anywhere from the coast of Tamilnadu to Bangladesh. Cyclones are also characterized as hurricanes (in Atlantic Ocean) and typhoons (in west Pacific Ocean). All these storms comprise of high winds, heavy rains, severe thunder and lightning. There is a possibility that two or three cyclones out of these could be severe and more hazardous to human life. In India, Tropical cyclones occur in the months of May-June and October- December. These cyclones are bimodal in character, and the primary peak generally occurs in November and secondary peak in May. At the time of landfall the destruction potential is quite high due to heavy wind, storm surges and torrential rainfall. Of these, storm surges are the greatest killers of a cyclone, by which seawater inundates low lying areas of coastal regions and causes heavy floods, erodes beaches and embankments, destroys vegetation and reduces soil fertility. GIS and remote sensing are highly beneficial in terms of tracking and monitoring, before and after cyclone to reduce causalities and damage of life and property. Satellites play a predominant role by providing the essential data to meteorological and oceanographic forecasters. This data used to estimate the cyclone structural parameters like geolocation, intensity etc. and assimilated in the numerical models to improve the forecasts. Satellites are the primary source of observation when the storms are over the ocean as the in-situ observational network over the ocean is sparse. Also during and after the cyclone, remote sensing data generate timely information that are required by the concerned authorities to identify the affected areas, to assess the damages and to undertake the corresponding damage mitigation measures.

b. Objectives:

The main objective of the meteorological satellites is to acquire satellite imageries to provide all the needed vital data for forecasting, tracking and monitoring the weather systems. As the country is vulnerable to cyclones, it is important to understand the impacts of cyclone, inundations in low lying areas and the timely accurate forecasts of tropical cyclone track, intensity, landfall, rainfall and associated storm surges. Using historical satellite data and digital surface models, all the required information is derived to meet the requirements of the preparedness, early warning and timely response. Another important factor is to have a proper management of tropical cyclones, which have great socio-economic concern for the Indian subcontinent, the only region in the world, which is facing two cyclone seasons within a year. Therefore it is important to minimize the losses due to destruction of properties and also saving of lives. A vast coastline of India with high density of population causes severe threat making it one of the worst cyclone-affected regions in the world. The varying coastal bathymetry of the Indian coast, causes the variation of the severity of the storm surge created by the cyclones from place to place and also the intensities of the cyclone. Hence, it becomes mandatory to generate these data for the effective management of cyclones. Geo-stationary and low earth orbit satellites are effectively utilised for providing experimental inputs on cyclogenesis, cyclone track, cyclone intensity. In India INSAT series of satellites with frequent imaging provide the cyclone parameters for near real time analysis. Near real time information on inundation due to cyclones are derived, using optical and microwave SAR data and the data so generated are provided to the concerned departments.

c. Expected Benefits to Society:

Tropical cyclones cause disastrous economic losses. Globally they are among the most destructive natural hazards. From 1980 to 2018 tropical cyclones were responsible for nearly half of all natural disaster losses worldwide, with very heavy damage running into thousands of billions of US $. When a hurricane is well offshore and out of effective radar range, forecasters use satellite imagery to continuously track the storm's movement and development. Satellites can also give information about the wind speeds over the ocean surface.

A cyclone's high winds can erode the soil, thereby damaging existing vegetation and ecosystems. This erosion leaves the area exposed and prone to even more wind erosion. Soil and sand that is blown into other areas can damage the vegetation there. Erosion also can be caused by storm surges from tropical cyclones. The information derived by satellites are factual and timely, and can address emergency situations i.e. dealing with diversion of inundated water, evacuation, rescue, resettlement, water pollution, health hazards and handling the interruption of utilities etc. Some important spatial outputs produced and analyzed in real time are the disaster extent maps, showing the damage to buildings and infrastructure. Moreover, meteorological reports based on real-time remote sensing data show intensity/estimates, movement and expected duration of rainfall for the next few hours. Both medium and high-resolution remote sensing images, together with an operational geographic information system, help to plan many tasks. The medium resolution data help to establish the extent of the damages whereas high-resolution data are suitable for pinpointing locations and the extent of damages. They can also be used as reference maps to rebuild bridges, washed-out roads, homes and other facilities.

Early warning on Tropical Cyclones helped in reducing the areas of evacuation by 300 km and reducing the evacuation cost by 60% during the last 20 years. In 2009, during the Super cyclone in Odisha, nearly 10,000 precious lives were lost. Today, similar category of cyclones results in very few casualties due to the effective evacuation programme by Government, with timely inputs from IMD.

d. Implementation mechanism:

ISRO has been using the space based data from its geo-stationary and low earth orbit satellites for cyclone monitoring. These satellites generate the experimental inputs on cyclogenesis, cyclone track, cyclone intensity. INSAT series of satellites are utilised to provide the cyclone parameters almost in near real time and these data are used for analysis. The meteorological satellites used by ISRO have been Kalpana-1, INSAT-3A,INSAT-3D and 3DR in the geosynchronous orbit. For accurate weather assessment , what is needed are the quick visualisation and analysis of data and products. Data from Megha Tropiques and ScatSat-1 (Scatterometer Satellite-1) are also used for weather forecasting, cyclone prediction, and tracking services to India. Global wind data, is very crucial for cyclone detection and weather forecasting applications. These data are gathered by Scatterometer instrument flown as one of the payloads in weather / ocean satellites. This data is also a very important tool for oceanographic studies. After Oceansat-2 satellite, the SCATSAT-1 was the next mission for Scatterometer payload. The wind vector, particularly its magnitude and direction at the ocean surface is a parameter for weather prediction, detection and tracking of cyclones. SCATSAT-1 was designed to generate this important wind vector products. The Ku-band Scatterometer payload carried by SCATSAT-1 has enhanced features compared to the similar one carried by Oceansat-2 launched in 2009.

SCATSAT-1 is built around ISRO's small satellite 'IMS-2 BUS' and the mass of the spacecraft is 371 kilograms. The spacecraft is positioned in sun synchronous orbit of 720 km. altitude with an inclination of 98.1 deg. This needs two days to cover the entire globe. The life span of the satellite was designed to be 5 years with non-stop 24 X 7 all weather operations. Wind speed is measured in 0-360 deg and wind vector grids of 25km X 25km over oceans are generated for the entire globe. Ku-band Scanning Scatterometer radar instrument on board the satellite operates at 13.515 GHz similar to Oceansat-2. This instrument is used to study wind patterns above the ocean, air-sea interactions, ocean circulation and their overall effects on weather patterns. The wind vectors generated using the satellite data are utilised by the meteorologists to predict the cyclone formation, its movement and estimated landfall accurately. The Ocean wind vectors data are effectively being used to predict all cyclones in India. These predictions over a period have been helping in mitigating and saving the lives of humans and livestock. The satellite imagery is very effectively used to identify and locate the various stages of the cyclone and to estimate the intensity and position.

The life cycle of a cyclone generally has four stages and individual stages may even occur more than once during the life-cycle. The four stages are:

1. Formation or Genesis Stage
2. Intensification or Deepening Stage (In this stage, the Tropical Cyclone central pressure falls and the maximum surface wind speed increases. An eye may develop at the centre of the TC if the stage continues).
3. Mature Stage (During the mature stage the TC attains its maximum intensity. The central pressure and the surface winds achieve their minimum and maximum values respectively).
4. Decay Stage (During decays, the central pressure increases, winds weaken)

Classifications of cyclonic disturbances for the Bay of Bengal and the Arabian Sea region for the exchange of messages among the countries are done as per the details given below:

Weather system	Maximum sustained wind speed
1. Low pressure area :	Wind speed less than 17 kt (31 km/h)
2. Depression:	Wind speed between 17 and 27 kt (31 and 61 km/h)
3. Deep Depression	Wind speed between (28-33 knots),
4. Cyclonic storm:	Wind speed between 34 and 47 kt (62 and 88 km/h)
5. Severe cyclonic storm:	Wind speed between 48 and 63 kt (89 and 118 km/h)
6. Very Severe cyclonic storm:	Wind speed between 64 and 89 kt (119 km/h) or more
7. Extremely severe storm:	Wind speed between 90 and 119 knots
8. Super cyclonic storm:	Wind speed 120 kt and above (222 km/h)

The initial estimates of cyclones formation and the accuracy of prediction are achieved by an efficient network, consisting of land based surface and upper air stations, Doppler Weather Radars (DWRs), satellites, ships and buoys. In addition, the enhanced numerical modelling capability, and understanding of cyclone dynamics have helped to improve the cyclone forecast accuracy substantially. The cyclone forecast has been continuously improving in the last two decades

e. Area Coverage: National / State / District

With the weather satellites in the Indian region the Country has the coverage of entire coastal region east or west and also to detect the cyclone formation in the ocean region of the subcontinent.

f. Results Obtained: (compare with item c above)

On average, 2–3 tropical cyclones make landfall in India each year, with about one being a severe tropical cyclone or greater. Cyclones are associated with strong spiralling winds characterized by a low pressure and numerous thunderstorms. The list of strong tropical cyclones in India are several over the period. To name a few are; Cyclone Thane, Cyclone Mora, Cyclone Megh, Cyclone Jal, Cyclone Roanu, Cyclone Lehar, Cyclone Nargis, Cyclone Mala and Cyclone Giri. Cyclone Tauktae was a very severe cyclonic storm of 2021, impacting the Indian states of Kerala, Karnataka Goa and Gujarat, also the Laksha dweep, Dadra and Nagar Haveli and Daman and Diu with heavy rainfall and flash floods. The movement of cyclone Tauktae 2021 in the west coast off India hitting the Gujarat region is given in Figure 1(Courtesy ;Website). Cyclone Amphan was a very powerful tropical cyclone of 2020 raising over the Bay of Bengal around the state of Odisha and West Bengal in India. The Super Cyclonic Storm Amphan was the first super cyclonic storm and also the first pre monsoon super cyclone of this century.

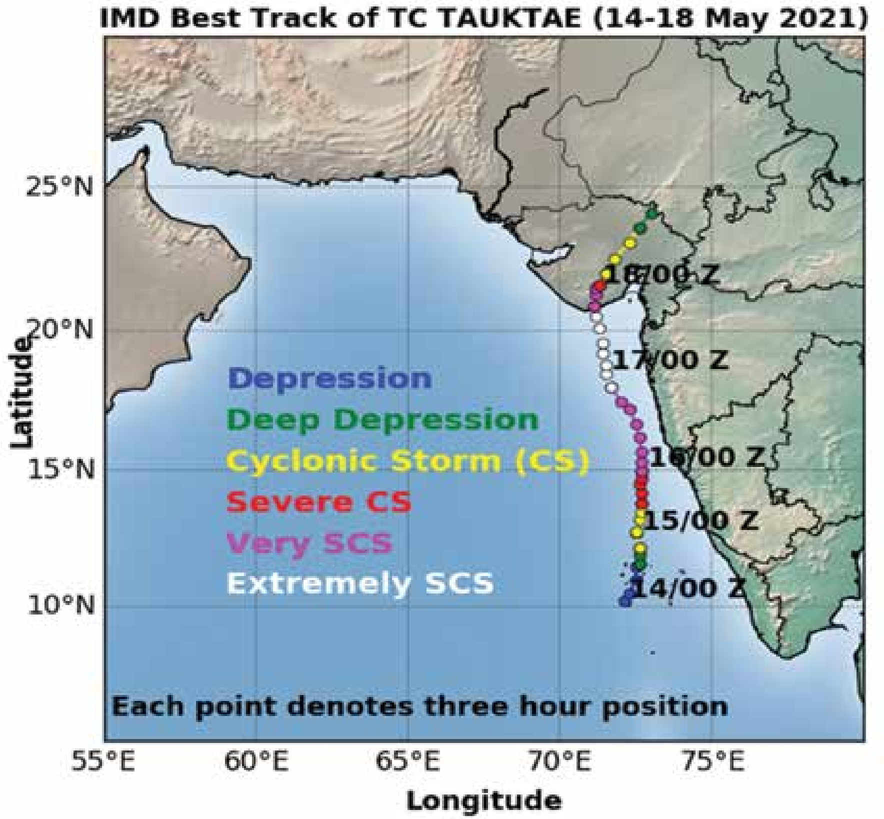

Figure 1 : Three-hourly IMD best track of TC TAUKTAE (14-18 May 2021) with its intensity categories

Kyarr and Maha are the 2 cyclones developed at same time within 10 days in the Arabian Sea, while Cyclone Kyarr moved towards the Gulf of Aden from Indian coast, Cyclone Maha moved towards to west coast of India. Cyclone Fani was an Extremely Severe cyclone and storm in the shape of hood of a snake, threatening Indian states of Odisha and Andhra Pradesh and the first severe cyclonic storm of the 2019 in India. According to IMD, data from satellites Insat-3D, Insat-3DR, Scatsat-1, Oceansat-2 and MeghaTropiques was used to study the intensity, location and cloud cover around Fani. There was a cloud cover around the eye of the storm up to 1000km radius, though the rain clouds were only up to a radius of 100 to 200km. The rest were at a height of around 3300 m (10,000feet).

The significant improvements in all segments of cyclone warning system over a period like observations, modelling and communication, the concerned agencies have efficiently mitigated the disaster due to Cyclones by reducing the loss of life in double digits. The improvement in the operational forecast by IMD in Cyclone landfall location and time, track and intensity during the years 2003-2018 as a five-year moving average has been shown in Figure 2. given below. All forecasts and satellite based cyclone inputs from ISRO are disseminated through web-portal SCORPIO linked to MOSDAC. (www.mosdac.gov.in/SCORPIO).

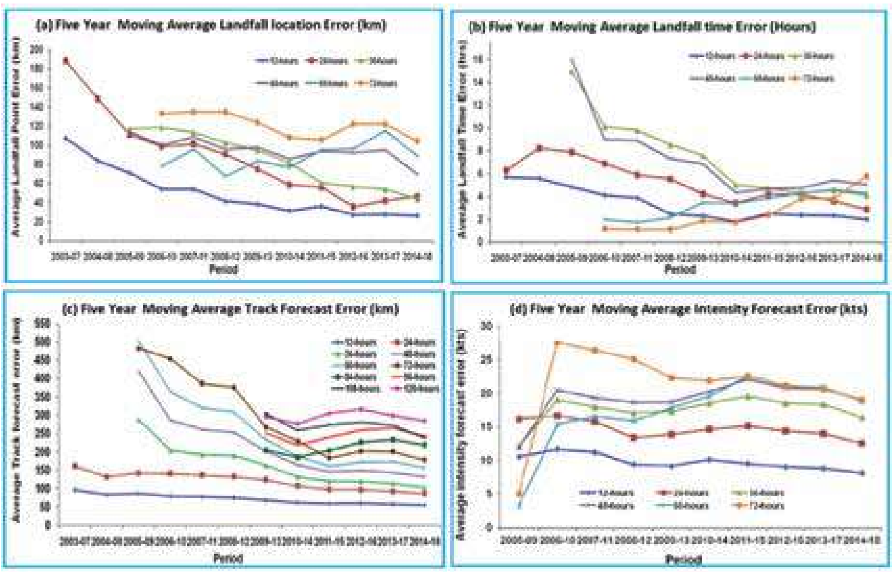

Figure 2: Five Year Moving Average (a) landfall location error (b) landfall time error (hours) (c) Track forecast error (km) and intensity forecast error (knots) **[Source: Mohapatra and Sharma 2019].**

Typical cyclone centric satellite products from SCATSAT-1 from all six channels of INSAT-3D satellites in addition to enhanced images are given in the Figure 3.

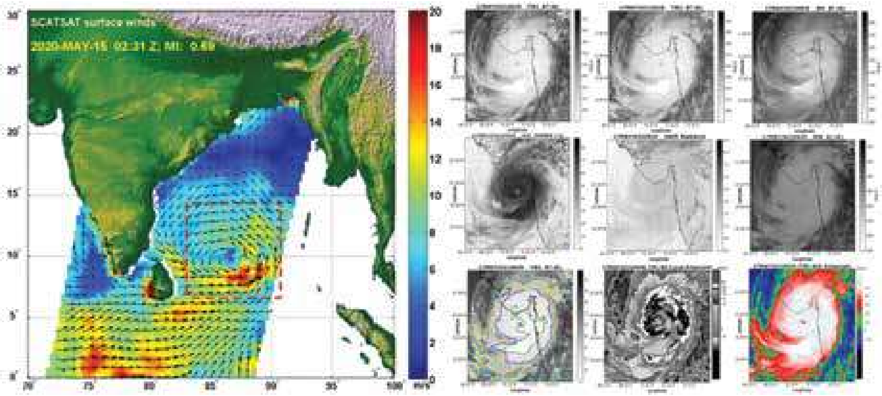

Figure 3 (a) Ocean wind surface observation by SCATSAT-1 during TC Amphan at 0230 UTC 15 May 2020 (a) INSAT-3d generated cyclone centric imager products and enhanced images.

A typical picture of the Bay of Bengal cyclone observed from INSAT visible imagery and Quickscat scattero meter winds is shown in figure 4 below.

f. Users' Perspective

India Meteorological Department (IMD) is the nodal agency to provide operational cyclone forecast to the Country. With the improvement in the technologies and better coordination with all stakeholders the early warnings, tropical cyclone prediction and the after cyclone tasks are effectively being coordinated and implemented all coastal regions in India by active involvement of all agencies.

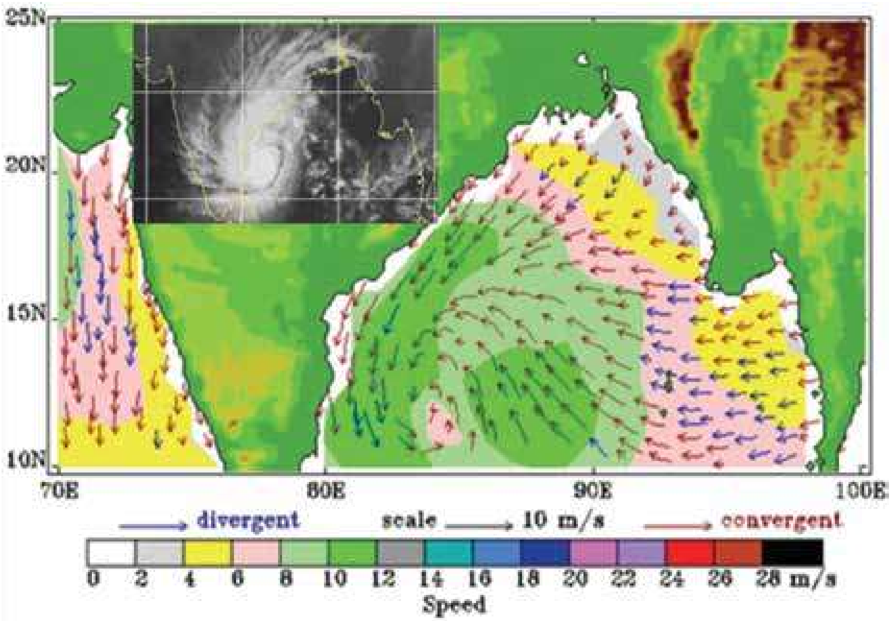

Fig 4. Bay of Bengal Cyclone as observed by INSAT visible imagery and Quickscat scatterometer winds

The multi-satellites multi-sensors observations are assimilated in the numerical models for improving the initial conditions and providing the predictions of cyclone track, intensity, rainfall etc. These forecasts help the decision makers in all concerned states in issuing the early warnings, planning of evacuation and mitigation from disaster like situations. To meet the ever increasing demand, there is a need of more advanced satellites to provide the observations over the vertical structure of tropical cyclone. This vastly helps in having better understanding of the systems and developing more accurate forecast models. As on date there is a well-structured cyclone prediction mechanism utilising all relevant data including the satellite data in the Country and all coastal areas are well equipped in alleviating the disaster impacts, in minimising the property losses and also in saving all precious lives.

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15. FOREST FIRE MONITORING

a. Background :

In India about 55% of forest cover is facing fires each year, (about 1.45 million hectares of forest are affected by fire annually as per the Forest Survey of India) resulting into huge economic losses of around 440 crores rupees per annum. In addition, it causes serious ecological disturbances. On a global scale, the only reliable source of observations of fires is through satellites. Active forest fire monitoring using satellite started in India during 2006 as part of the Disaster Management Support Program of ISRO. The programme envisages providing the timely information on fires to Forest Survey of India (FSI) and state forest department users on a regular basis (by SMS and emails) across India. This vastly helps for efficient forest fire control and management activities.

Forest fires are caused either intentionally or unintentionally. Some of the intentional causes are ;

- Often deliberately burnt by people to get easy access into the forest to pick forest produce
- Wild grass is burnt to search for animals
- Firing by miscreants

The unintentional fires are due to :

- Not extinguishing the campfires by trekkers, laborers etc.
- Spark of fire coming from various sources including the railway engines or careless throwing of fire by forest users
- Un-extinguished cigarette butts, matchsticks etc., by people like , travelers, picnickers or even forest laborers
- Burning of agricultural fields adjacent to forested areas.

- Negligence of staff during controlled burning by the department and accidental spread of fire to forests

In addition, there are natural causes for fires, like, lightening, due to volcanic eruptions etc. However, in India there are no reports of forest fire due to natural cause.

b. Objectives

The main objectives are to detect forest fires and inform the concerned department/s in the shortest possible time to ensure environmental safety and to help in minimizing the damages to the forest wealth. This helps vastly in better conservation of Flora and Fauna. Forest or biomass burning results in large amount of carbon through put into the atmosphere that could be detrimental to the upper atmosphere and also the depletion of the protective ozone layer. Hence early information on the biomass burning helps in effective fire-fighting and restoring safer climate conditions for the future of humankind.

c. Expected Benefit to Society:

Forest fires cause severe stresses on some of the important environmental issues which include land cover, land use, biodiversity, climate change and forest ecosystem. These fires cause much greater impact on human health, particularly, the human respiratory issues and also on the socio-economic system. The economic losses caused by fires are also huge. Therefore, proper monitoring of forest fires using satellite data and alerting the right agencies in near-real time is important to initiate appropriate action, so that it can result in vast benefits to the nature, society, not only in cutting down the vast losses but also in minimizing the ill effects on the environment.

Forest resources are very precious and very important not only for the human kind but also for the entire globe to ensure sustainable living conditions. Forest biomass helps in a big way to ensure that proper water-cycle is maintained and at the same time results in many positive impacts to local and global community. Forest fires and biomass burning is a global concern and is widely studied scientifically with respect to the emissions into the atmosphere, namely, aerosols, particulate matter and greenhouse gases (GHGs). These emissions cause major alterations in the atmospheric physics and chemistry, thereby contributing to climate change

Early warning on forest fires helps in improved fire-fighting strategies and results in better biomass conservation, sustainable forest reserves, sustainable development of flora and fauna, significant contribution to climate conditions, reduced carbon emission to upper atmosphere and hence protect our ozone layer. This also ensures that rare and endangered species are protected, improves the economic value of forests, enables sustainable use of forest produce – particularly with regard to species that have medicinal value and also conservation of Biodiversity of rich forests of the country.

d. Implementation mechanism:

As part of Disaster Management Support Programme (DMSP) of the Indian Space Programme, a Rapid Response and Emergency Services (RRES) for forest fires are being carried out at NRSC for working towards effective disaster management in India. Under RRES, following activities are being carried out towards the fire monitoring

a. Generation and dissemination of near real time day/night active forest fire alerts during predominant fire season (Feb - June every year)

b. Forest fire burnt area assessment using high/moderate resolution optical data, based on user-specific requests

c. Daily reporting of the fire outcomes to MoEFCC & CPCB on number of fire counts, and also on the agriculture stubble burning in 4 north Indian states (Punjab, Haryana, Rajasthan and Uttar Pradesh) during kharif and rabi seasons every year.

d. Burned area assessment of stubble burning for 2 states. Particulrly for Punjab and Haryana.

A simple space imaging-based methodology is operationally being used to address forest fires at national level. The burnt-area pixels are characterized by high temperatures against their non-fire background pixels. The average temperature of vegetation fire is around 700-800 K whose emittance shows a distinct peak around 4 μm wavelength band (MIR). The satellite sensors in the respective wavelength bands offer the most viable choice of active fire detection in terms of (a) coverage and (b) temporality (day & night) within the polar orbiting sector. Contextual fire algorithms are used to detect active fire pixels with elevated brightness temperature values (@ 4μm) against their non-fire background pixels (@10-11μm). An automated data processing chain has also been developed and deployed at the Shadnagar earth station to quickly process the data and get the products ready. That is, data acquisition, processing, product generation and dissemination of the fire related information to the respective State forest department and FSI, MOEFCC happens automatically as part of the automated-processing-chain mechanism. The entire process chain enables the dissemination of the data to the field with in 30 minutes of the data acquisition, which is critical for near-real time action on the ground. In addition, the forest guards at the respective forest departments would also get an SMS alert on fire occurrence and its locations so that they can quickly swing into action. The fire alerts are also disseminated by emails, while Web-based publishing of fire alerts is also done through BHUVAN Geoportal (https:// bhuvan-app1.nrsc.gov.indisaster/ disaster.php?id=fire) which can even be accessed on mobile devices. Updates on active fire locations are published up to eight times daily (nominally at about 1030, 1230, 1330, 1430 hrs in the day and similar times at nights). The fire information is disseminated in the form of simple text or GIS compatible files with necessary attribute information pertaining to locations, like, latitude, longitude, confidence value, brightness temperature and fire radiative power etc.

Also active fire monitoring uses satellite data from the Moderate Resolution Imaging Spectro radiometer (MODIS), which is a satellite-based sensor used for earth and climate measurements and flying on the TERRA and AQUA space crafts and also from the Visible Infrared Imaging Radiometer Suite data from the Suomi National Polar-orbiting Partnership (SNPP-VIIRS). Data from these Satellites are received and processed at NRSC, Shadnagar in near real-time using Science Process Algorithms (SPAs) obtained from the

Direct Readout Portal (https://directreadout.sci.gsfc.nasa.gov) and the fire product is disseminated through Bhuvan geoportal.

Over a period ISRO/DOS has been studying all these relevant aspects of detecting the forest fires and providing quick information on fire affected areas, using space based information, in the shortest possible time to minimize the danger to the climate and environment. The implementation mechanism has also been worked out in such a manner that the information can be directly used for action on the ground in the near real-time.

e. Area Coverage: National / State / District

The service covers the entire country, irrespective of the area of fire. Hence, the data can be queried on BHUVAN geoportal as an online national service. One can drill down to State or District or Block or Village level, including the localized locations using GIS functions.This forest fire services has been operational for over 2 decades. With the improved spatial and spectral data and number of satellite missions, the frequency of data availability has also increased. The automation built into the processing and delivery mechanism, acts as an effective mechanism to provide accurate data on fire occurance without any operator's interventions, because of the automation built at the data acquisition and processing facility of NRSC. The system is fully operational in providing relevant information to not only officers in-charge, but also to the grass-root level forest guards, who have the responsibility of managing forest fires at field level.

f. Results Obtained: (compare with item c above)

This is one of the most successful EO services being provided by NRSC to all the States and the nation for decades. With the availability of Bhuvan geoportal and newer imaging capabilities, both the frequency of online services and near real-time fire services have drastically improved.

During the fire seasons, the FSI and the state forest departments continuously look out for this online services to control the fires in the forest. This is one of the very successful services rendered by NRSC for more than two decades. All the historical fire data are also captured and stored on the Bhuvan Cloud for any reference in the future on the Forest Fire Regime, particularly for modelling exercises.

With regard to stubble burning, ever since 2018, district wise daily active fire detection, their location, count/total (consolidated for all passes) are all provided to Indian states in the Indo-Gangetic plain viz., Punjab, Haryana, Rajasthan and Uttar Pradesh. The Information so provided on active fires have been effectively used for identification of the regional patterns in agricultural burning.

The ground- based burnt area assessment is very laborious and time consuming. It is possible to achieve the near real time damage assessment through satellite based burnt area assessment and it helps to protect the ecologically important forested areas. In 2004 burnt area assessment for Rajiv Gandhi National Park was done using IRS P6 LISS-III data. Figure 1 depicts the corresponding range-wise Forest burnt area.

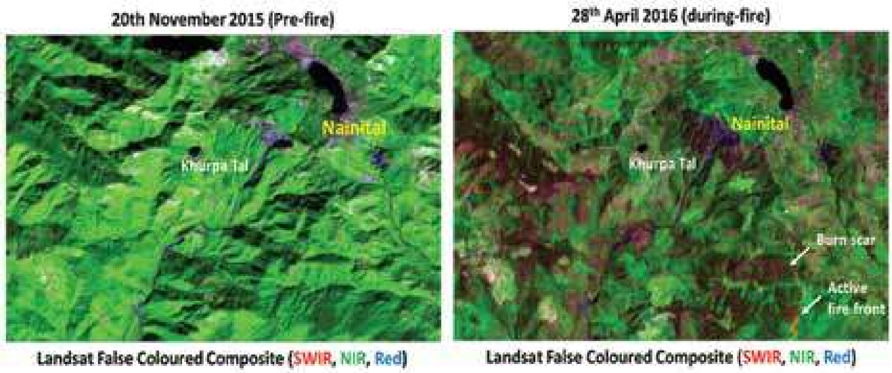

Figure 1. Forestfire burnt area, Uttarakand

f. Users' Perspective

The services are actively utilised by all the States, particularly the south Indian states, Uttarakhand and others during every fire season for decades. Also, the same portal is able to provide the stubble burning data in Punjab, Haryana and other selected north Indian states, which is also used by the agriculture departments of the States and Ministry of agriculture-MOA. Users have always been appreciating the timely response mechanism that is established by ISRO. The fact that the entire mechanism is made fully automatic has further added its success and the system operates 24 x 7 capturing both night fires and day-time fire incidents.

Active fire alerts are regularly disseminated to user community through Bhuvan Geoportal (https://bhuvan-app1.nrsc.gov.in/disaster/disaster.php?id=fire). A typical plot in the geoportal is given in the Figure 2.

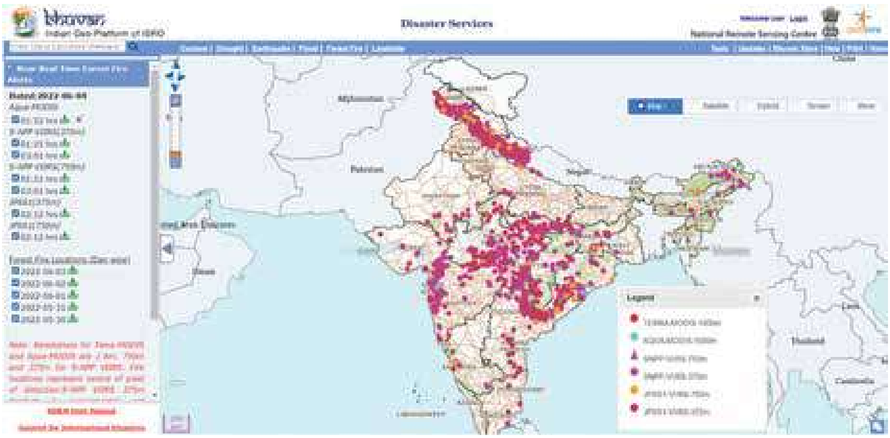

Figure 2: Illustration of active fire alerts dissemination through Bhuvan Geoportal

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16. ISRO'S GEO-PORTAL BHUVAN: GATEWAY TO INDIAN EARTH OBSERVATION

a. Background

Bhuvan is a unique Geospatial Platform (Geo-platform) of ISRO (http://bhuvan.nrsc.gov.in), established in August 2009, to provide a host of applications services to several users to meet their remote sensing application needs. The name "Bhuvan" is derived from Sanskrit where "Bhuvan means The Earth". The services provided by Bhuvan are wide ranging and these services enable visualization of multi-date, multi-platform, multi-sensor satellite data, including thematic map display, query and analysis, free data, products downloads and near real-time disaster management support. In addition to these, Bhuvan also supports multiple language interfaces, like English, Hindi, Tamil and Telugu. The Display services and other Earth observation data usage is provided to users in public domain. This helps in direct access to a wealth of satellite images, natural resources maps and other useful services on the fly.

The Bhuvan related activities started with a simple objective of displaying satellite images with some basic GIS functionalities, including thematic map, etc., as part of display functions. Over a period of time, it has grown in diverse areas of applications and also grown in terms of a number and varieties of services including the providing of services through 2D and 3D image rendering. This has also resulted in a significant increase in its popularity and hence the user base, services and outreach. More than 20 Lakh unique visitors login to Bhuvan every month with average of about 20 Million hits per day. The platform has slowly emerged into a versatile geo-platform with rich data and unique services. The platform presently supports more than 43 state/central ministries, departments in their applications requirements through more than 195 online applications,catering to various sectors and governance functions. The mobile apps platform on Bhuvan has been providing certain vital services with more than 75 Mobile Applications to help various Ministries to fulfill the need for Field data collection and analysis.

Bhuvan with its rich image/map display and data services has diversified many of the major areas of applications and services and also catering to disaster support, crowdsourcing and applications-mashup and so on. All this has happened based on the user requirements, active collaborations with State, Central Government agencies and private players. Bhuvan is the defacto National Geo-Platform for our country with free access to data and services over India, and being used by wide varieties of user community including school children.

b. Objectives:

The objective of developing Bhuvan Geoportal was simply to provide service-oriented architecture for enabling various applications of remote sensing technology in the country. IRS series of satellites with diverse spectral, spatial and temporal resolutions has been providing high quality of images that can be used for national development in many ways. Bhuvan was built to show-case such possibilities by providing all possible IRS satellite images on the fly, derived thematic maps, various possibilities of application services including tools for governance. Bhuvan, today, serves a wide gamut of applications towards policy perspectives, natural resources management, disaster support, environmental aspects, diverse possibilities on land, water, air and ocean and touches humans across various sections of the society. Bhuvan is a powerful web-geoportal that has very good online facilities for any one to produce interactive maps and images with the resources available online. It provides images/maps of IRS satellite that can be rendered on a 2D platform or 3D virtual globe, thus enabling a unique interactive capability. It displays satellite images of varying resolution of India's surface, allowing users to visualize any area-of-interest at a very high spatial resolution, such as, cities, villages, specific place with required information in the form of attributes. One of the important objectives is to use this capability to do effective monitoring, impact assessment, change detection, near real-time assessments, support Govt in decision making, track disasters and enable suitable measures for planning for relief and towards disaster mitigation.

In Visualization, Bhuvan supports high quality 2D and 3D image rendering, with rich quality of IRS satellite images upto 1m for the entire country along with administrative, infrastructure data. In addition, Bhuvan also supports vector layers upto village level with well integrated census information, road network up to street level etc., that enables better visual analysis of any spatial data. Bhuvan 3D also has all the information along with the height information with a rendering capabilities that enables virtual reality kind of visualization with 3 dimensional perspectives. All the applications and services catered through Bhuvan are developed using our own tools, developed using Free Open Source Solutions (FOSS). All these services fully comply with Open Geospatial Consortium (OGC) Compliance Services, because of which Bhuvan has got a unique global recognition by the OGC consortium itself.

c Expected Benefit to Society:

The biggest benefit of hosting Bhuvan web geo-portal is the availability of a national level databases on natural resources, one of the largest data geospatial repositories, at one place with necessary security features to provide services under all circumstances. Bhuvan has been providing an able support for the management of disasters, such as, Cyclone, Floods, Landslides, Earthquakes, Forest Fire and Drought by providing near real-time data updates and software tools for users. This has become very useful for the disaster managers to be agile and use data from bhuvan under various phases of disaster management, particularly preparedness and post-disaster response. Some of the unique examples where the nation has fully utilized the data, software and services are, Uttarakhand disaster in 2013, J&K floods and Hudhud Cyclone in 2014 and Nepal Earthquake in 2015. Landslide forewarning system is yet another important forewarning solution provided by Bhuvan for the Char-Dham yatrees. For the past few years the rain induced landslide warnings for major pilgrimage routes in Uttarakhand hills are being provided for the benefit of pilgrims. Regular updates on the potential landslides alert are issued based on rainfall and other parameters that helps as an early warning system in these hilly regions.

Bhuvan web geoportal contains a number of thematic data layers that help in various natural resources applications. It supports simple visualization of image data & their legend display with attribute querying capability of the selected layer. Some of the important thematic layers are, land use / land cover (annual mapping for past 15 years using AWiFS data; every 5 years using LISS3 data and One-time mapping from LISS4 data), multi-temporal wasteland and land degradation monitoring, geomorphology, geological structure/ lineaments, erosion, salt affected and waterlogged area, urban sprawl, water bodies monitoring, glacial lakes and waterbodies(Indian Himalayan region), near real-time disasters – floods, cyclone, forest fires, flood hazard etc., thus providing all such data through online means to benefit users in the country. The site not only provides above mentioned layers to the users on-the-fly, but also provides geospatial tools to carry out online analysis on the Bhuvan platform to derive end result, without having to depend on another system for further analysis. The platform allows multiple GIS layers for analysis, overlay functions, allows use of APIs for specific operations like buffering and proximity analysis and also helps in producing end-products for use.

Today, Bhuvan is one of the successful Indian Geo-Platform because of its adaptability to any given situation and in providing the quick solutions. The base layers and Images are all well organized as geospatial base for catering to various sectors and governance functions, building rapid applications or solutions, as per the requirement of the users. Some of the important geospatial facilities extended by this versatile platform are 1. All Base and Foundation Layers; 2. High Resolution Satellite Imageries upto 1m resolution; 3. Multi-date/ Multi-resolution Satellite Images; 4. Hydrological Layers; 5. Digital Surface Model (30m placing); 6. Physiographical Base; 7. Transportation network Layer; 8. Point of Interest Locations (POI) - More than 10 million points and many more facilities

d. Implementation mechanism:

Open source WebGIS tools are adopted for the design and development of Bhuvan geoportal by deploying multiple instances of applications on 100s of servers at NRSC facility. The tool basically uses open sources RDBMS, Map Server/ GeoServer for vector and raster data layers. State of the art coding scheme is used in designing the front-end and back-end tools and utilities, including the user-friendly interfaces for various operations on Bhuvan. Earth resources data are generated by utilizing a number of satellites built and launched by ISRO and even other satellite data, as required. Satellite data of different resolutions have been organized on Bhuvan over a period of time (more than 60 TB data) in multi-resolution, multi-temporal and multi-sensor to help the users in various modes of visualization and analysis through online interactions, including all the thematic data derived from such images. All the data is easily available for access and use through a simple user interface. The content is systematically organized using simple naming conventions, such as, 'Land Services, Weather Services, Ocean Services, Disaster Services and Collaborative Services' and made available with standard cartographic representation.

The various data sets used from different satellites are listed in the Table-1

Table 1. Satellite used in Bhuvan Portal
(Ref: Bhuvan Flier: Version 1.25, NRSC, ISRO)

Satellite/Sensor	Resolution	Availability	Coverage & Remarks
Oceansat-1 : OCM Oceansat-2 : OCM	360 m 360 m	1999, 2004, 2006 2009	India Oceansat2 data sets are available
IRS P6 – Resourcesat-1/2 : AWiFS	56 m	2008, 2009, 2010, 2011, 2012, 2013, 2016,2019, 2020,2021, 2022	India
IRS P6 – Resourcesat-1/2 : LISS III	23.5 m	2006, 2008, 2011, 2012, 2013, 2016, 2018, 2019, 2020, 2021,2022	India
IRS P6-Resourcesat-1/2:LISS IV MX	5.8 m	2006-08,2017	India
IRS 1C/1D – LISS III + PAN Merged	5.8 m	2005-06	India
Cartosat-1	2.5 m	2009-10, 2011, 2016	India, 17 Foreign Cities**
Cartosat-2	1 m	2009, 2013-14	440 Indian Cities, 17 Foreign Cities #
HRS Data	1 m	2012-2016, 2017, 2018	India

A series of geophysical products and more than 60 data products pertaining to atmosphere, cryosphere, ocean studies and terrestrial sciences are generated under National Information System for Climate and Environment Studies (NICES), a special program initiated by ISRO/DOS, on climate studies. The products generated are made available for dissemination through Bhuvan platform with no costs, to encourage researchers to utilize such projects for climate models. Bhuvan Thematic Services has been making available different theme specific data as OGC Compliant WMS/ WMTS service for use by researchers and others. Data on more than 10 themes in different scales and year of mapping, are being served through this geo-portal. These thematic datasets can be consumed as WMS/WMTS services in any of the commercial or open source software like ArcGIS or Quantum GIS and also in Mapping libraries like Leaflet, Open Layers etc.

The various services that are being offered on Bhuvan, their description and the kind of data that are made available are detailed in Table-2.

Table-2 : Services on Bhuvan
(Ref : Bhuvan Flier: Version 1.25, NRSC, ISRO)

Name	Description	Data Availability
Bhuvan 2D / 3D	Allows visualization with pan, zoom, place name search, overlays and online editing	Resourcesat-1/2: AWiFS, LISS III & LISS IV, Cartosat-1 & 2: PAN (merged with LISS IV), Oceansat - 1 & 2: OCM
NRSC Open EO Data Archive	Allows download of free satellite data and products of specified period and resolution	Resourcesat-1/2 : AWiFS Ortho & LISS III Ortho, IMS-1 : HySI, CartoDEM (V1.0, V1.1R1, V2.0R1, V3), Oceansat-2 : OCM2 : NDVI (LAC, GAC), Filtered NDVI, VF, Albedo, Surface Water Layer, Water Bodies Fraction, Snow Cover Fraction, Snow Albedo, NICES's Products (TCHP, OHC, D26 MM5, WRF & Wind, SSM, SMF, DTO, OMT, Chlorophyll OC2, OC4, KD490, Currents, SLP, Planetary Boundary Layer Height, Cloud Fraction, Cropland, Land Degradation, Soil, Forest - Regime, Fraction, Type)

Thematic Services	To display or analyze using WMS / WMTS (OGC web Services)	Thematic Maps of 1:10000, 1:50000, 1:250000 - Land Use Land Cover (LULC), Wasteland, Land Degradation, Geomorphology, Lineament, Urban Land Use, Urban Sprawl, Erosion, Water Bodies, Salt Affected & Water-Logged Area, Flood Hazard, Flood Annual Layers, Glacial Lakes and Water bodies (Indian Himalayan region)
Disaster Services	To provide timely information on various disasters for better decision making	Cyclone, Drought, Earthquake, Flood, Forest Fire, Landslide, Experimental Landslide Early Warning System, Landslide Hazard Zones, Active Agricultural Fire, Forest Fire Alerts, Flood Hazard Zonation (1998-2019) : Assam, Bihar, Odisha, Uttar Pradesh.
Projects	To provide platform to create, visualize, share, analyze Geospatial data products and services towards Spatial Mashups	MANU (crowd sourcing based), Municipal GIS, Tourism GIS, Forestry, Irrigation, Agriculture, Urban, Rural, E-governance etc.

e. Area Coverage: National / State / District

The area coverage is whole of India. Within the Country, Bhuvan has the options of getting state and district wise statistics and also area of Interest (AOI) based analysis

f. Results Obtained: (compare with item c above)

Bhuvan has generated a variety of results over a period utilizing its contents which are rich and unique to meet the users requirements. Bhuvan has been enriched over a period with more than 40 ministry portals and 30 state portals and is also providing active support for flagship programmes of the government including Integrated Watershed Development Program (through development of tools like Srishti and Drishti), National Mission for Clean Ganga, AMRUT, MGNREGA, PMAY etc. Bhuvan has initiated many major applications with several ministries and these are at different stages of implementation.

The projects initiated with the ministries have been translated into web applications and are now available on Bhuvan. There are many important thematic layers that are available on Bhuvan at different scales, which is a unique contribution at national level, such as, Land use /land cover at 1:250,000 and 1:50,000, urban land use 1:10,000, multi-temporal wastelands 1:50,000, water bodies 1:50,000, geomorphology 1:,50,000, lineament 1:50,000, flood hazard layer (variable scales), erosion 1:50,000, urban sprawl 1:50,000, etc. Point of interest (POI) datasets contain more than 100 lakh points. The POIs are diversified set of data elements, ranging from different names of places, localities, tourism and information derived from various projects on different themes. These layers are of great importance in different regions of our country, that helps in providing required assistance for use by a number of projects/ programs for specific applications. Following are some of the results from Bhuvan, which are effectively utilized by the policy makers are indicated here.

Some of the geospatial data products and services are highlighted that brings out some unique possibilities from space data. Here are a few applications developed in the field of urban development, 1. An example of Municipal GIS (Ludhiana), 2. National Urban Information System (NUIS) developed for Ministry of Urban Development (MoUD), 3. Urban Growth Monitoring Characterization and 4. Monitoring of the urban growth patterns usingmulti-temporalandmulti-spectral satellite data. Maps are generated for 150+cities including Bangalore, Cochin, Mysore.

Some typical web based urban map examples are shown below:

For example, the municipal GIS in Bhuvan projects facilitates citizens to know about the wards and facilities available, various schemes executed by the government, grievances redressal system etc.

Considerable work has been done for Tourism. Web GIS through Bhuvan facilitates the users to select the city/tourism places of their interest and find the places of interest and search nearby places along with routing.

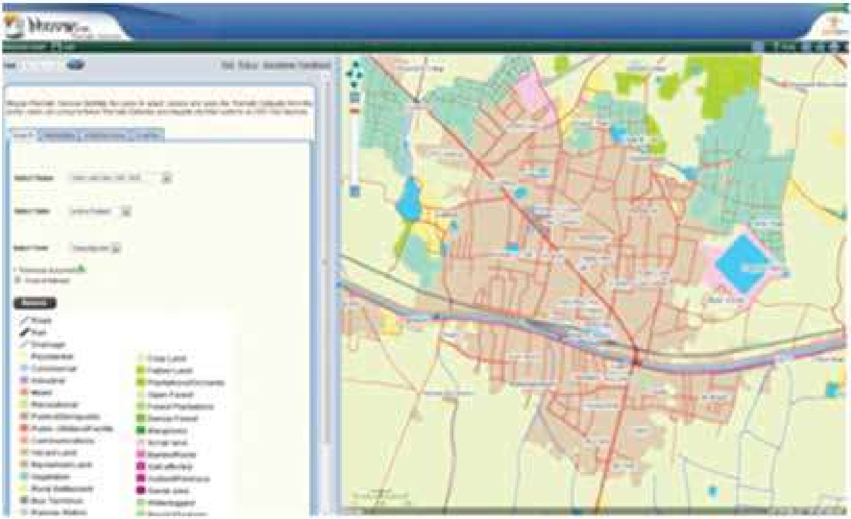

Figure 1. Urban – NUIS (A screenshot from Bhuvan Flyer Version 1.25, NRSC)

A typical tourism WebGIS on Amritsar with utilities like facility search, get directions, proximity analysis etc is shown in Figure 2. Similar tourism WebGI Shave been generated for Badami, Hampi, Nalanda, Vijaywada etc.

Figure 2. Tourism-Amritsar (Bhuvan Flyer version 1.25, NRSC)

Several other application products include areas related to Irrigation, satellite based monitoring of Irrigation projects for inventory, monitoring AIBP projects, forestry for Karnataka and Himachal Pradesh, E-Governance, to visualise the status of SISDP thematic data generation 1:10000 scale and its spatial depiction and crowd sourcing. Other application products are webbased portal togeo-tag field level information, points, lines and area information and events and exclusive pages to provide timely information onvarious events, such as, Uttarakhand Floods, KumbhMela, Sports in India etc,.

The Bhuvan facilitates the administrators and planners to have a one stop online planning tools towards better governance. The applications sectors in Bhuvan web geoportal are quite diverse, catering to various sector with specific use-cases, such as, agriculture, water, forestry, tourism, urban, rural, e-governance and so on. Similarly, the tourism Under planning and development and property tax mapping are some of the other applications. Telangana has utilized the web geoportal for property tax mapping of Telangana, and more than 12Lakhs properties have been benefitted by geotagging across 72 Urban Local Bodies (ULBs), where the data related to not-assessed properties was not available earlier. The tool has helped Govt. of Telangana in improving the proper tax assessments.

Under National Hydrology Project (NHP), Bhuvan is engaged in generation of important geospatial products & services pertaining to water resources, generation of high resolution digital elevation models, development of flood early warning systems, decision support system for irrigation water management, modelling & dissemination of hydrological products to support water resources management and capacity building to NHP stakeholders. For Integrated Watershed Management Project (IWMP) of Rural development ministry, specific online applications for monitoring and evaluation with tools, Android apps for field data collection etc. have been developed and deployed. Online monitoring of major Irrigation projects is facilitated with specific customized application, using the latest high resolution satellite imageries and tools provisioned for Central Water Commission (CWC). In order to disseminate the above geospatial products and to provide related services, NRSC has developed a web geoportal on Bhuvan Geo-platform, called Bhuvan-NHP. This portal hosts various geospatial hydrology related products and has functionalities for image/map display, query and download of the products. The various sub-modules deal with spatial flood early warning, flood forecast, glacial lakes information system - Himalayan region of Indian river basins etc. Bhuvan-Bhujal portal is another powerful tool which provides nationwide scientific database on prospective ground water source information from the state-of-the-art ground water prospects maps. They are being generated for the past one and half decades.

g. Users' Perspective

Bhuvan platform is used by a number of users within and outside the country and also all sectors within the nation. The Government agencies use this platform, share and host their data as per their requirements, enabling specific applications, based on their needs. The crowd sourcing services are utilized for field data collection of various government programmes. Some of the States like Punjab, Karnataka, Himachal Pradesh, Andhra Pradesh and North Eastern states are actively using Bhuvan platform for Forestry, Tourism, Municipal GIS, Geo-tagging and so on. Bhuvan is used as a common platform for the State's applications while at the same time treating them as national assets. Bhuvan presently hosts a number of state geo-portals, and expected to grow in capabilities. In addition, public sector, private users and NGOs host their data and utilise the services of Bhuvan for a variety of purposes too. For example, ENVIS program of Ministry of Environment, Forests & Climate Change (MOEFCC), started using services of Bhuvan actively sometime back. Similarly, "Bhuvan Panchayats"- a Web geoportal dedicated to Panchayat level planning of developmental activities, is facilitating decentralized planning related activities at grass root level using Bhuvan. The information in spatial and non-spatial format assists the development activities of the local bodies in rural and urban areas, Bhuvan Panchayats also provide vital information on various themes with high-resolution satellite images in the background. Household amenities data and Census Population data at district and village level respectively are provided by the portal.

Various Government agencies and Ministries have been using the applications of Bhuvan geoportal to cater to the requirements of projects on national development. Some of them are : a) Asset mapping and inventory creations; Bhuvan-MGNREGA portal has been very popular for geotagging of all assest being created under Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). This aims at livelihood security of people in rural areas and Bhuvan platform has been supporting this important Application for the last 6 years in creation of Inventory and enabling monitoring of the program. Through this Application, more than 7 Crore Assets are already created, b) Monitoring & evaluation: The applications for monitoring and evaluation in the rural, Irrigation, forestry sectors etc. by building the customized tools and utilities specific to project. At national level, more than 86,000 watersheds are being monitoring using EO based impacts and Geo-tagging tools and c) Decision making: Bhuvan-Jaivoorja, is a good example for decision support system. This is a spatial information system on biomass potential from crop residues over India using geospatial techniques. A spatial decision support tool built here has enabled the policymakers & industry developers to assess the availability of biomass resources from user defined tool for carrying out fetch area and facilitate planning/establishment of tailored made biofuel plants. Bhuvan successfully provided support for planning and monitoring of polling in the undivided Andhra Pradesh during General Elections 2014 through geospatial technology based solutions.

Apart from the Planning, Monitoring, decision making applications,several Government Organizations and Ministries have been using specific applications built on Bhuvan. Bhuvan-Jal-Shakthi Application has been supporting the Jal Shakti mission to improve ground water regime across the country. More forestry related applications have been developed recently for the States like Tripura, Telangana and Punjab. It is a joint effort of Forestry Departments and ISRO towards developing a geospatial query system. School Bhuvan, is an e-learning portal for the school students which was done as per the requirements of NCERT, New Delhi. This portal has been enabling the school students to learn GIS technology on the fly and prepare interactive maps, hence enabling a map based learning to bring awareness about country's natural resources, environment and their role in sustainable development.

Bhuvan has become a clearinghouse for satellite data and value added products. They are effectively used for scientific studies and help students, researchers and organizations to take up the scientific projects for applied research. Lakhs of products have been downloaded by users in the last three years. Important inclusion is the generation of scientific products for studying land, ocean and atmosphere as part of National Information System for Climate and Environmental Studies (NICES) program.

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Communications Area

17. SPACE BASED TELE-EDUCATION PROJECT

a. Background

The satellite communication technologies have been playing a major role in enhancing the education and development communication in a vast Country like India particularly catering the services to the remote and far off places including the Indian villages. The educational institutions of the country have also been continuously upgrading their facilities with the latest technologies and have realised that to accelerate the education scenario in India, the satellite-based technology is one of the powerful alternatives, since it increases access and decreases the need for face-to-face contact with teachers. Recognising this fact, ISRO initiated several projects/ programmes over a period of more than 3 decades to cater to the country's need for education, training and mass awareness. These efforts are discussed below.

India has been utilising the space programme since its inception for societal development and has carried out several experiments on space based education, over a period to understand concepts and to gain the needed experience in the Country. Some of the important experiments carried out in India so far are Satellite Instructional Television Experiment (SITE), Kheda Communications Project (KCP), Jhabua Development Communications Project (JDCP) and Training and Development Communication Channel (TDCC).

The SITE project carried out in 1975-76 provided instructions in the areas of family planning, agriculture, national integration, school education and teacher training. Kheda Communications Project (KCP), conceived with the idea of "limited rebroadcast" by setting up a low power TV transmitter in Pij village (about 60 KM south Ahmedabad) and linking it to a studio and earth stations complex at Ahmedabad. The intention was to relay local programmes (originated from the studio) or the central satellite programmes received at earth station. With the support of state government and a local cooperative organisation, (around 550 community sets to about 400 villages) of Kheda district, with the transmission of 90 minutes of local programmes. Training and Development Educational Channel (TDCC) experiment during 90's introduced the interaction provision by having two way audio teleconferencing interactive network for education and training. Initially, a number of (around 24 experiments) were carried out under TDCC during 1992 – 95 in collaboration with different agencies like IGNOU, UGC, SBI, etc. and this network became a popular feature during 1995 using INSAT spacecraft. Jhabua Development Communications Project (JDCP) was similar to SITE and KCP but added one more component of Interactive Training Programme (ITP). The objective was to gain experience in the setting up and operations of a development-oriented satellite based broadcast and interactive network to support development and education. Development oriented programmes were broadcast for two hours in evenings. The interactive training programmes were also telecast to village functionaries like teachers, anganwadi workers and panchayat members.

Subsequent to these programmes, India decided to build and launch first thematic satellite dedicated exclusively for educational services - the 'EDUSAT' (GSAT-3), launched by GSLV-F01 in September 2004 with the main aim of spreading the education all across the Country including far-off places. In addition to providing connectivity to schools, colleges and higher levels of education,Edusat made provision to support non-formal education.

b. Objectives:

the EDUSAT program was planned with manifold objectives supplementing the curriculum-based teaching, imparting effective teachers training and providing access to large number of students with quality teachers. The main aim was to take the education to every nook & corner of India. EDUSAT a dedicated satellite for education provided connectivity to schools, colleges and higher levels of education and also supported non-formal education. These efforts helped to improve the quality of education in some of the remote areas where they lacked skilled teachers.

c.Expected Benefits to Society:

Major benefits derived from satellite based education was to reach out of education all over the country including the remote areas as planned. As per the details available on ISRO website and as on December 2012, a total of 83 networks were implemented connecting as many as around 56000 schools and colleges (4900 SIT's and 51100 ROT's) covering 26 states and 3 union territories of the Country. Approximately 15 million students got benefitted every year from this effort. In addition, the satellite network was extensively used by various agencies for training programmes directly with the target groups as against the then existing approach of training master trainers, key resource persons and then reaching out to the target groups. Further the satellite connectivity was effectively used for holding the virtual conferences, exchange of data and other services.

d. Implementation mechanism:

Edusat was conceived with multiple beam transponders covering different parts of India. To meet this requirement Edusat was built with multiple beams transponders covering different parts of India (Details are given in para e of this document). The tele education coverage is as shown in Figure 1.The satellite was specially configured to relay through audio-visual medium, employing multi-media multi-centric system, to create interactive classrooms.

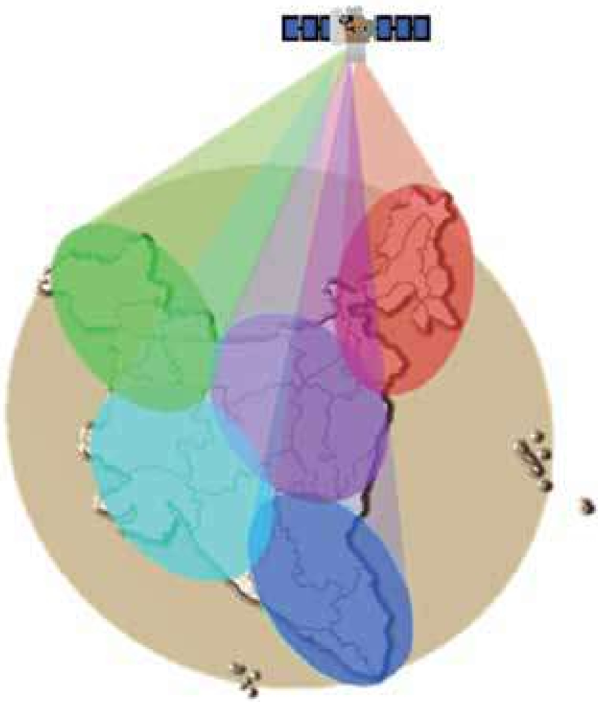

Figure 1. Tele-education coverage in India

Delivery mechanism underwent major changes since SITE days. From big chicken mesh antenna to small VSAT dish, deployment of DVB/DVB-RCS/DVB-S2 technologies and IP-based delivery in particular made new age content delivery possible making e-learning more effective. Edusat provided a wide range of inter-active educational delivery modes like one-way TV broadcast, video conferencing, computer conferencing, text chats, etc.

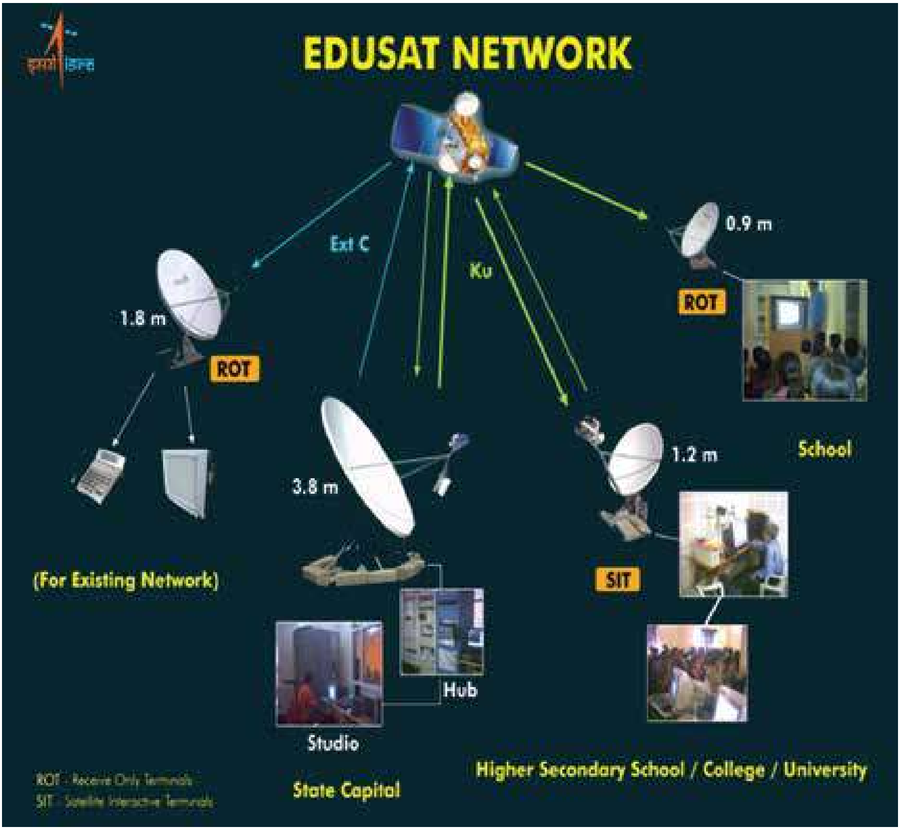

Figure 2: Tele-education Network Configuration

Fig 2 gives the configuration of the tele-education network. The Network was IP-based, thus not needing expensive studio facility. The equipment used at the teaching end or hub consisted of camera, PCs and DVD player (if needed) in addition to the indoor and outdoor units of the hub hardware. The educational content was accessed through two types of ground stations namely the ROTs (Receive Only Terminals) for one-way communication and SITs (Satellite Interactive Terminals) for two-way communication depending on the requirement of interaction, both in national as well as in regional networks. The equipment needed at the interactive classroom end, consisted of Camera, PC, LCD Projector, Speakers, Microphone, UPS (due to intermittent power supply conditions) in addition to the satellite terminal. The Receiver Only Terminals typically consisted of a set-top box, TV, UPS in addition to the satellite terminal.

In EDUSAT, various successive advancements in technologies of Content, Delivery mechanism, Collaborative interaction, Virtual classrooms incorporating ICT tools were introduced. The content matured from plain black & white video to new age multimedia and graphics enriched informative, searchable (through Metadata) and effective videos. Other than video, content got newer components like digital files, emails, messages, etc.

Collaborative interaction and virtual classrooms were introduced using Learning Management System (LMS) in EDUSAT projects by virtue of IP based technology. LMS enabled the live lectures/power point presentations with student interaction, web-based learning, interactive training, virtual laboratory, video conferencing, data/video broadcast, database access for reference material/library/recorded lectures etc., on-line examination and admissions, distribution of administrative information, etc. The collaboration amongst students and teachers in distance mode made lectures more interesting and content more meaningful. The virtual classrooms concept effectively utilized distant coverage of satellite medium for imparting education to remote institutes/schools.

The ground hardware requirements included a HUB, Receive Only Terminals (ROT), Satellite Interactive Terminal (SIT). A hub in most of the state capitals was introduced to act as a main station and the network for the whole state was controlled from here. The Receive Only Terminals had the capacity of receiving TV broadcast. Secondary and higher secondary schools and colleges were provided with SITs for interaction. An SIT return channel for video and data communication through direct connectivity over the satellite. Further, wide ranges of technological possibilities were enabled to enhance the quality of education. The technologies provided were TV broadcast, computer connectivity & data broadcasting, talkback channel and video conferencing.

The EDUSAT (GSAT-3) satellite provided its services till September-2010, supporting Tele-education, Telemedicine and Village Resource Centres

(VRC) projects of ISRO. After its de-commissioning, the traffic of Tele-education networks was migrated to other ISRO satellites. Most of the tele-education networks operating in Ku-band were migrated from GSAT-3 to INSAT-4CR and later to GSAT-18and those in Ext. C-band networks were migrated to INSAT-3A, INSAT-3C and GSAT-12.

e. Area Coverage : National / State / District

The satellite coverage is all over India, encompassing all states and Union territories. The multiple beam transponders were - five Ku-band regional spot beams covering northern, north-eastern, eastern, southern and western regions of the country, a single Ku-band national beam transponder with its footprint covering the Indian main-land region and six extended C-band transponders with their footprints covering the entire country

f. Results Obtained: (compare with item c above)

Edusat, as a part of Pilot Phase, networks for education were implemented at three universities: Visvesvaraya Technological University (VTU), Belgaum, Karnataka, Yashvant Rao Chavan Open University (YCMOU), Nashik, Maharashtra, and Rajiv Gandhi Technical University (RGTU), Bhopal, M.P. using INSAT. Each university used its own teaching end and 50 interactive terminals (two way communication) and 50 receive only terminals (one way communication). These universities used this network to impart curriculum based teaching to their students using one way video and two way audio allowing them to interact with the teacher via satellite from the classroom with the help of live lectures, power point presentations, text chats, return audio-video interactions, etc. During the semi operational phase, ISROmanaged the network in collaboration with the users. More than 100 user agencies utilised the network covering full spectrum of education including: primary education, secondary and high school education, degree college education, professional/technical education, distance education, training, agriculture education, as well as healthcare related learning, training and general awareness programmes.EDUSAT, networks were used by IGNOU, CEC/UGC, CIET/ NCERT, AICTE, Blind People’s Association (BPA), Karnataka school network, VTU, YCMOU, Goa University, Amrita VRC, Kerala/ Tamil Nadu. BPA network had aunique nature of application. The teaching end was located at the main office of BPA at Ahmedabad and the classrooms were spread over the blind people schools state of Gujarat.

Over a period, under the EDUSAT utilisation project, ISRO had deployed 83Edusat networks in 26 States & three Union Territories covering almost the entire country including all islands (Andaman & Nicobar and Lakshadweep), North–Eastern states and Jammu & Kashmir. The implementation in remaining states was subsequently pursued. The Edusat network at one time comprised of more than 55000 terminals covering over three million populations. The satellite with the national as well as regional beams in Ext. C and Ku-bands catered to the specific requirements of the states and the user agencies.

The tele-education networks established by ISRO included the networks set up for users with special requirements like: Blind People's Association (BPA) of Gujarat – for Visually challenged, the Rehabilitation Council of India (RCI) Central Institute of Mentally Retarded (CIMR) and C-DAC for Mentally challenged in Kerala. BPA network helped vastly the visually impaired students, for keeping abreast with the latest developments. The Edusat network helped to deliver live audio for visually challenged students and enable them with the transfer and printing of audio data files with the help of a Braille printer. Data files, which can be referred laterwere also provided to the students.

In the initial phase, ISRO set up 1 transmitting end at BPA, Ahmedabad and 10 receiving ends across similar institutes in Bhavnagar, Jamnagar, Sayla and other places. The network functioned in two distinct but independent modes - data broadcast and audio broadcast. In data mode, the sender's (or teacher) instructions were automatically stored in a file at each and every receiving unit (or a classroom) while in audio mode, live audio instructions were transmitted to the students.

As a special impetus to providing support to tele-education networks installed in North-East (NE) States, support for annual maintenance and hub operations is extended by ISRO. A Users' Meet of NE-EDUSAT networks was conducted at North East-Space Applications Centre (NE-SAC), Shillong, with an objective to campaign for enhancing the utilisation.Continuous technical consultations/guidance on operations and maintenance isprovided to various user agencies at national level as well as state level. The Technical Support and Training Centre (TSTC) was established at Guwahati, Assam to provide technical support on continuous basis to all the Remote Sites, Hubs and Teaching-Ends of various state networks in the North East Region. The 'Network Monitoring Facility' established at DECU, Ahmedabad is used to obtain the feedback on the utilisation and assess the quality of programmes transmitted on Ku and Ext C Band EDUSAT networks.

Educational Needs Assessment, Feedback and utilization studies through field surveys of networks like Meghalaya, Tripura, Arunachal Pradesh, Haryana, CEC (New Delhi), Chhattisgarh, RGPEEE (Madhya Pradesh), Rajasthan, VICTER, Odisha etc. were carried out. VICTER Channel is one of the initiatives of IT@School Project at Kerala. It is an exclusive channel for education wherein the educational programmes were/ aired from 0600 hrs. to 2300 hrs. Under Kerala Edusat network, 134 SITs and ROTs at few places were installed at various locations of Kerala by ISRO. The SITs are installed at DIET, IT@School office and the primary target audience is teachers' trainees either in service or pre service. While ROTs are installed at schools where the primary target audience is students.

g. Users' Perspective

EDUSAT pilot projects were conducted during 2004 in Karnataka, Maharashtra and Madhya Pradesh with 300 terminals. The experiences of pilot projects were adopted in semi-operational and operational phases. During semi-operational phase, almost all the states and major national agencies were covered under EDUSAT programme. The networks were expanded with funding by respective state governments/user agencies.

It was estimated that more than three crores of individuals have viewed the programmes in SITs. From user's perspective, most of the resource persons found tele-education much more useful due to its multimedia content and provision for enhanced presentation skills. According to the reports a large number of students got highly benefitted due to access of good teachers and their understanding of content was much better due to usage of multimedia and other means of presentation. It gave an opportunity to rural students for education; allowed direct interaction with the students and the teaching became uniform across the broadcast receiving locations. In addition, tele-education network became useful for training of officials,teachers& functionaries and also for conducting various meetings thus saving the time and resources. Based upon the requests from North-Eastern States, J&K and Uttarakhand Governments, their Tele-Education networks were revived during 2014 to 2017

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18. SPACE BASED TELEMEDICINE PROJECT

a. Background:

The telemedicine connectivity (TM) started in 1998on a simple telephone line by establishing the connection between Rajkot and Gandhinagar to Ahmedabad. Subsequently the TM system was gradually expanded at several places. The connectivity between Bhuj and Ahamedabad military Hospitalswas established in 1999 and further extended to Air Hospital, Gandhinagar. In 2000, a TM network was set up between General Hospital, Ballabgarh and AIIMS, New Delhi. Apollo Hospital, Chennai and its centre located at Aragonda, Andhra Pradesh were connected through VSAT technology thus providing telemedicine to Indian villages. Further in 2001 Tripura Sundari Hospital of Tripura was connected to Rabindranath Tagore International Institute of Cardiac Science (RTIICS), Kolkata and Narayana Hrudayalaya (Bangalore). Through a project of Asia Heart Foundation; a satellite link was established between Chamarajanagar District Hospital, SVYM Hospital and Narayana Hrudayalaya, Karnataka and so on.

The Telemedicine network slowly started expanding and by the year 2005 ISRO had installed 31 Super Speciality Nodes, 99 Patient's end and 10 Mobile units across many states like Karnataka, Andaman & Nicobar, Ladakh, Lakshwadeep, Odisha and North-East. By the mid of year 2010 ISRO TM network had grown with 389 TM nodes located across country.

b. Objectives:

Technology aided health care system is very essential to improve the health conditions of a big country like India. Telemedicine as a concept was introduced to bridge the gap between urban and rural health sectors. The major objective of telemedicine is to ensure a more equitable access to health services across the social and geographical expanse including the far-off and remote areas of the country. Therefore, in order to provide quality health care services to all remote locations of the country, the concept of Telemedicine was conceived in 2000 by Government of India along with Ministry of Information & Technology (IT), Indian Space Research Organisation (ISRO) etc.

ISRO started the Telemedicine pilot project in the year 2001 with the broad objectives of providing the telemedicine technology & connectivity

a) for remote/rural hospital and super speciality hospital to provide the Telemedicine consultation for treatment patients

b) to provide the medical training and updating the medical knowledge to remote doctors/paramedical staff through conducting Continuing Medical education (CME) programs from super speciality hospitals to medical colleges & post graduate medical institutions/hospitals

c) Mobile telemedicine units with various medical disciplines like ophthalmology, general medicine, diabetes, etc. provides TM services in the remote and far flung areas and for disaster management support and relief.

c. Expected Benefit to Society:

The benefits of telemedicine are several. It has helped vastly in medical consultations with patients in remote areas of the Country and providing training/updating the medical knowledge to medical professionals through Continuing Medical Education (CME) programs. With these two components, the entire society has been benefitted. Before the induction of telemedicine, the patient had to travel to long distance for a consultation. The telemedicine now has enabled a specialist doctor to virtually visit a patient who is in a remote and far off place, offering the advantages of immediate access to the medical specialist/s, thus saving the time and cost incurred in consultation. With telemedicine, seeking help from the doctors has become substantially easier and the number of consultation cases also increased. For doctor too it provides the advantages of having better follow up of a patient, saves time, can attend to many patients and also can make informed decisions about the in-clinic visit for patients. The patients too are reluctant to seek medical advice unless a dire situation results in their lives. As on 2014 as per the data available, around 5 lakhs patients from all over India have been benefitted.

d. Implementation mechanism:

A typical space based ISRO telemedicine (TM) network configuration is given in the Fig 1. Presently ISRO TM network is configured in star topology and is using Ext. C-band frequency band on GSAT-12 satellite. The Telemedicine hub of this network is located at ISTRAC, Bengaluru. The TM hub provides the hub services like TM network configuration, control and monitoring. Telemedicine VSAT Hub comprises Antenna system, RF system, hub baseband, network monitoring systems, Network Management System(NMS), TM and CME servers. The remote Telemedicine node connectivity is provided through a 1.8m antenna system with 2 W Block-Up converter(BUC) for the mainland and 5W Block-Up converter(BUC) for the off-shore islands. The telemedicine facilitates the transmission of patient's diagnostic data like ECG, X-ray reports, etc., patient history records to the TM server with a provision to have two-way audio and video conferencing. Super specialist's doctors access the patient data with a login ID and password. The standards for the transfer of the images confirm to the Digital Imaging and Communication in Medicine (DICOM 3.0). For the patient health record, part of health level-7 (HL-7) is used. With the help of these details the specialist doctor advises the non-specialist doctor at the patient end. Super specialist doctor examines the patient history and diagnostic data and interact with the remote doctor/patient through videoconference. After that doctor gives the medicine prescription on line to remote doctor through the TM network. Remote doctor takes the print of the medicine prescription and give it to patient. For patient health record and diagnostics the data is transferred at 512 Kbps, data rate and also conducts the video conference. TM network is synchronous means the data rate from patient and doctor end are equal. TM consultation is purely point to point and the secrecy is maintained (no other person can see the patient data other than designated doctor). CME program is point to multi-point means program is multicast from one terminal to many remote terminals.

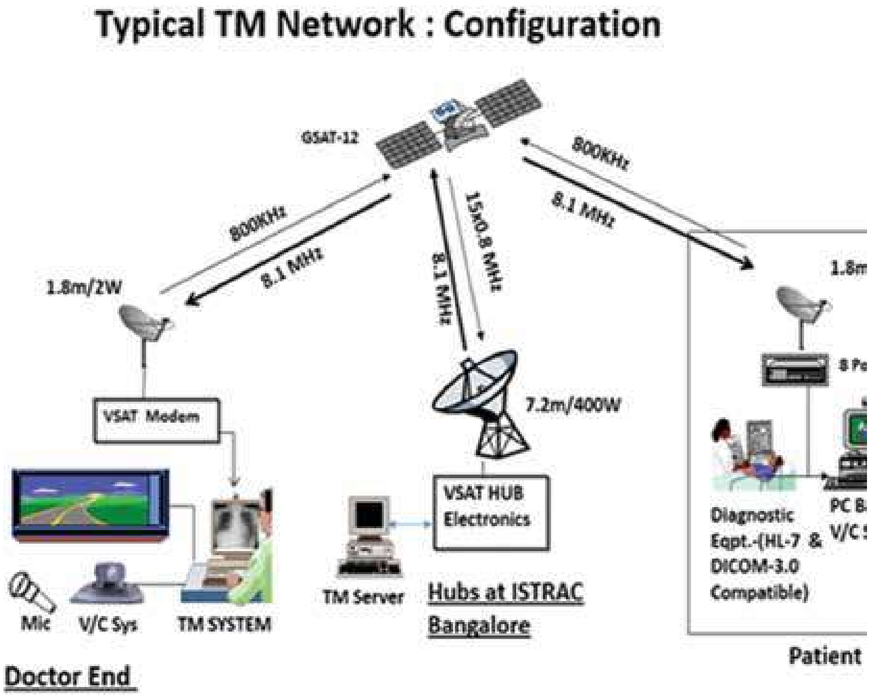

Fig 1: Typical TM Configuration

Satellite bandwidth equivalent to about 1.5 transponder in C band, Extended C band and Ku band on INSAT-4A and GSAT 12 were utilised for supporting telemedicine network till 2010 and subsequently, 36MHz bandwidth is allocated on GSAT-12 Ext. C-band transponder No-1.The satellite communication hub is located at ISRO Telemetry Tracking and Command Network (ISTRAC) in Bangalore supporting most of the telemedicine nodes and a few nodes (10 in Gujarat and 13 in A&N Islands) supported with Hubs in Ahmedabad and Port Blair respectively. Since 2015 full ISRO telemedicine is migrated to GSAT-12 (Now CMS-01) and presently only one transponder of 36Mhz is allocated for telemedicine services.

Started as a pilot project in 2001 with 3 TM nodes (1 Doctor node and 2 Patient nodes), using INSAT 3A. TM network has grown by 2005 with 31 Super Speciality Nodes, 99 Patient's end and 10 Mobile units across many states like Karnataka, Andaman & Nicobar, Ladakh, Lakshwadeep, Odisha, J&K and North-East Region. Around 140 nodes were established with a centralized Telemedicine Hub at ISTRAC, Bengaluru. Further addition of other TM hub on GSAT-3 in 2005, then total TM nodes increased up to 389 by the endo of 2010. Out of this 389, 306 were patients' nodes located at remote/ district hospitals; 66 were super speciality hospitals and 17 were mobile vans with Telemedicine facility. From year 2012 onwards, ISRO started the migration of old TM nodes of GSAT-3 TM hub to existing INSAT-3A TM hub and around 134 nodes were made operational across the country by the end of 2012. Thereafter by end of 2014, full TM network was migrated to GSAT-12 satellite with single TM hub located in ISTRAC, Bengaluru. In November 2014, ISRO started Continuing Medical Education (CME) programme from DECU Studio, Ahmedabad for benefiting the medical fraternity through its countrywide TM network.

Further the Telemedicine services were extended to Indian Armed Forces in difficult regions such as Siachen, Amarnath, North Eastern states etc. In year 2018, 100 New TM nodes including 2 Mobile TM nodes have been established across the country. Army, Air Force, Navy, ITBP, Indian Coast Guards, ESIC hospitals, pilgrim places etc. have been the major users. The 18 old nodes were also reactivated, and thus as on 2018 there are around 210 TM nodes are operational across the country.

e. Area Coverage: National / State / District

The coverage is all over India and as already mentioned earlier by the year 2009, 389 nodes are available catering to almost all States in the Country. In September 2010 GSAT-3 was decommissioned and with that the TM network got affected for a while. But subsequent to that the networks were transferred to many other satellites of ISRO as explained earlier. Besides, some of the old nodes were reactivated and some new nodes were also added. A few were directed towards the tough terrains like such as Siachen, Amarnath, North Eastern states etc. According to data available as on July 2019, there are around 200 nodes, located in almost all states of India. The overall distribution of the telemedicine nodes across the states is shown in Fig.2. The telemedicine usage across the Country was quite widespread and some of the details from the inception are as given below.

Figure 2: Location Wise Distribution of Telemedicine Nodes (As on 2018)

f. Results Obtained: (compare with item c above)

Two decades have passed since the introduction of space based Telemedicine by ISRO. During the initial phase of tele-consultations, most of the institutes who adopted the space based telemedicine used ISRO's technology for tele-consultation and by the year 2005 number of Telemedicine centers grew steadily to connect to 389 centers with Telemedicine facility across the country. Out of 389 centers, 301 were rural/district/medical college hospitals (remote hospitals), 17 were Mobile Telemedicine units, 66 were Speciality Hospitals and 5 Monitoring nodes. There was a dip for a while and as on now we have more than 200 centres across the country and this telemedicine facility has firmly established its services in the Country. Subsequently, the National knowledge network(NKN) introduced the dedicated 100 MB/s NKN network in the Country. With this, the usage of NKN network has increased substantially for tele-consultations. Presently, the VSAT network is operational in more than 70% of the institutes and some of the institutes have been using ISRO's connectivity for tele-consultations where consultations are needed with very remote areas such as CHC Poonch, Andaman's etc. and also during natural disasters where terrestrial modes of communication are disturbed.

The Telemedicine connectivity covered far-flung areas of Jammu and Kashmir, Andaman and Nicobar Islands, Lakshadweep Islands and North Eastern States. The states like Kerala, Karnataka, Rajasthan, Chhattisgarh, Madhya Pradesh, and Maharashtra adopted telemedicine connectivity using satellite connectivity to most of the District Hospitals. Exclusive Telemedicine networks were established for defence in collaboration with Indian defence staff (IDS), Medical RK Puram Delhi, and for paramilitary forces with 83 and 21 centers connected respectively. These nodes include 15 TM nodes located at high altitudes in Siachen region and North east region.

The results of TM are quite encouraging. According to the doctors of different hospitals who have used the TM set up of ISRO have observed that the network is highly beneficial. It has helped many patients to avoid travelling long distance and the corresponding expenditure in travel. DECU-ISRO has been organising CME regularly since end of 2014. This programme is viewed at all the telemedicine centres located across the country for the benefit of the medical fraternity. The network was used very effectively by all the users and the participants have found the CME programmes to be very useful and feel that the network is advantageous for upgradation of knowledge.

g. Users' Perspective

ISRO has connected a number of major super speciality hospitals to many general hospitals across the Country and many hospitals have used the telemedicine facility very effectively. For example, the hospital like Shankar Netralaya, Chennai have treated more than four lakh patients through telemedicine for ophthalmology, especially through medical camps and taking mobile vans into the interior villages. Similarly, one of the very effective use has been delivering healthcare services to residents and lakhs of pilgrims visiting holy Amarnath caves. ISRO, Ministry of housing, Family and Welfare (MoH&FW) and health ministry of J&K have joined hands to set-up a Satellite based Telemedicine facility at Sheshnag area, located at an elevation of around 13,000 feet in the Kashmir valley, enroute to Amarnath Shrine under extreme weather conditions, difficult terrains and other unexpected challenges. On a similar note, the benefits of CME conducted by ISRO is helping the medical fraternity. During the period of 2014-2017, a total of around 8000 personnel from the medical fraternity have been benefitted.

The telemedicine network grew in numbers and covered many geographical locations of the country providing the health care services even to the remotest part of the country. In addition to benefitting the patients, the system has helped the medical fraternity to enhance the medical education. Thus the space based telemedicine demonstrated the technological capability and its effective usage in many parts of the Country. The network has also undergone its own evolution in many ways during these years. Some networks providers have given connectivity like NKN, broadband and the usage of a suitable network has been the choice of the users. Besides, many cellular phone based applications are also utilised for patient interaction. Based on the experience in difficult terrains, satellite based telemedicine has proved to be advantageous and can be very efficient health care delivery system in the remote places with the support of concerned ministry. In all such cases the space based telemedicine no doubt will continue to be a right solution to the health care system of the country. Overall, telemedicine has emerged as an effective tool for better health delivery in a vast Country like India.

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19. COMMUNICATION FOR DISASTER MANAGEMENT SUPPORT ACTIVITIES

a. Objectives:

Satellite based communication (SATCOM) and navigation (SATNAV) system separately or together is utilised effectively for supporting the disaster management activities. It is being applied in many of the disaster management situations particularly in the regions where there is no access to any of the terrestrial communication link. The applications developed using SATCOM and SATNAV is commonly called NAVCOM applications.

Some of the important activities carried out as a part of disaster management activities by ISRO/DOS are; i) Satellite Communication (SATCOM) based Virtual Private Network (VPN) for disaster management support (DMS); ii)Satellite Phones for Voice Communication to support emergency requirements; iii) Fishing vessel tracking system to ensure its safety; iv) NavIC alert Message Receiver (NMR) for Fishermen to provide the distress information; v) Distress Alert Transmitter (DAT)to aid search and rescue operation for fishermen while in sea; and vi) second generation DAT.

b. Expected Benefit to Society:

Natural disasters cause significant loss to the human habitat in both property as well as human lives. One of the major reasons for the loss is attributed to disaster warning or distress alerts not reaching the public or local administration well in time due to snapping of communication links in the affected zone. Timely availability of information can aid in rescue and reduce the magnitude of human and property loss to a great extent. The SATCOM, SATNAV or NAVCOM based system can be used in such situations.

Inland disasters such as forest fire, flash floods, earthquake, avalanche, tsunami, etc. and ocean disasters such as high wave, cyclone, etc. are the most common areas where satellite based applications can be very effective.

c. Implementation mechanism:

The implementation of any system for disaster management is a daunting task. Various Central/State government, Local bodies play significant role during any disaster management. The architecture of SATCOM and SATNAV systems is kept simple such that it can be utilised by general public with minimal training.

The SATCOM based Virtual Private Network (VPN) for disaster management support (DMS) network is implemented using the Extended-C band in GSAT-12 satellite built by ISRO. This network has 9 Primary Nodes supporting up to 2.5 Mbps and 44 User Nodes supporting up to 825 Kbps data rates. It is a point-to-point network supporting Video Conference, IP data communication and telephony.

In order to have effective and efficient utilisation of this space resource and also for enhancing the reach of the network it is proposed to be upgraded with latest technology. The upgradation is proposed with multilayer communication architecture including optical fiber backbone. The user nodes support integration with diverse terrestrial communication services is to improve the communication reach at disaster sites. The upgraded network is expected to have initial deployment of 350 user nodes at critical locations with scalable capacity of VSATs and shall operate using 9.3m hub. The existing DMS network has been given in Figure 1.

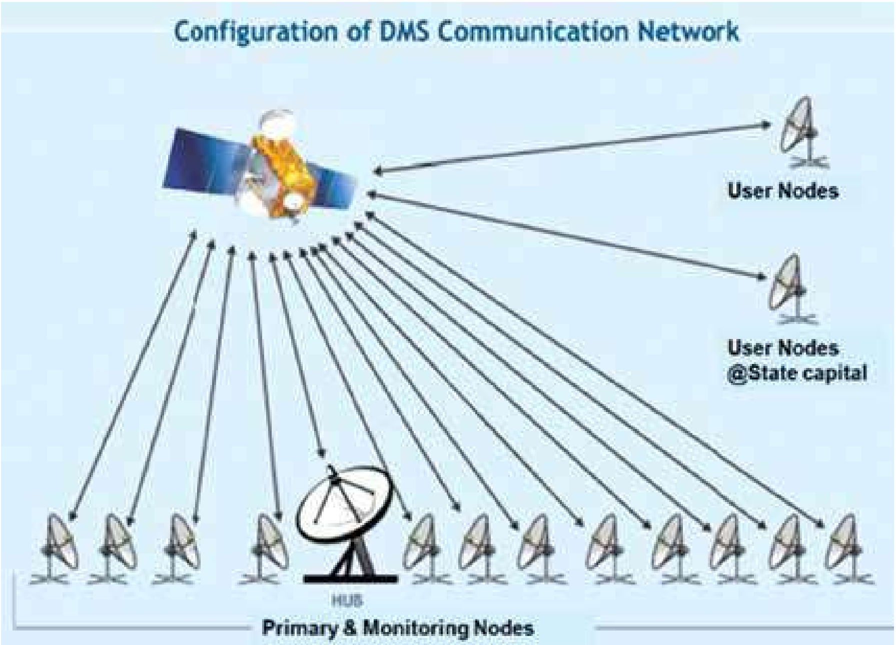

Figure 1. Existing DMS Network

Figure 2. A Typical Satellite phone

ISRO has developed satellite phones using S-band in GSAT-6 satellite. (Figure 2) About 25 terminals are built at Space Application Centre (SAC) and they are available for meeting emergency requirements. Additional requirements are planned to be met through industry with whom ISRO has executed transfer of technology for manufacture of user terminals.

ISRO has developed a vessel monitoring system using S-band in GSAT-6 satellite mainly for tracking sub 20 m boats at sea.(Fig. 3). It can be used to monitor large number of vessels at coast. Other possible applications include disaster warning dissemination, asset tracking, messaging services, etc. The system is capable of handling up to 2.4 lakhs of fishing vessels. The channel is accessed through dynamic TDMA where the messages are sent in burst mode with time sharing with other similar units. IT has bluetooth/ Wi-Fi enabled user interface and a battery backup for seamless operation.

Figure 3. Fishing vessels monitoring system using S-band in GSAT-6 satellite

This system also caters to coastal surveillance and security applications under Ministry of Home Affairs (MHA). MHA is in the process of building an exclusive ground system. Until then, the services are provided through ISRO's Earth station located at Delhi.

ISRO/DOS has devised a ground transmitter viz., Distress Alert Transmitter (DAT) aiding search and rescue operation for fishermen while at sea. The DAT combines the message with position of the boat obtained through navigation satellite, and transmits the same to a central HUB station via Data Relay Transponder (DRT) of ISRO's INSAT satellites. A typical system of distress alert system is given in Figure 4.

This system provides the fishermen with the option of sending an appropriate pre-defined emergency message (e.g. fire in boat / boat sinking/ medical help / other emergency) when at sea which has the boat's co-ordinates to the Coast Guard Maritime Rescue Co-Ordination Centre, at Chennai for immediate action. The ship's location is displayed on a map to the rescue personnel. This helps in coordinating an efficient rescue operation.

***Figure 4**. A typical system of distress alert system.*

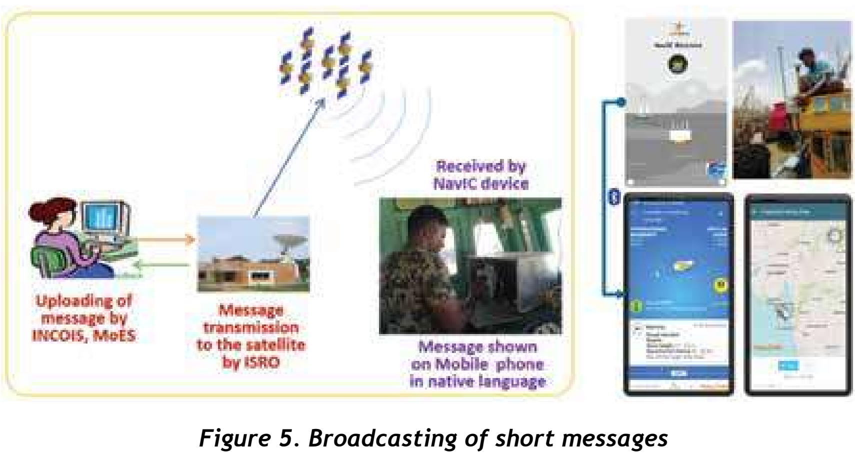

***Figure 5**. Broadcasting of short messages*

ISRO has operationalised - NavIC Satellite Constellation a Regional Navigation System. In addition to its primary functionality of navigation, they allow broadcasting of additional short messages. ISRO has conceptualised a system based on the short messaging feature, wherein,

Indian National Centre for Ocean Information System (INCOIS) generates alerts messages, like high wave, Tsunami, Cyclone etc. and broadcasted through NavIC messaging system. (Fig 5) The broadcasted messages are received by a NavIC Messaging Receiver (NMR) which in-turn is connected to an android based smart phone. An app is developed to display the messages in local languages.

ISRO has recently developed a system viz., DAT Second Generation (DAT-SG) which integrates the functionalities of both NavIC messaging services and the standard DAT. It uses NavIC constellation to compute the position of the device. This information is displayed in the smartphone app. When the DAT emergency button is pressed, this information is transmitted to the Coast guard for initiating rescue operations. Once coast Guard acknowledges the receipt of alert, the fishermen will be notified that rescue is in progress through NavIC messaging channel. The details of Distress Alert Transmitter: Second Generation are given in Fig 6.

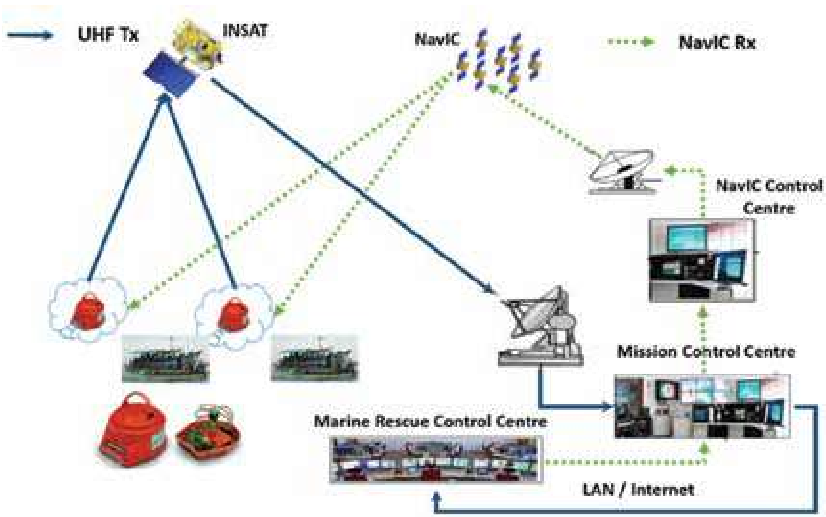

Figure 6 Distress Alert Transmitter: Second Generation

d. Area Coverage: National / State / District

SATCOM and SATNAV systems are developed essentially to give a coverage in the Indian region. As already mentioned the VPN network was used effectively during disasters in Uttarakhand, Jammu & Kashmir many other such disasters in the Country. The Satellite Phones for Voice Communication can be utilised under emergency conditions in the Country. The fishing vessel tracking system caters up to 200 nautical miles from the Indian coast. Distress Alert Transmitter (DAT) coverage is the over entire Indian Ocean covering areas from eastern Africa up to Western Australia. NavIC Message services can cater upto 1500 km beyond Indian Coast.

e. Results Obtained: (comparing with item b above)

All these systems have been designed for effective use by the right agencies at the time of distress and alleviate the hardships faced at the time of emergent conditions. SATCOM based VPN network has been effectively utilised during disasters in Uttarakhand and Jammu & Kashmir. However, as the network elements of VPN are becoming obsolete and the maintenance is becoming very difficult it will be phased out from Jan 2020.

The vessel monitoring system (VMS) has been demonstrated on-board the fishing vessels. More than 500 terminals are deployed in Gujarat and Tamil Nadu as per the guidance of Ministry of Home Affairs (MHA). Other applications include disaster warning dissemination, asset tracking, messaging services, etc. The development was mainly to meet the demands of Coastal surveillance and security applications under Ministry of Home Affairs. The Ministry of Fisheries and Indian Coast Guard are coordinating for the effective implementation with fishermen all over the Country and all of them are utilising its benefits.

The Distress Alert Transmitter (DAT) is operational since 2005 and more than 10000 terminals are in field and Marine Rescue Coordination Centre has been involved in rescue of fishermen using DAT. As far as NavIC Message Receiver (NMRs) are concerned they are initially distributed among the fishermen from Kerala and Tamil Nadu. The fishermen are satisfied with the information on potential fishing zones, geo-fencing applications etc., through their regional language and easy to use hand-held instrument. They are saving time and get an economic benefit due to the potential fishing zone information received through NavIC.

ISRO has hand held Indian Industries to manufacture the VMS, DAT and NNRs and state governments have been requested to approach industry to meet the requirement.

f. Users' Perspective

The SATCOM and SATNAV services are a sustainable solution with low initial cost and zero recurring cost.

The fishermen all across the coast of India can be benefitted with the Fishing vessel tracking system and also NavIC alert Message Receiver (NMR). The fishermen have been effectively utilising the alerts on emergencies such as cyclone, high waves, tsunami, etc., which was not available earlier and it has helped them to move to the safety using the alerts. However, the feedback from the fishermen community on possible improvement in the system has been taken into consideration. Based on this, ISRO has now devised an integrated NMR and DAT system viz., DAT-SG. The system is under trial and is expected to be operational shortly.

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20. DIRECT TO HOME (DTH) TELEVISION SERVICES

a. Objectives:

The Direct-to-Home (DTH) services acquired a key position in Indian TV broadcasting Industry for the past two decades. Main objective of DTH (Direct-To-Home) is to provide desired information on regional, global news, education,sports, entertainment etc., to all viewers through direct television services to the homes, situated anywhere in the country, even remote locations with high quality digital signals beaming best sound and clear picture quality. The attendant advantages are no requirement of wires like cable TV connection. The subscriber has the option to choose his own package or channel as DTH service works on single channel. The channel change is effected through the set-top box of DTH service. However, there are disadvantages like very weak or no signal during heavy rain preventing to view the channel. In addition, change of the service provider is difficult as one needs to buy a new set top box from new service provider.

b. Expected Benefit to Society:

Before the introduction of DTH, the cable TV sector in India used to often face serious conflicts between channel owners and cable operators over varying subscription charges. Cable subscription rates used to be revised very often in a single year and frequent black out of channels were also used to be reported. This conflict used to peak during important national events which used to attract higher viewership. The arrival of the direct to home (DTH) broadcasting in 2003 provided the needed solutions to these frequently occurring problems. DTH with a small dish antennae and set-top box has the ability to reach the remotest of areas since it does not require the cables from the cable operator to one's home. Thus it was possible to have access to television even in remotest places in any part of the Country. DTH also offered better quality pictures than cable TV because the cable transmission is still analogue. DTH offers stereophonic sound effects too.

The cost of installation has also come down drastically over a period.

A new era for satellite television in India,started with the launch of DTH thuse liminating the last mile operators, providing better choice to consumers, increased transparency and the range of services offered. In addition, the government's plan of providing multiple dishes through DD, free across the Country enabled increased community viewing of the DTH services. As on end of 2020 there were only four DTH service providers in the country in addition to Prasar Bharati. The private operators are Tata sky (33.03%), Bharati Telemedia (25.17%), Dish TV India 25.45%) and Sun Direct TV Pvt (16.35%). The indigenous GSAT satellites have been a major driving force for the expansion of Television coverage in the country. Required transponders capacity for Broadcasting sector has been met through GSAT satellites as well as leased capacity on foreign satellites.

Doordarshan is presently operating 36 satellite channels and has a vast network of Studios and terrestrial Transmitters (includes 23 DTTs) of varying power installed throughout the length and breadth of the country. Doordarshan is using a total of 18.70 Transponders (12.03 C Band & 6.67 Ku Band) of 36 MHz each on GSAT System. Doordarshan has 41 C-Band earth stations for program contribution & distribution of their Channels and one C-Band DTH earth station for providing DTH service to Andaman and Nicobar Islands. In addition, Doordarshan provides its free-to-air DTH service "DD Free Dish" with coverage over the entire country. Free Dish bouquet comprises of 110 TV Channels (including one HD Channel) and 48 Radio Channels.

Apart from Doordharshan the public broadcaster, initially 6 private DTH operators started providing services in India,presently with only four operators due to mergers and demergers. It is estimated that (TRAI Report : Apr - Jun 2020);as on 2020 there are about 70.58 Million active subscribers availing private DTH services. About 909 TV channels are permitted by Ministry of I&B.About 103 Ku-band transponders from both Indian and Leased satellites are catering to DTH television services. Apart from DTH, about 63 C band transponders are used for supporting Television uplink. These figures do not include subscribers of free DTH services. Thus one can see that DTH has revolutionised the broadcasting in the Country reaching every nook and corner of the Country providing high quality signals.

c. Implementation mechanism:

The signalsare relayed from communication satellites which orbit around the earth at35,786 KM above the equator in geostationary orbits. The signals are received via an outdoor parabolic reflector antenna usually referred to as a satellite dish and a low-noise block down-converter (LNB). A satellite receiver then decodes the desired television program for viewing on a television set.Receivers can be external set-top boxes, or a built-in television tuner. Broadcast signals may or may not be encrypted, in India free dish broadcasts from DD are unencrypted signals which can be decoded by generic set top boxes while commercial operators like Tata sky, Videocon DTH, Dish TV etc. broadcast encrypted signals which are decrypted based on information in the chip of the smart card.

DTH (Direct to Home) System consists of the following components 1. Dish Antenna2.LNBF (Low Noise Block Down Converter plus Feedhorn) 3.Coaxial Cable 4 Set Top Box and 5. A Dish Antenna, a parabolic reflector. It receives the signal and redirects it to the LNBF which works as receiver for signal transmitted by satellite parabolic reflector.LNBF is a small metal horn antenna on the dish is called as feedhorn. It collects the signal from dish and amplifies the signal bouncing off the dish and filters out the noise (signals not carrying programming). Coaxial Cable is the Cable that connects mini Dish and Set Top Box.DTH Set Top Box, unlike the regular cable connection, decodes the encrypted transmission data and converts these signals into audio & video signal. Fig 1gives the components of DTH Technology.

Satellite Television signals are beamed in two types of bands: C band- This band is comprised of Analogue or Digital signals in the 4 to 8 GHz frequency range used for Television Receive Only (TVRO) broadcast and requires larger size of dish antenna (6 to 8 feet) to receive the signals and is not effected by bad weather conditions like rain. Ku band- This band is comprised of Digital signals in the 12 to 18 GHz frequency range used for Direct to Home (DTH) broadcast and requires much smaller dish antenna (2 to 4 feet) to receive the more focused signals but is susceptible to outages during bad weather conditions like heavy rains.

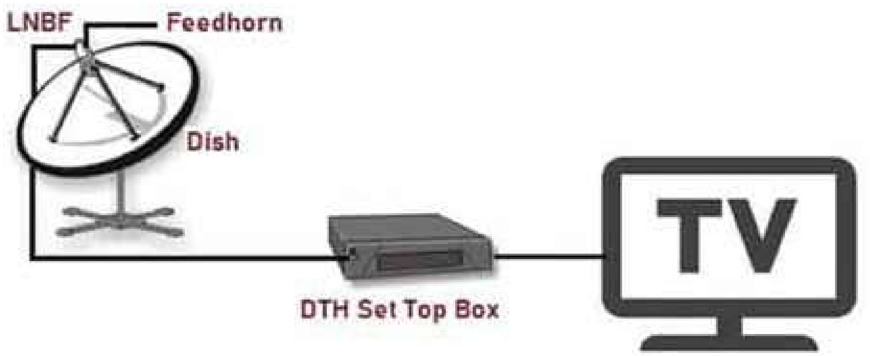

Fig 1. Components of DTH System (Courtesy: from Web)

The compression standards used for broadcasting DTH signals are of two types namely 1. MPEG 2, older standard of signal compression which was used by incumbent DTH operators like Dish TV and DD free dish where each transponder can carry approximately 20-SD channels (Fewer in case of HD) and MPEG 4, the newer standard of signal compression introduced in 1999 and is being used in India by the newer DTH operators like Airtel Digital, Videocon D2H, Reliance digital TV, Sun DTH and now since October 2015 even Tata sky has completed switching over from MPEG 2 to MPEG 4. With this compression standard each transponder can carry approximately 40-SD channels (Fewer in case of HD)

Currently there are 4 private and 1 government DTH operators providing service in India. The department of space (DOS) permits DTH operators to use only the satellites commissioned by Indian Space and Research Organisation (ISRO) or in case there isn't sufficient capacity on ISRO satellites then they are permitted to use capacity leased by ISRO from foreign satellites.

The details of the Satellites being used by Indian DTH operators are given below:

Sl No	Satellite	Owner	Launch Date	Geo Stationary Position	Operator
1	SES-8	SES SA	3rd DEC, 2013	95° East	Dish TV
2	MeaSat- 3	Measat	11th Dec 2006	91.5° East	Sun Direct
3.	MeaSat-3B	Measat	12th Sep, 2014	91.5° East	Sun Direct
4	SES-7	SES SA	16th May 2009	108.2° East	Airtel Digital TV
5	ST-2	Sing Tel	20th May 2011	88.2° East	D2h(Subsidiary of Dish TV)
6	SES-9	SES SA	4th March 2016	108.2° East	Airtel Digital TV
7	GSAT-10	ISRO	29th Sept 2012	83° East	Tata Sky
8	GSAT-15	ISRO	10th Nov 2015	93.5° East	DD free dish and Sun Direct
9	GSAT-30	ISRO	16th Jan 2020	83° East	Tata sky

SES 7:This is a satellite owned by SES world skies, which was launched on 16th May 2009 with a mission life of 15 years. It's geostationary position is 108.2° East longitude. This satellite has 19 Ku band transponders of which 12 have been leased by ISRO for making available to Indian DTH operators. Airtel Digital TV is using these 12 transponders for broadcasting its SD and HD channels using MPEG4 compression.

SES-8:This is a satellite owned by SES world skies, which was launched on 3rd December 2013 with mission life of 15 years. It's geostationary position is 95° East longitude. This satellite has 33 Ku band transponders out of which 13.5 have been leased by ISRO for making available to Indian DTH operators. Dish TV is using these 13.5 transponders to broadcast it's channels using MPEG2 compression and HD channels using MPEG4 compression.

SES-9 :This is a satellite owned by SES world skies, which was launched on 4th March 2016 with a mission life of 15 years. It's geostationary position is 108.2° East longitude. This satellite has 33 Ku band transponders of which 10.5 have been leased by ISRO for making available to Indian DTH operators. Airtel Digital TV is using these transponders for broadcasting its SD and HD channels using MPEG4 compression.

MEASAT 3: Satellite owned by Malaysia East Asia satellite systems, launched on 11th December 2006 with a mission life of 15 years. This satellite has 24 Ku band transponders of which 3 have been leased by ISRO for making available to Indian DTH operators. Sun Direct uses 3 Ku band transponders for broadcasting channels using MPEG4 compression

MEASAT 3 B: Satellite owned by Malaysia East Asia satellite systems, launched on 12th September 2014 with a mission life of 15 years. This satellite has 48 Ku band transponders of which 6 have been leased by ISRO for making available to Indian DTH operators. Sun Direct uses these transponders for broadcasting channels using MPEG4 compression

ST 2: Satellite owned by a joint venture between SingTel and Chunghwa telecom, launched on 20th May 2011 with a mission life of 15 years. Has 41 Ku band transponders of which 17 are leased by ISRO for making available to Indian DTH operators. Dish TV (D2H) uses these 17 transponders to broadcast its SD and HD channels using MPEG4 compression.

GSAT 10: Satellite owned by ISRO, launched on 29th September 2012. It is co-located with INSAT 4A. This satellite has 12 Ku band transponders. Tata Sky is using all GSAT 10 transponders in addition to existing INSAT 4A.This satellite uses MPEG4 compression.

GSAT 15: Satellite owned by ISRO, launched on 10th November 2015 in position of 93.5° East longitude. This satellite has 18 Ku band usable transponders of which 5 are being used by DD free dish for broadcasting unencrypted SD channels using MPEG2 compression and 1 for broadcasting encrypted SD channels using MPEG4 compression. Additionally, 1 transponder is being used by Sun Direct for broadcasting only HD channels using HEVC compression. 5 transponders are being used by Dish TV, 4 transponders by Sun Direct, 1 by BISAG and 2 by MHRD.

GSAT 30: Satellite owned by ISRO, launched on 16th January 2020. It is co-located with GSAT-10 . This satellite has 12 Ku band transponders. Tata

Sky is using all GSAT 30 transponders in addition to existing GSAT-10.This satellite uses MPEG4 compression.

d. Area Coverage: National / State / District

DTH Coverage is all through India even the remotest of remote areas. Today million subscribers are using DTH services all over the Country. DTH services can be utilised any where in India and regardless of where one's home is.

e. Results Obtained: (compare with item b above)

On 2 October 2003,the first DTH service was launched in India by Dish TV owned by Zee. Their focus was providing services to rural areas and regions not serviced by cable television instead of competing with cable operators. With this approach Dish TV acquired 350,000 subscribers within 2 years of the launch. It was in December 2004 the Prasar Bharati launched DD Direct Plus (now DD Free Dish). The service was offered free. In August 2004, Tata Sky,a joint venture between the Tata Group and Star India's parent company launched DTH services. Tata Sky focused on metros and large cities with a view to offer better picture and audio quality and wider selection of channels compared to cable TV operators. In 2007 STAR and Zee, in 2007, sorted out their differences and decided to share their channels on each other's services. Meanwhile Dish TV's acquired more transponders. In 2007 and 2008 Sun Direct and Airtel digital TV launched services respectively. Reliance Big TV (now Independent TV) was launched in August 2008. The service acquired 1 million subscribers within 90 days of launch, the fastest ramp-up ever achieved by any DTH operator in the globe. Videocon d2h launched its services in June 2009. The total number of DTH subscribers in India rose from 1.5 million in 2005 to 23 million in 2010. Sun Direct was the first DTH provider to offer high-definition (HD) channels in early 2010. Tata Sky began offering HD channels later in 2010. Other DTH providers subsequently began carrying HD channels.

The direct-to-home (DTH) subscriber base in India as on 31st December 2019 was 69.98 million. It reached a base of around 70.99 million in 2020, according to the Indian Telecom Services Performance Indicator Report

October-December 2020 published by the Telecom Regulatory Authority of India (TRAI). This means an addition of 1 million in a year

At the end of 2020 there are four big DTH private operators in India after mergers and demergers, in addition to DD's free service channels. They are Tata sky (33.03%), Bharati Telemedia (25.17%), Dish TV India 25.45%) and Sun Direct TV Pvt (16.35%) The numbers shown in the bracket are the percentage share of DTH.

f. Users' Perspective

There are 926 private satellite TV channels permitted by Ministry of Information and Broadcasting at the close of financial year 2019-20, out of which, 235 are SD pay TV channels and 98 are HD Pay TV channels. Apart from an increase in the availability of conventional TV channels, the pay DTH operators have continued to add several innovative offerings and value-added services (VAS) such as movie-on-demand, gaming, shopping, education etc. The services offered by DTH channels all over the Country including remote places are utilised by a large section of users all across the Country. The Telecom Regulatory authority of India (TRAI) oversees the overall regulations so that the users and operators interests are protected. DTH operators are not permitted to include the foreign TV channels that are not registered in India. Downlinking permission is given by the Central Government under the policy guidelines issued or amended by it from time to time. DTH operator is bound byorders/directions/regulations issued by TRAI in respect of DTH services including platform services provided by the operator. All broadcasters have to offer all their channels on a la carte basis to DTH operators. Additionally, they may also offer bouquets, but will not insist to include the entire bouquet being offered by DTH operators to their subscribers. This provides the free choice of channels by users and it has helped vastly the users to utilise the channels of their interest.

Channels offered by DTH cable providers has the provision to configure to customize the audio settings in terms of language. This is a big advantage in a Country like India where multiple languages are used. Today DTH services are functioning seamlessly providing a range of services covering the regional, national and global news, sports, movies and a wide variety of entertainment. The cost has dropped drastically so that most of the Countrymen can afford to commission the services. Today India is the largest DTH market in the globe by number of subscribers and asper the present estimates has been adding 1 million every year. The services have also become quite popular due to the quality and cost of the services and also the flexibility it offers.

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21. SATELLITE BASED WEATHER AND CLIMATE

a. Back ground

The weather, no doubt has very great influence on several economic activities of the Country like agriculture, transport, energy generation, industrial development and many more since all of them depend on the nature of monsoons. Therefore proper understanding of weather and its accurate prediction are very vital for efficient planning of many of these activities. The disaster management also demands early reliable forecast of heavy precipitation and cyclonic situations fairly in advance. This helps to initiate appropriate actions to handle the natural hazards to ensure the safety of lives and property. The appropriate methodology for the prediction of weather using mathematical model has been evolved over a period and today the operational weather forecasting relies heavily on the numerical weather prediction (NWP) models using the fundamental laws of dynamics, thermodynamics and complex computational techniques. But these techniques need accurate atmospheric parametric values as inputs. Although, the ground based observations have the capability to provide the needed critical inputs to the weather prediction, it has serious limitation to generate the inputs over inaccessible areas like mountains, forests, deserts and vast oceanic areas. However, the meteorological satellites have advantages in terms of having wider coverage, generating the meteorological data at difficult terrains. The transmission of meteorological data needs narrower space segment and data is transmitted via satellite frequently. Therefore, observations of all critical atmospheric parameters from spacecraft are inevitable for weather prediction. As per the present practice a very high percentage of observations needed for weather prediction models are provided by space based systems. The global system of geostationary satellites in conjunction with earth observation spacecraft are truly a backbone of operational weather services worldwide.

b. Objectives:

The objective is to generate the valuable and very crucial earth observations parameters from spacecraft positioned at low-earth orbit as well as geostationary orbits needed for the complex weather prediction models for weather forecast. Spacecraft in low altitude in the range 400-800 km facilitate high resolution measurements of the atmospheric and oceanic parameters e.g., vertical variance of temperature and humidity, moisture, structure of clouds and rain, sea and land surface temperatures, aerosols, ocean surface winds, salinity, rainfall and many other associated parameters. The geosynchronous spacecraft compliment with many other useful parameters like atmospheric winds sea and land surface temperature, air-quality etc. The major advantage is these satellites provide the continuous observations of weather data, which help to track the clouds, tropical cyclones and thunderstorms.

c. Expected Benefit to Society:

In India agriculture is a predominant sector and depends heavily on the weather and climate. Weather forecasts, have a great influence on the quality and quantity of agricultural harvests. The accurate weather prediction and rainfall enable proper assessment of water resources. Weather monitoring on a continuous basis is essential not only to predict the present climate but also required in identifying the climate change by generating and providing the data for future changes in environment which are needed for weather prediction model. Some of the vital data are solar radiation, wind speed, wind direction, pressure, air temperature, humidity and net radiation. More frequent data on minute or hourly basis are generated by the development and widespread deployment of automatic weather stations (AWS's). The INSAT series of satellites with Very High Resolution Radiometer (VHRR) are generating cloud motion vectors, cloud top temperature, water vapor content, and other associated parameters to predict the rainfall estimation, genesis of cyclones and their track prediction to alert all coastal states well in advance so that necessary remedial measures are taken to safeguard the lives and properties.

d. Implementation mechanism:

For weather forecasting the constellation of geostationary and Low Earth Orbiting (LEO) meteorological satellites are used in combination. High resolution measurements of the atmospheric/ oceanic parameters are obtained by low altitude spacecraft by utilizing the appropriate payloads. For Numerical Weather Prediction models the vertical structure of atmospheric temperature and humidity by LEO satellites are important. The LEO satellites visit the regions of the earth every 10-12 hour making it difficult for these satellites to continuously monitor the development of the weather. Therefore they have to be complimented by geostationary satellites orbiting at 36000 km above the equator. Figure 1 gives the constellation of the geostationary and Low Earth Orbiting (LEO) meteorological satellites across the globe.

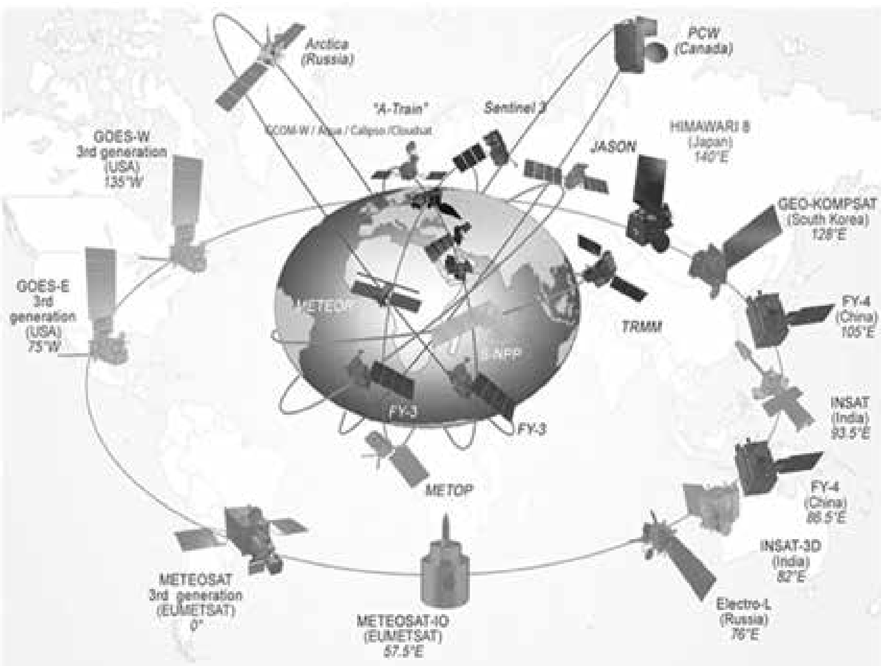

Figure 1. The global geostationary and low earth orbiting meteorological satellites (Source : WMO/CGMS)

The implementation of weather forecasting is done in India using the operational meteorological satellite systems which provide both global and regional observations. The Indian Space programme initiated in the mid-70's selected meteorology and weather forecasting as one of the thrust areas. The INSAT series are geostationary satellites conceptualized to meet the operational needs of meteorology and weather services. The INSAT 1 series (1980's) consisted of a Very High resolution Radiometer (VHRR) payload operating in two spectral bands- visible [0.55-0.75 μm] and thermal infrared [10.5- 12.5 μm]. This system was designed to provide a) round the clock surveillance of weather systems around the Indian region b) operational parameters for weather such as cloud cover, cloud top temperature, sea surface temperature, snow cover, cloud motion vector, out- going long wave radiation etc. c) meteorological, hydrological and oceanographic data from remote/inaccessible areas d) timely dissemination of warnings for cyclones and e) processed images of weather systems through Secure Digital Ultra Capacity formats (SDUCs). INSAT 1 series (4 satellites) provided visible images with 2.75 km resolution and thermal data with 11 km resolution. It had the capability to provide 3 hourly Images and in sector mode half hourly images.

INSAT 2 series kept up continuity of services with 5 satellites. INSAT 2A and 2B (1992 and 1993) carried VHRR payload with improved resolution of 2 km in visible and 8 km in thermal band. The imaging capability had three modes, such as full frame, normal mode and sector mode of 5 minutes. The latter one was for rapid coverage of severe weather systems. INSAT 2E (1999) with an advanced VHRR payload was operating in three channels - visible (2 km), thermal and water vapor (8 kms). The water vapour channel is capable of giving water vapour distribution and flow patterns in the lower troposphere. It also carried a CCD camera with 3 channels - visible, near infrared and short wave infrared with 1 km resolution to map the vegetation cover.The first exclusive Indian Meteorological satellite in geostationary orbitMETSAT, carried VHRR operating in visible, infrared and water vapour channel. INSAT 3A had identical payloads as INSAT 2E, whereas INSAT 3D carried atmospheric sounder for temperature, water vapour profiles and split thermal channels for accurate sea surface temperature retrieval. Currently in service are the third generation INSAT-3D & 3DR. INSAT-3D

(2013) with 6 channel imager is generating 48 fine resolution images per day. The 19 channel sounder gives temperature and humidity profiles of atmosphere every hour. INSAT-3DR (2016), and INSAT-3D are working in tandem providing observations at every 15 minutes. The products generated by these spacecraft are used for a host of weather services such as weather monitoring, weather forecasting, air quality monitoring and agricultural applications.

In addition to satellite based observations several in-situ observations are utilized to improve the model outputs. Prominent among them are Indigenously developed Pisharoty radio sondes, Doppler weather radars in C and X-band, Automatic Weather stations and wind profiling radars. Two wind profiling Radars at Gadanki and Sriharikota(SHAR) developed by ISRO, working in around 50 MHz region have been helping to improve the weather prediction.

Some of the payloads in IRS series spacecraft have applications to meteorology. Aerososl detection using the Modular Opto-electronic Scanner (MOS) with 13 narrow channels in visible/near infrared is one such instrument used for meteorology. The Oceansat-1 (1999)) with Multi Spectral Microwave Radiometer (MSMR) provides atmospheric parameters such as cloud liquid water content, total water vapour besides sea surface temperature and winds.

The operational forecast for monthly mean rainfall over different parts of India started in 2000. For using the satellite based data for weather forecasting a fast track system "INSAT Meteorological Data Processing System (IMDPS) was established at Indian Meteorological Division (IMD) in 2010. The IMDPS has a facility termed as "Real Time Analysis of Products and Information Dissemination" facility called RAPID. In addition during 2005 to 2009 a project called Prediction of Regional Weather with observational Meso-network and atmospheric modelling (PRWONAM) was implemented to provide short term weather forecast on time scales of 1-3 days. From 2015, heavy rainfall alerts and heat wave prediction on all India basis are regularly being posted and updated every half hourly on MOSDAC web portal.

f. Area Coverage: National / State / District

The combination of geostationary and Low Earth Orbiting (LEO) meteorological satellites available over the Indian subcontinent as explained in section c ensures the full coverage for the entire Indian region. Presently Indian Meteorological Division (IMD) using both spacecraft and also ground based instruments are able to provide the weather and climate forecast for all critical users of weather in India.

e. Results Obtained: (compare with item c above)

The INSAT series of satellites carrying Very High Resolution Radiometer (VHRR) have been generating data on cloud motion vectors, cloud top temperature, water vapour content and other associated parameters for rainfall estimation, genesis of cyclones and their track prediction. These satellites are also carrying Data Relay Transponders (DRT) which facilitate reception and dissemination of meteorological data from in-situ instruments located across vast and inaccessible areas. Three meteorological satellites Kalpana-1, INSAT-3A and INSAT-3D are in the geosynchronous orbit. Quick visualization, analysis of data and products enable accurate weather assessments. Towards this, Space Applications Centre (SAC), ISRO, Ahmedabad has developed a weather data explorer application - Real Time Analysis of Products and Information Dissemination (RAPID) which is hosted in India Meteorological Department (IMD) website. This software acts as a gateway to Indian Weather Satellite Data providing quick interactive visualisation and 4-Dimensional analysis capabilities to various users like application scientists and forecasters.

By using the Imager payload of INSAT-3D and INSAT-3DR in staggered mode, 15 minutes temporal resolution is achieved. During extreme weather events, INSAT 3DR imager is used for RAPID scanning. Rapid scan has been conducted during major cyclonic events like Amphan, Nisarga, Gati, NIVAR, Burevi, etc.

The space based weather prediction including the disaster warning well ahead of time was able to warn citizens through well planned mechanisms with State Governments about the natural hazards and disasters drives thus helping vastly to reduce the economic risks and save precious lives of humans and animals. Similarly the farmers would be vastly benefitted in terms of their harvesting, and fishermen with reliable information would avoid risking their lives at sea and improve efficiency on their boats. Early warning systems help to prevent the unsafe movement of people and goods during heavy storms and cyclone periods. The well planned program introduced in the Country is enabling the weather data more accessible and provide the concerned officials and other decision makers the opportunity to provide better weather prediction services to all their citizens.

Figure 2 below gives the Infrared 1 data from INSAT 3D IMG 24th Jan 2022 giving the typical weather picture across the Indian continent. (Courtesy IMD Website)

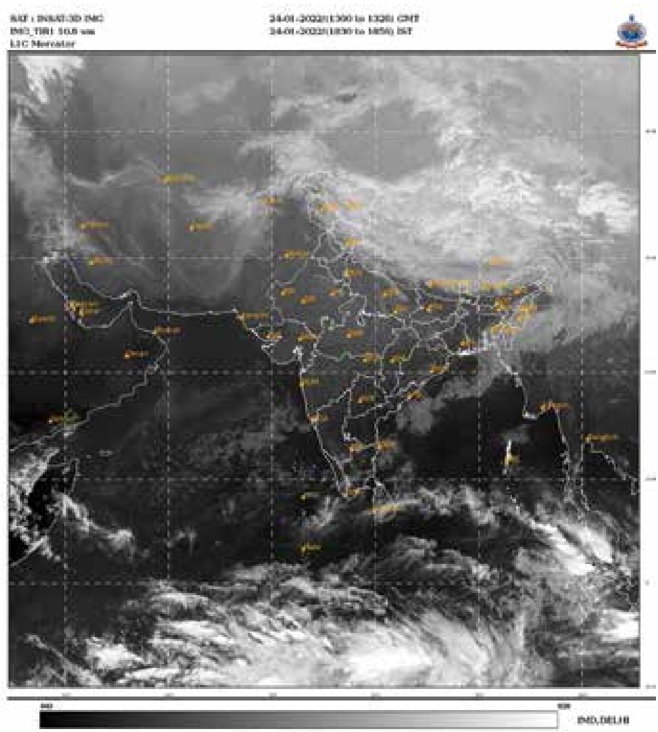

Figure 2. Infrared 1 data from INSAT 3D IMG 24th Jan 2022 (Courtesy IMD Website)

f. Users' Perspective

With the climate changes happening , the management of weather risks in agriculture assumes greater importance. The Indian meteorological system has been issuing regular bulletins on weather and climate and also on early warning systems to assist the farmers.

National Meteorological and Hydrological Services (NMHSs) have been playing a very vital role by providing the weather and climate information to farmers, big and small. The timely Agromet Advisory Services have been helping to develop sustainable and economically viable agricultural systems, improve production and quality, reduce losses and risks, decrease costs, etc. Therefore, Agromet Advisory Services have now been established at district levels in India. Presently, IMD is implementing operational agrometeorological schemes across the country under a five-tier structure, a top-level policy planning body in Delhi, b)by the National Agromet Service headquarters in Pune c) monitoring by State Agromet Centres d) district or local level extension and training for input management advisory service and e) by involving the state agricultural universities. Using weather satellites the El Niño and its effects on weather are monitored daily. Additionally, the Antarctic ozone hole is also mapped from weather satellite data. Collectively, To provide nearly continuous observations for a global weather watch the weather satellites of the U.S., Europe, India, China, Russia, and Japan are collectively utilised.

Both INSAT and IRS series of satellites have been continuously monitoring the weather and providing the warning dissemination and damage assessment all across the Country wherever the need arises. All these spacecraft have been tracking the cyclones on a regular basis. Utilising the Geographic positioning System (GPS) of USA and our IRNSS series, the location of position the events are also precisely projected. The Resourcesat and Cartosat series have been helping vastly in managing the disaster effect, particularly floods. Technology Experiment Satellite (TES) was used to monitor the potential flood threat to Himachal Pradesh in 2004 with high spatial resolution. For various users like Shipping Authority, Airports Authority of India, Coast Guard, Defence (Army, Navy and Air force ISRO is providing satellite-aided Search & Rescue services through participation in the COSPAS-SARSAT international programme. The Decision Support Centre (DSC) established at National Remote Sensing Centre (NRSC), Hyderabad, generates the disaster related information as per the user needs and such information is further distributed to the State and Central user agencies. NRSC/ISRO also has been providing flood information services, free of cost, to several states through State Remote sensing Application Centre (SRSACs). A Cyclone Warning Dissemination System (CWDS) consisting of over two hundred disaster warning receivers installed across the coastal region in cyclone prone areas of the country, provide warning to coastal villages about cyclone. One of the examples being Phailin at Odisha & Andhra Pradesh in October 2013.

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22. MARITIME AND IN-FLIGHT SATELLITE COMMUNICATIONS

a. Objectives:

The Satellite technologies enable the provision of seamless coverage across the globe. This seamless connectivity regardless of their location on land, in the air or on the sea helps to provide telecom services like voice, video and data services. This excellent feature of satellite communications has enabled to have easier maritime connectivity and also in-flight connectivity (IFC). In maritime connectivity it is possible to have ship to ships, ship to rig and ship to shore services. In IFC it is possible for the passengers to have telecom services in the Aircraft travelling at 800 Km per hour and 10,000 meters in the sky due to satellite-enabled connectivity. With the kind of advancements made in technologies it has become possible to meet ever increasing consumers' expectations both in maritime and IFC.

Maritime communication:

There are a variety of maritime platforms, such as merchant, cruise and government vessels. The safety and efficiency of maritime businesses and operations are very vital. To achieve these objectives real time communication, play a major role. The communication has to address voice, video and data services seamlessly. In addition communication between crews and passengers, videoconferencing facilities and video data downloading facilities are also essential ingredients. For conducting smooth professional work interacting with business partners, and family back at home are also important. All this eventually helps to improve performance and efficiency of maritime systems. In all these operations the satellite based systems facilitate smooth real-time communication

In addition, along the various coastlines one witnesses disastrous accidents time to time involving oil tankers with a potential to cause catastrophic economic and environmental consequences. Due to high volume of traffic and the possible risk of collision the maritime agencies have introduced ship routing systems, approved by the International Maritime Organization (IMO). These things are carried out by the space-based navigational constellations like the global positioning system (GPS). Due to the impact of the land/sea terrain the performance of the system at times degrades. To overcome this problem signals are augmented further using a mechanism called the differential GPS, with an accuracy of 1 to 5 m and becomes very essential in the maritime context.

Inflight satellite communication

It was in 2007, in-flight communication services were introduced by airlines in Africa, Asia, Australia, Europe, the Middle East and South America. (Reference 2).As on 2017, the IFC services were not allowed over Indian airspace. The Telecom Regulatory Authority of India(TRAI) generated a consultation paper, (Consultation Paper 14/2017) on in flight connectivity (IFC) in September 2017 and released the same for seeking comments from the right stakeholders. Telecom Department cleared the WiFi services on board the airlines for commercial operations but the implementation is quite slow due to high cost of the on-board equipment and also interruption due to Covid for almost two years from the second quarter of 2000.

b. Expected Benefits to Society:

The satellite based maritime communications offer several benefits. One of the major benefits, particularly with the INMARSAT series of spacecraft, is its near-global coverage (to 75° latitudes) as can be seen in the Figure 1 given below (Reference 1)

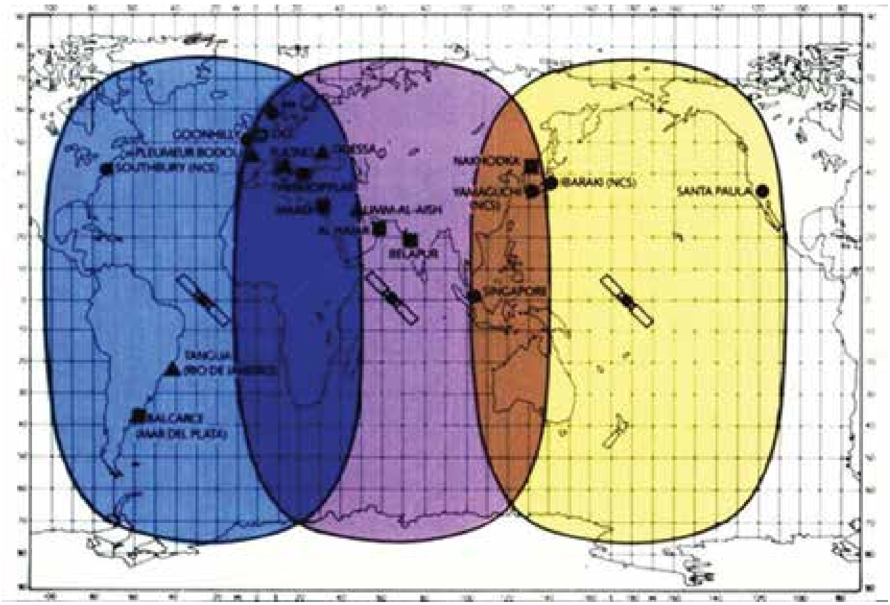

Figure 1 : Inmarsat's near-global coverage (reference 1)

With respect to emergency reporting, it offers priority access to Inmarsat satellites for distress alerts and also enables to have interconnection of services to the worldwide public telecommunication networks. The privacy of communications is also ensured. The biggest advantage of satellite based system is its instantaneous, high-quality service at all through the day or night, and not affected by weather or ionospheric disturbances

c. Implementation mechanism:

India's satellite GSAT-7 launched in August 2013 by Ariane space's Ariane 5 rocket supports the multi-band India's maritime communications. This satellite has enabled the strategic users to provide the major communications link. Among other things, this satellite assists to overcome the limitations from line of sight and ionospheric effects, GSAT-7 is an advanced communication satellite providing a wide range of service from low-bit-rate voice to high-bit-rate data communication and it is India's dedicated satellite for maritime communications, providing UHF, S-band, C-band, and Ku band relay capacity over the Indian landmass and surrounding seas.

Earlier, satellite communications for the strategic users was ensured through INMARSAT (International Maritime Satellite Organisation). Inmarsat, was established in 1979 at the behest of International Maritime Organization (IMO, a UN body) for building a satellite communications network for the maritime community. It has been providing maritime communication services to a large number of states including governments, airlines, oil and gas industry, mining and constructions, aid agencies among others.

In the Indian context, the surveying activities in the Indian Ocean Region and the surrounding seas are extremely essential. It is also important to have better understanding of the maritime domain to improve the overall maritime operations.

Inflight communication system

In a satellite-based WiFi system in flights, the on-board antennas are fitted on the top side of the aircraft. In order to receive the signals they have to constantly adjust their position to look at the spacecraft. The data is transmitted to the passenger's personal device through an on-board router, which, in turn, is connected to the aircraft's antenna. Atechnology shift is also seen from basic Wi-Fi systems to faster systems. The launch of High Throughput Satellites (HTS) in both Ku-band and Ka-band has vastly improved the in-flight connectivity. HTS systems not only increase the data speeds substantially but also bring down the costs, Over a period there is ever increasing interest by airlines for their quicker adoption with enhanced capability.

To utilise the IFC services, it is necessary to have a mobile earth station in the Aircraft to establish backhaul link with the ground. As per the International Telecommunication Union´s (ITU) mandate the mobile satellite service on board aircraft is defined as aeronautical mobile-satellite service (AMSS). This has to be combined with on-board access technology (Wi-Fi or mobile networks), for passengers to have telecom connectivity. AMSS networks comprise of three segments, as shown in Figure 2.

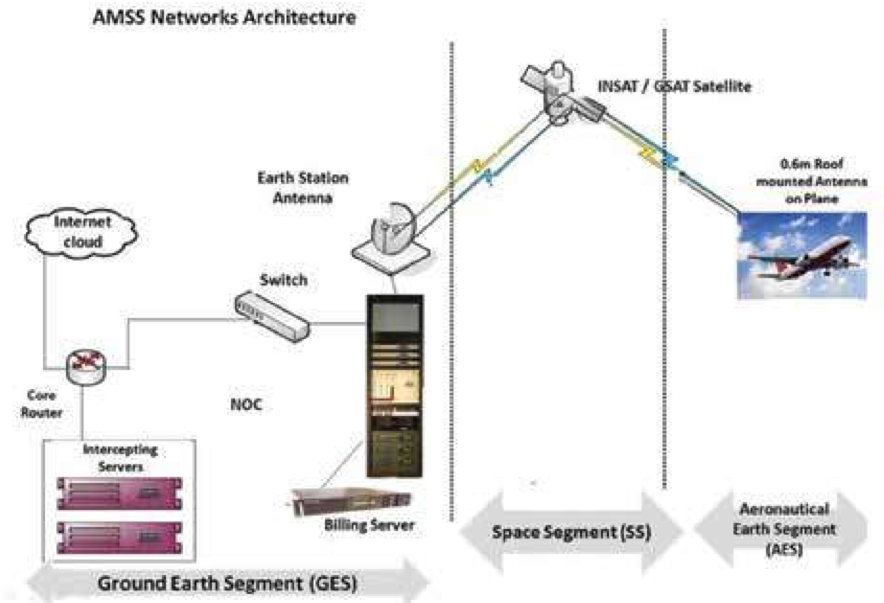

Figure 2. Aeronautical Mobile Satellite Services (AMSS) Network architecture (Reference 1)

The three segments of AMSS are as detailed below. The three segments are also distinctly indicated in the Figure 2. As AMSS has to operate on national and international airlines around the world, it has to be in conformance to global technical standard and operational requirements.

I. A"Space Segment (SS)", a satellite system (INSAT/GSAT series) providing a wide coverage;

II. An "Aircraft Earth Station (AES) segment", comprising of the equipment located on the aircraft like antenna, VSAT equipment, Wi-Fi APs etc., AES provides safety related broad-band data communication services (e.g. internet and other type of data services) to users on board. The frequency of operation of AES is generally in the Ku bands (operating in 14-14.5 GHz frequency) allocated to the mobile satellite service (MSS) and in the fixed satellite service (FSS) allocations at 10/11/12 GHz, operating on a non-protection basis.

a. For the purpose of IFC, Earth Station in Motion (ESIM) functionally serves the same purpose in Ka band as AES does in Ku band. Therefore, following are the frequency ranges that can be used for IFC in Ku and Ka bands in the space segment:

b. Frequency Ranges in Ku – Band
14.00 - 14.50 GHz (Earth-to-space);
10.70 - 11.70 GHz (space-to-Earth);
12.50 - 12.75 GHz (space-to-Earth).

c. Frequency Ranges in Ka – Band
19.7-20.2 GHz (space-to-Earth);
9.5-30.0 GHz (Earth-to-space).

III. "Ground Earth Segment (GES)" with the Hub/ Earth station for the network located at ground controlling the remote mobile earth stations and hosting the network operation center (NOC). NOC controls the emissions of the AMSS network and prevents interference with other systems

The on-board access technology, combined with AMSS, enables passengers to have telecom connectivity. The on- board access technology is essentially Wi-Fi having access to Internet, e-mail, on board aircraft. Presently the mobile phone in aircraft was not allowed to use in active mode, due to potential interference to safety-critical aircraft systems. 'Mobile Communication services on board Aircraft' (MCA) system is the solution to minimize the interference from airborne wireless devices with terrestrial networks. (Reference 2)

The MCA System consists of an airborne picocell – a very small low power mobile base station; and a network control unit (NCU). This unit prohibits onboard phones connecting with land-based networks.

The satellite link in MCA connects the aircraft to public phone networks on the ground. An Aircraft GSM Server (AGS) integrates the main modules onboard like NCU and the satellite modem. The figure 3 shows the block diagram of the system. A picocell is an antenna system used in the aircraft. The mobiles onboard connect to onboard pico base station using any standard radio interface, like GSM.

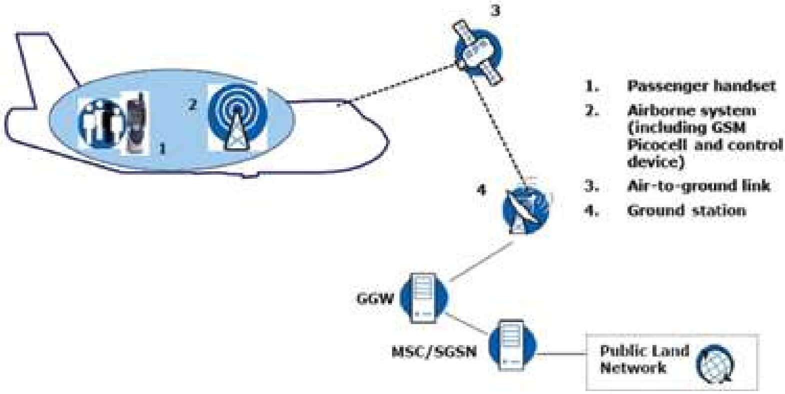

Fig 3 : Typical Block Diagram of MCA (Reference 2)

d. Area Coverage: National / State / District

The Indian satellites have the wide coverage over the Indian landmass as well as the surrounding seas. The payload of GSAT 7 is designed to provide communication capabilities to users over a wide oceanic region including the Indian land mass.

e. Results Obtained: (compare with item b above)

Regarding air flight connectivity, it has been three to four years since the Department of Telecom has permitted WiFi services on commercial flights (December 2018) in India. The larger installation costs and slower passenger demand due to COVID-19 have slowed down the implementation of WiFi services on board in India. As on date only Indian airline carrier Vistara is offering the service to its customers since September 2020 and spicejet is trying to implement it. However, the new jets from Airbus and Boeing come fitted with the needed equipment. (Reference 2). Although the introduction of these services are slow it is going to be accelerated in the coming years particularly for the in flight connectivity.

f. Users' Perspective

India is one of the fastest growing markets in the globe, in the air travel and the passengers numbers are also substantially increasing. Therefore, the need for the IFC has been increasing in both Indian and foreign airlines operating in the Indian region. Similarly the demand for maritime services are also on the increase for the ships operating in the region.

As far as search and rescue services are concerned, India has been a member of the international COSPAS-SARSAT programme. Under this scheme India has been providing distress alert and position location service through LEOSAR (Low Earth Orbit Search And Rescue) satellite system. To meet this requirement India has established two Local User Terminals (LUTs), one at Lucknow and the other at Bengaluru. The Indian Mission Control Centre (INMCC) is located at ISTRAC, Bengaluru. The system is operational more than 23 years. The development of indigenous search and rescue beacons has been completed. Indian LUTs have been providing coverage to a large part of the Indian Ocean region rendering distress alert services to many of the neighboring Countries. (Reference 3)

The notification on the Flight and Maritime Connectivity Rules was released in December 2018 and with that the path has been defined for airlines and telecom service providers to give inflight connectivity in the Indian airspace. However, the commercialization and subsequent revenues are dictated by the costs of service provision. It is expected that there will be more participation from the private sectors and also there will be lowering of the cost of satellite bandwidth. It is also important to provide adequate bandwidth and make the cost of in-flight connectivity affordable for consumers

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23. SATELLITE BASED IOT NETWORKS FOR EMERGING APPLICATIONS

a. Background:

Satellite based-Internet of things (IoT) networks have proven to be an omnipresent technology for several existing and new applications in terms of providing both accuracy and sustainability in the emerging services and applications. It also offers long term sustainable network solution for several applications. IOT is essentially a group of objects consisting of sensors, processors, associated software, and technologies which deal with the connection and exchange of data with other devices and systems over the communications networks which can be internet too. The biggest advantage of satellite communication is that it gives a wide coverage thus reaching the remotest and unreachable areas particularly in a vast Country like India including the north-eastern states and many other hilly regions. The satellite communication technologies have been evolving over the years and presently it offers low-bit-rate applications having low cost, low power and small size terminals. The major advantage in such systems is the signal transfer with minimum loss. This becomes very effective in numerous sectors where the applications can be implemented by utilizing a suitable satellite networking protocol and sensor connectivity solutions. In fact internet helps to enhance the dimensions in many ways using IOT's. It enables humans and machines to transact using IOT based networks. The several dimensions of IOT facilitates numerous applications and also large communications networks. This write up attempts to highlight the usage of Satellite based IOT networks in several emerging applications. The Internet of Things (IoT) is expected to bring new opportunities for improving several services for the Society, from transportation to agriculture, from smart cities to fleet management and many more.

b. Objectives:

The Internet of Things (IoT) is aimed at enabling the interconnection and integration of the physical world and the cyber space. The main objective is to utilize the satellite based IOT networks for many emerging applications which includes disaster management and military communications by proper networking. These are mission critical applications, and in such cases the network coverage has to be there all the time. The location determination, navigation monitoring, and location based services are equally important. Another essential feature needed in such critical systems is security of IoT, which has more vulnerabilities from several grounds. To assist the rapid growth of the Country's development, increased usage of IoT in several applications all through the Country is imperative. The reach to even the most remote and unreachable parts enables to bring in many transformative progress to several industries

c. Expected Benefit to Society:

Satellite based IoT can have vast benefits in several emerging applications as it provides not only different levels of coverage but also in difficult geographical locations. Several applications demand wide coverage, low power and high reliability for the communication. Due to wide coverage of Satellite networks the satellite based IoTs are advantageous over the cellular IoT, which has the limitation of coverage and also the high radiation densities. Satellites with proper constellation configuration gives the coverage 0f 99.9% and is essential for the mission critical applications like disaster management and military communications. Usage of satellite network no doubt helps to enhance the overall stability, so that applications such as remote asset monitoring can take advantage of an always on connectivity.

Some of the vital services like transport infrastructure , smart cities and offshore works are major beneficiaries of satellite-backed IoT. The use of broadband connections on trains, maritime vessels and cargo vehicles has been made possible due to satellite communications. So also smart cities need up-to-date data to allow administrators to guarantee sustainability. The biggest advantage of satellite IoT is the smart grids which can extend into more rural areas where the existing traditional, terrestrial networks are not be able to reach. In offshore work the satellite based network enhances the safety of work, particularly for the oil rigs where they can use IoT sensors to improve safety and monitoring of their employees.

d. Implementation mechanism:

Internet of Things (IoT) is one of the evolutionary directions of the Internet. One solution is to have the low earth orbit (LEO) satellite constellation-based IoT services. In most of the cases, IoT devices can be distributed to remote areas (e.g., desert, ocean, and forest). However in some special applications, they are placed in some extreme topography, where it is extremely difficult to have direct terrestrial network access and can be covered only by satellite. If one considers the traditional geostationary earth orbit (GEO) systems and the, LEO satellite constellation the latter one has the advantages of low propagation delay, small propagation loss and global coverage. The existing IoT protocols are to be revised to enhance the compatibility of the LEO satellite constellation-based IoT with terrestrial IoT systems. Proper details in terms of LEO satellite constellation structure, efficient spectrum allocation, heterogeneous networks compatibility, and access and routing protocols are all have to be carefully analyzed and implemented for proper efficient functioning of the system.

A typical architecture of satellite based IOT network is shown in Figure 1. (Reference 1) It shows a sample deployment scenario of a satellite IoT system. What is explained in the Figure is an harbour area, in which transport ships and logistic units exchange goods, whereas on the space side, spacecraft is gathering data from the system located on earth.

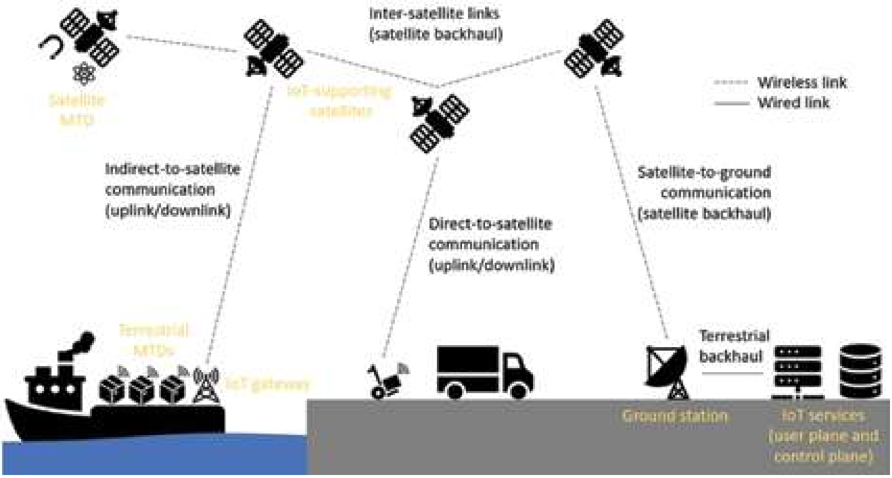

Figure 1. A Typical architecture of satellite based IOT network
(Courtesy : Reference 1)

d. Emerging applications

Satellite based Iot's are finding applications in many emerging areas. Some of the applications are detailed as given below.

1. Supply Chain Management

Asset tracking: vehicle fleet management, on-time delivery, real-time location, inventory, cold chain management of refrigerated items like medicine/food, etc.

2. Smart Grids

Some of the applications are monitoring of remote transmission towers, management of load distribution, supply/demand estimation. In additions other attractive applications are sensor-based systems for Remote Industries and Connected Healthcare, Supervisory Control and Data Acquisition (SCADA) and many more.

3. Traffic monitoring.

While implementing smart cities, the Internet of things is highly advantageous in the management of vehicular traffic in large cities. While using the mobile phone as sensor, in collecting and sharing the data from a vehicle through applications such as Google Maps, one is using the Internet of things to inform the route. The other functions are traffic monitoring, showing the traffic densities at different routes, distance, estimated time of arrival etc..

4. Fleet management.

In fleet management, the installation of sensors vehicles establishes a very effective interconnectivity between the vehicles, the controlling officer, the vehicles and drivers. Both driver and controlling officer are updated in real time the status on operation of the vehicle, needs etc, through the software which collects, processes and organizes the data. The alarm in real time is a great boon. The geolocation assists in big manner towards, (and with it the monitoring of routes and identification of the most efficient routes), performance analysis, fuel savings, the reduction of polluting emissions to the environment and also in providing the valuable information to improve the driving of vehicles.

5. Disaster Management

The Satellite based Iot's applications in disaster management are very crucial. Many of the applications are delivery of real-time and geo-location alerts in case of floods, landslides, etc. These systems cannot afford the absence of the network for even a short time During the natural disasters the wireless infrastructures are directly affected. Very often the functioning of the networks gets affected for days and in some cases even for months. The satellite based IoTs are not vulnerable to the natural disasters and therefore preferred for such situations. Emergency alert broadcasts and SOS messaging for fishing vessels, real-time tsunami alerts from marine buoys, detection of fires in rural forests or strategic buildings are other vital applications. Managing logistics of disaster management vehicles, boats, fire engines, ambulances, etc., during natural disasters and accidents are also equally important.

6. Railways

The application in Railways will be similar to the automobile fleet management. What are very vital for railways are geo-location of rolling stock assets, monitoring of safety systems in a train, safety critical two-way data, etc. It has been proven that this system helps to implement very effective tracking the large fleet of trains thus assisting efficient usage, improvement in time management, considerable savings in the cost of fuel and many more.

5. Agriculture.

Smart farms are becoming a reality and towards that satellite based IoT's make a significant contribution. One of the important input provided by the system is the quality of soil to farmers giving valuable information on the soil condition. What is needed is right choice of IoT sensors. The data to be gathered are state and stages of the soil, information on soil moisture, level of acidity, the presence of certain nutrients, temperature and other chemical characteristics. These data facilitate the farmers to control the irrigation, make water use more efficient and choose the best times to start sowing. It is even possible to discover the presence of diseases in plants and soil and this is of immense help in saving their produces.

6. Fisheries

Fisher men and the fishery industry derive great benefits form Satellite based IoT services by utilizing the sensor-based connectivity for location, vessel monitoring, and maritime boundary alerts.Identification of geo-fenced fishing zones, for monitoring the cold-chain of stored fish, two-way emergency messaging system for distressed vessels, inclement weather

7. Health services response mechanism

There is vast scope to assist and improve the health services response mechanism. One of the essential applications is the tracking of ambulance and medical logistics especially in rural areas and also vehicle telemetry. Live monitoring of patients' diagnostics, etc., is a very vital area. The use of wearables or sensors connected to patients, allows doctors to monitor a patient's condition outside the hospital in real-time. The care of the patients improves substantially by continuous monitoring of certain metrics and send automatic alerts on their vital signs. In cases of high –risk patients IoT helps not only in improving the care for patients but even prevents of lethal events in such patients. Smart beds is another important tool where the integration of IoT technology into hospital beds, equipped with special sensors to observe vital signs, blood pressure, oximeter, body temperature, and disease specific instruments.

8. Smart grid and energy saving.

Very efficient monitoring and control of the electrical network can be done by the progressive use of intelligent energy meters equipped with appropriate sensors, which are installed in different strategic points. Further the establishment of bidirectional communication between the service providers and the end user, is of great help in the detection of faults, decision making and and also repairs. The consumption patterns and the means to reduce or adjust the energy expenditure can also be derived very effectively in such IoT assisted systems

9. . Water supply.

Water meters incorporated with sensors and connected to internet with suitable software greatly assists to gather, process and analyze data. This in turn facilitates to understand the, the behavior of consumers, to report results and to detect faults in the supply service. Based ont this the service provider can initiate the corrective actions. Even consumers have the advantage of tracking their own consumption information, through a web page and in real time. They also can get the automatic alerts in case of consumption out of range compared to their average consumption record, which helps to detect the presence of a leak.

10. Hospitality.

The quality of service in hotel industry can be greatly enhanced by the application of the IoT it is possible to automate various interactions, where the information with the electronic keys, are sent directly to the mobile devices of each guest, Many other services which can be automated are, the location of the guests, the sending information of interest to guests on activities of interest, room service, the automatic charge of room request of personal hygiene supplies etc., Many more such activities can be very efficiently and quickly managed through integrated applications using the Internet of Things.

11. Maintenance management.

Most extensive application of IoT technology is in maintenance management. Through the combination of sensors and software specialized in Computerized maintenance and Management System (CMMS) or even Enterprise Asset Management (EAM), very effective maintenance management can be carried out. EAM is a combination of software, systems and services used to maintain and control operational assets and equipment. These kind of maintenance management can function as a multifunctional tool and its use can be applied to a multiplicity of disciplines and practices, The main objective in all these cases is to extend the useful life of physical assets, and also to guaranty the asset reliability and availability. The applications can become unlimited when the software is designed to specifically address the maintenance management needs of physical assets. The real-time monitoring of physical assets helps to determine the out of range measurements. If the application of Artificial Intelligence (AI) algorithms such as Machine Learning or Deep Learning are used in conjunction, it further helps to predict the failure before it happens.

12. Location based services

Many services need the exact locations to execute or deliver their services. Satellite based IoT networks provide much better location compared to cellular networks. It becomes very important in strategic applications and in many other cases too location accuracies are highly critical. Satellite based positioning systems using IoT are preferable over other available alternatives due to their accuracies.

e. Area Coverage: National / State / District

The satellitesare located such that it gives full coverage over the entire country including the remotest places a, hilly areas and also north eastern region. Certainly more and more services are finding the applications of satellite based IoT's. All such applications are very attractive and have been helping in accelerating the development in the Country.

f. Results Obtained and scope for extensions: (compare with item c above)

In India, there is an increased adoption of IoT's in several areas like customer engagement, supply chain management, virtual conferencing. The examples include smart doorbells, CCTV and surveillance, telepresence robots, etc. India has a rich talent ecosystem for IoT and also there is increased investment in digital infrastructure.'Make in India' and 'Digital India' are the two flagship programmes of the Indian government. The satellite connectivity in India is well established. With proper policy support and strong public-private partnership the working in silos are to be linked so that satellite based IoT's will bridge many gaps. This kind of collaboration not only assists to boost India's economy but also in India becoming a leader in the usage of satellite based IoT services and creating a real-time virtual world.

The viability of satellite technologies for IoT, which is mainly supported by low-orbit constellations, has to be assessed in the Indian context and also in the framework of the specific requirements. More efforts re needed to take a close scrutiny towards a renewed, future, vision of IoT technologies. The emerging standards also need attention.

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Navigation Area

24. GPS AIDED GEO AUGMENTED NAVIGATION (GAGAN)

a. Objectives:

The current navigation techniques employed by the aeronautics globally are limited in various aspects including accuracy and coverage. To overcome these limitations, International Civil Aviation Organisation (ICAO) introduced Global Navigation Satellite Systems (GNSS) into civil aviation. However, further improvement in the position accuracy, integrity and availability of GNSS signals was necessitated. This has resulted in conceiving Space Based Augmentation System (SBAS). The basic function of SBAS is to provide additional ranging signals to improve availability and to provide integrity data of navigation satellites.

Currently, SBAS has been established by USA (Wide Area Augmentation System – WAAS), European Union (European Geostationary Navigation Overlay System - EGNOS), Russia (System of Differential Correction & Monitoring – SDCM), China (BeiDou Navigation Satellite System SBAS – BDSSBAS) and Japan (MTSAT Satellite Augmentation System – MSAS) providing services in a specific region as given in figure below

After USA, Europe and Japan, India is the fourth country in the world, in establishing an SBAS called as GPS Aided Geo Augmented Navigation (GAGAN) system. The prime objective of GAGAN is to meet the ICAO requirements ofcivil aircraft operation services over India and adjacent regions, not covered by any other SBAS systems. The method of operation of GAGAN is by augmenting thesignals of GPS signalsand providing information required for enhanced accuracy and integrity as demanded by civil aviation in India and adjoining countries.

b. Expected Benefit to Society:

GAGAN, unlike other SBAS,is designed with a unique IONO algorithm considering the equatorial anomaly region. Hence, GAGAN system enables users to rely on GPS for all phases of flight, from en-route through approach for all qualified airports within the GAGAN service area which falls under equatorial region.

The GAGAN system brings numerous benefits to the aviation sector in terms of fuel saving, reduction in equipment cost, flight safety, increased air space capacity, improved efficiency, enhancement of reliability, reduction in work load for operators, coverage of oceanic area for air traffic control and importantly high accuracy positioning. This improves the air traffic management over Indian airspace

GAGAN is also expected to provide benefits to non-aviation sectors. This includes all modes of transportation, including maritime, highways, railroads and public services such as defence services, security agencies, telecom industry and personal users of position location applications.

c. Implementation Mechanism:

GAGAN is implemented such that it is interoperable with other SBAS systems and provides seamless augmented navigation across regional boundaries.

GAGAN system mainly constitutes of three segments

1. Space Segment
2. Ground Segment
3. User Segment

GPS and geostationary satellites together form the space segment. The GAGAN payloads operate in two frequencies: L1 (1575.42 MHz) and L5 (1176.45 MHz). The GAGAN payloads are incorporated on three geostationary satellites of ISRO; GSAT-8, GSAT-10, and GSAT-15.

A network of Indian Reference Stations (INRES), Indian Master Control Centres (INMCC), and Indian Land Uplink Stations (INLUS) form the ground segment. Fifteen reference stations have been established all across the country. These are used for collecting data for the grid-based ionospheric model transmitted by GAGAN.

The user segment is primarily the airlines of civil aviation sector.

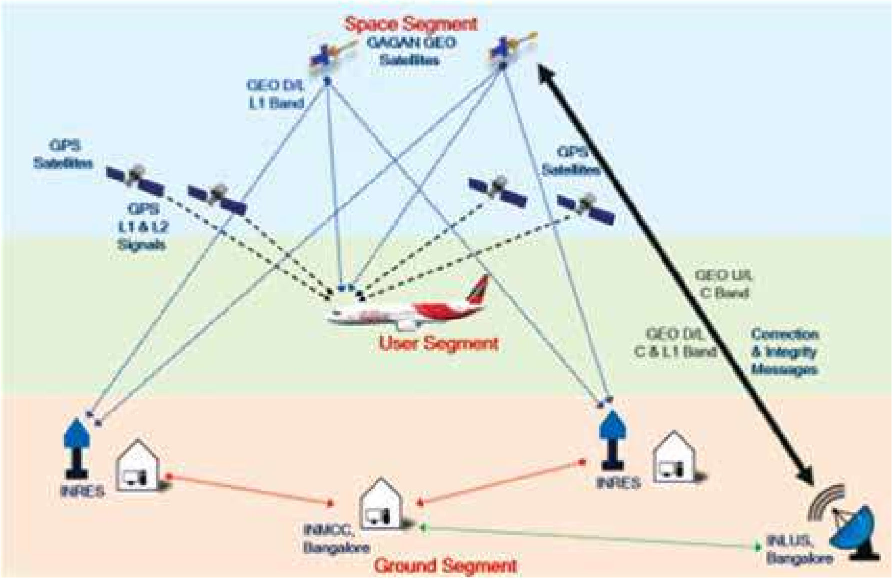


Figure 1. Gagan System

The Fig.1above explains the way GAGAN signal is being broadcast through geostationary satellites covering the entire Indian Flight Information Region (FIR) and beyond.

The GAGAN system utilises a network of 15 Indian Navigation Reference Earth Stations (INRES) spread over the country. They are precisely surveyed to compare the position determined from GPS satellite signals against the location of the receiver. The deltas so observed are then sent to Indian Navigation Master Control Centre (INMCC) through Optical Fibre Cable Data Communication Network as well as VSAT link. The control centre processes the data to generate correction parameters for GPS signals applicable within the service region and is uplinked to geostationary satellites through Indian Navigation Land Uplink Stations (INLUS). The user receiver processes the GPS data and the correction parameters broadcasted from geostationary satellites to compute more precise position. The GAGAN signal is not encrypted. The GAGAN message uses a modulation scheme similar toGPS wherein the same Gold code family, chipping rate, BPSK modulation of the same GPS carrier frequency of 1575.42MHz with the difference being that a 250 bps bit stream is modulated instead of the 50 bps data stream as in GPS. The 250 bps data stream contains messages such as satellite integrity and differential corrections.

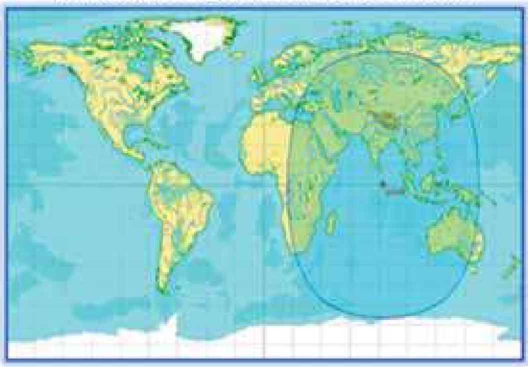
Airports Authority of India (AAI) is in the process of updating and implementing the en-route and approach procedures at various airports of India for aircraft operations using GAGAN as published in Aeronautical Information Publication(AIP) by AAI.

d. Area Coverage: National / State / District

USA, European Union, Japan, India, Russia and China have established SBAS system. South Africa, Australia, and South Korea are also in the process of establishing SBAS system for their regions.

GAGAN is the first SBAS system to be established in the tropical region of the world covering fairly large area beyond Indian Territory, from Africa to Australia and supports seamless navigation.

Common coverage of GAGAN GEO satellites



Indian Flight Information Region

e. Results Obtained: (compared with item b above)

The system stability test was successfully carried out in June-July 2013 and with this the GAGAN system was certified for use by civil aviation to meet their requirements. The Stability Test was essentially to evaluate the system performance and its critical parameters. This has been done in an integrated manner with live environment using the satellite signals and ground based systems. The various tests conducted were on integrity, accuracy, continuity and also its availability for aviation use and tests were all satisfactory. The Directorate General of Civil Aviation (DGCA), India,hascertifiedGAGAN System for Navigation Performance level of Approach with Vertical Guidance (APV-I) over India and Required Navigation Performance (RNP 0.1) within Indian Flight Information Regions.

f. Users' Perspective

As far as users are concerned GAGAN system provides enhancedaccuracy, reliability and reduces delays to aircraft. GAGAN system also helps to reduce the workload of flight crew and air traffic controllers. GAGAN system along with existing Ground Based Augmentation System can enable the aircraft approach/landing operations during in inclement weather conditions. Further the users will have reduction in delays and increases the capacities of the airport and airspace.

GAGAN is also being used innon-aviation applications. I) In UAV applications by defense research organizations. II) Indian National Centre for Ocean Information Services (INCOIS) uses GAGAN message system for broadcasting early warning / alert messages for oceanic regions and potential fishing zones for the benefit of fisherman in deep seas along with navigation information using GAGAN signals. III) Indian Railways for relaying train-running data by equipping the locomotives with GAGAN enabled GNSS devices. IV) Many government, scientific and private sector agencies are using GAGAN signals in areas of survey, forest, land management through terrestrial mapping, geo fencing, geo mapping of assets and asset management, location based services, research applications etc.

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25. NAVIGATION WITH INDIAN CONSTELLATION (NAVIC)

a. Objective

Indian Regional Navigation Satellite System (IRNSS), owned and operated by the Government of India is an autonomous system designed with an objective to cover the Indian region and 1500 km around the Indian mainland. The system is made operational in 2018/19 with 7 satellites. In 2016, IRNSS was renamed as the Navigation with Indian Constellation (NavIC), meaning "sailor" or "navigator". NavIC is Designed to provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary, its primary service area. An Extended Service Area is between primary service area and area enclosed by the rectangle from Latitude 30 deg South to 50 deg North, Longitude 30 deg East to 130 deg East. The services provided are of two types, namely, (i). Standard Positioning Service (SPS), provided to all the users and (ii). Restricted Service (RS), an encrypted service provided only to the authorised users. Position accuracy expected is better than 20 m (2σ) in the primary service area. The configuration of the system is given in Figure 1.

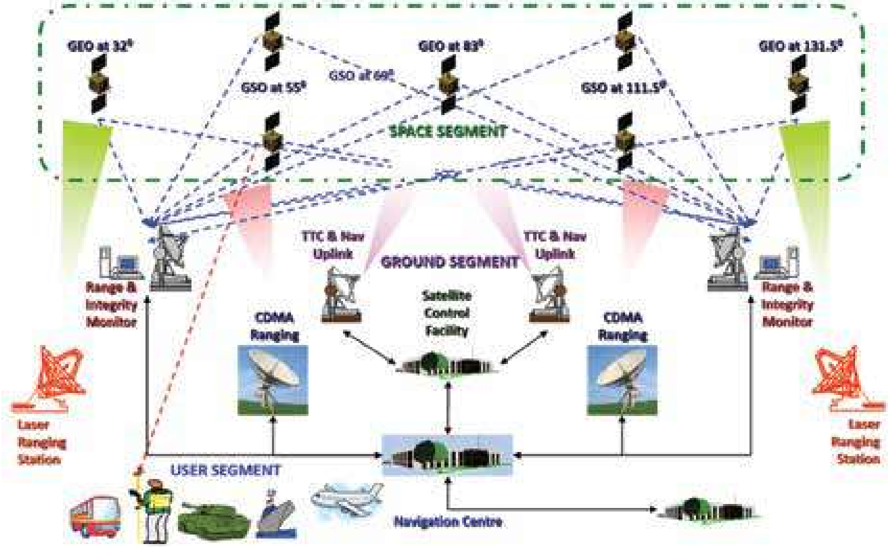


Figure 1: Configuration of IRNSS System.

b. Expected benefits to Society

Successful developments of NavIC constellation and GAGAN augmentation system have been providing immense benefits in the Country in several areas. The global systems like GPS, GLONASS etc., are controlled by the respective countries and there is a possibility that the services may be denied at times. Therefore, India decided to have an independent, self-reliant navigation system. The benefits of navigational applications are several not only in civilian applications but also in strategic sectors too. The IRNSS is used in a number of applications like a) Terrestrial, aerial and marine navigation b) Disaster management c)Vehicle tracking and fleet management, d)Location based services through integration with mobile phones e) Precise Timing, f)Mapping and geodetic data capture, g) Terrestrial navigation aid for hikers and travelers and h) Visual and voice navigation for drivers and in many more similar applications. NavIC system is useful in providing the short message broadcast services, such as disaster alerts, information on potential fishing zones, and alerts on approaching an international border to fishermen in local languages. The space-based systems like GAGAN and NavIC have been benefiting the common man and has been helping in transforming the livelihood of our citizens. With the entire system in place the utilization of IRNSS is going to increase several fold in the coming years and extensive use would vastly help the Country to derive maximum benefits.

c. Implementation mechanism:

The Indian system is configured as a regional system comprising of seven satellites: three in geostationary orbit (GEO) and four in geosynchronous orbit (GSO) with 29^{o} inclination. Three satellites are located in suitable orbital slots in the geostationary orbit and the remaining four are located in geosynchronous orbits with the required inclination and equatorial crossings in two different planes as shown in the Figure above. All the satellites of the constellation are configured identically. The satellites are built with I-1K Bus to be compatible for launch on-board PSLV. The first satellite of the programme, IRNSS-1A, was launched on July 1, 2013 and the latest on April 12, 2018.

The selection of orbital positions of IRNSS satellites is made to have continuous visibility over the service area and to provide the required geometric dispersion and to achieve good Geometric Dilution of Precision (GDOP). The determined position accuracies are comparable to the other GNSS. NavIC is designed to provide Position, Navigation, and Timing (PNT) services over the Indian subcontinent, covering India and the surrounding region up to 1500 km. Designed to have the position accuracy better than 20 meters. Navigation satellites use atomic clocks having an accuracy of +/- 5 parts within 10^{11}. These clocks are synchronised by the more accurate ground-based caesium clocks to ensure that they only gain or lose a second over 1,000,000 years.

Two types of services are supported through NavIC, Standard Positioning Service (SPS), which is provided to all the users, and Restricted Service (RS), which is encrypted and provided only to authorised users. Based on coordination with the other GNSS systems at the time, India decided to use L5-band (1164.45 to 1188.45 MHz) and S-band (2483.5 to 2500 MHz) using grid-based ionosphere corrections. BPSK modulation for SPS service is used in NavIC. The NavIC service area is shown Figure 2

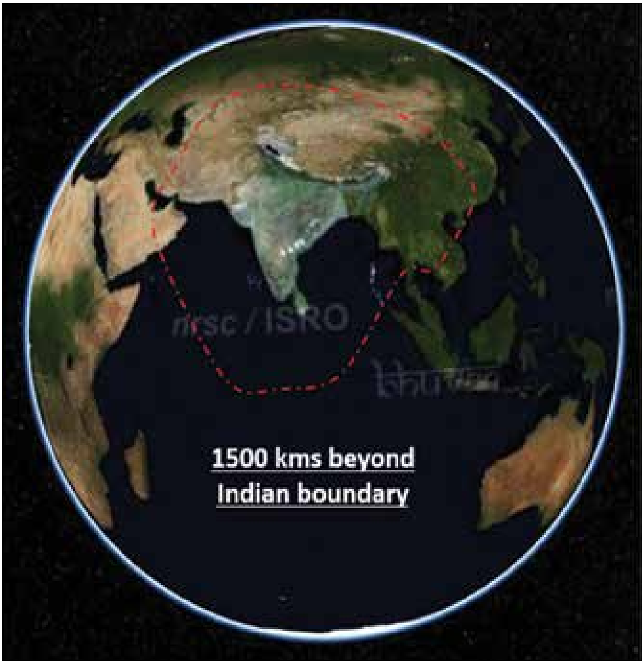


Figure 2: NavIC service area

The ground segment of NavIC is responsible for the maintenance and operation of the satellite programmes. The navigation services include navigation parameter generation, its transmission, satellite control, ranging and integrity monitoring, time keeping, mission control, and various other activities. Spacecraft control facilities, range and integrity monitoring stations, navigation centres, network timing facilities, CDMA ranging stations, laser ranging services, and data communication networks (for connecting all these ground facilities)form the ground segment. Different types of user devices and applications have been deployed in India to utilise the full potential of NavIC. The use of S-band frequency due to its lower ionospheric delay provides has potential to provide better position accuracy when compared to an L-band. This is beneficial to single-frequency users. Development of special ionospheric models provide improved position accuracies.

If we look at the global scenario, Global Navigation Satellite System (GNSS), the GPS and GLONASS satellites are fully operational. In 1998, the European Union started a satellite navigation system independent of GPS and GLONASS. The European system is named Galileo, consisting of 30 satellites. Chinese system named BeiDou and has its own satellites in orbit. There are two regional constellations of satellites: the Navigation with Indian Constellation (NavIC) and the Japanese Quasi-Zenith Satellite System (QZSS) have placed satellites in orbit.

While it is possible to use civilian navigational services through the clusters of satellite systems from other countries, it becomes essential to have one's own system to meet the specific strategic requirements. Therefore, expansion of regional services to global services becomes important. Improvement of accuracy is also another requirement. India has plans to expand NavIC into a global system in the years to come. The important features of GPS, GLONASS, Galileo, BeiDou, and NavIC are given in the following table

	GPS	GLONASS	Galileo	BeiDou	NavIC
Owner	USA	Russia	EU	China	India
Orbit	MEO 20,180 km	MEO 19,130 km	MEO 23,222 km	GEO and MEO 21,150 km	GEO or GSO 36,000 km
No. of Satellites	24+ 7	24+4	24+6	5 GEO, 30 MEO	7 GEO/GSO
Frequency	1575.42 MHz (L1) 1227.6 MHz (L2)	~1.602 GHz ~1.246 GHz (L2)	1164–1215 MHz (E5a&b) 1260–1300 MHz (E6) 1559–1592 MHz (E2-L1-E11)	1561.98 MHz (B1) 1589.742 MHz (B1-2) 1207.14 GHz (B2) 1268.52 MHz (B3)	1164.45–1188.45 MHz (L5) 2483.5-2500 MHz (S)
Coverage	Global	Global	Global	Global	Regional
Status	Operational	Operational	Operational	Operational	Operational

d Area Coverage: National / State / District

IRNSS provides accurate position information service to users in India as well as the region extending up to 1500 km from its boundary, its primary service area. Seven NavIC satellites are always present for the users in the primary coverage area supporting stand-alone NavIC solution or supplementing multi-GNSS solution.

e. Results Obtained: (compare with item b above)

The NavIC is used by several agencies in India, across the Country. Some of the user agencies are telecom, automobiles sector, power grid, safety of life, maritime, scientific applications like space weather. The details of usage in these areas are given below.

Telecom:

Major mobile chipset manufacturers (Qualcomm, Mediatek) have developed mobile processors supporting NavIC. In Indian market, mobile handsets with NavIC capability have already been released by various mobile OEMs (Xiaomi, Realme, OnePlus) in the Indian market. NavIC is a part of telecom specification for Assisted-Global Navigation Satellite System (GNSS) by 3rd Generation Partnership Project (3GPP) - an international standards body. In this technology, the cell tower transmits data of GNSS to the mobile handset, which helps to obtain its location in significantly less time and with less computation.

NavIC enabled chipsets

Major chipset manufacturers viz., Quectel, Telit, U-TraQ, SkyTraQ, Allystar have developed NavIC enabled processors that can be used in handheld devices, vehicle tracking devices, UAVs, and other general position, navigation and timing receivers. The device manufacturers can use these chipsets available in Indian market for their applications.

Figure 3. NavIC enabled chipsets

Automobiles:

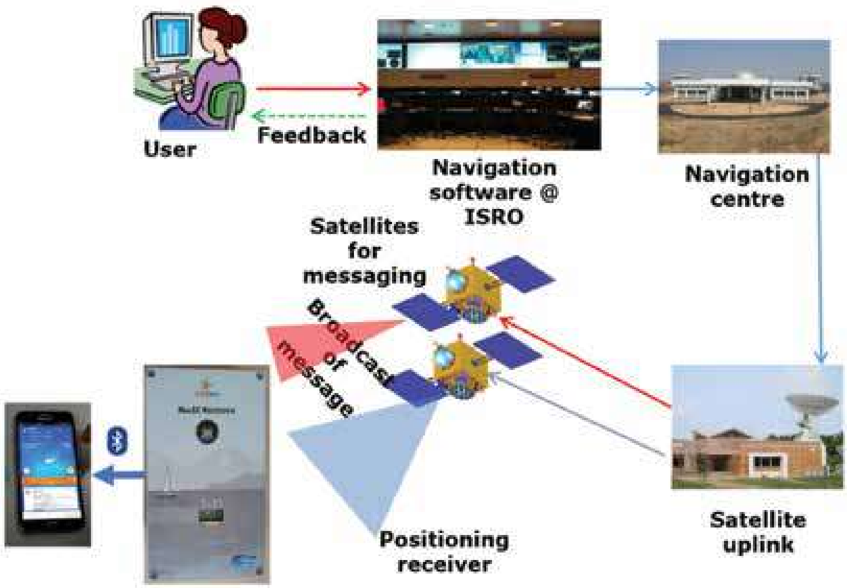
From 1st April 2019, use of NavIC-based vehicle tracking system has been made compulsory for all public and commercial vehicles in India. The automotive R&D centers and device manufacturers are routinely carrying out tests and certification for NavIC enabled vehicle tracking devices. More than 120 products have been certified. The details are available online. Several thousand vehicles are now plying the roads equipped with these devices. NavIC is also enabled for incorporation in multiple sectoral transportation platforms like autorickshaws, mining, etc.

Power grid:

NavIC timing receivers have been installed at phase measurement units (PMUs) at five major sub-stations operated by the Power Sector Operations Corporation (POSOCO). These stations are located at Shillong, Patna, Dadri, Boisar and Tumkur. Trials have indicated successful timing reference to synchronize the power grids through these NavIC receivers. POSOCO is now in the process of procuring NavIC enabled PMUs from OEMs for deployment in all the sub-stations.

Safety of life:

NavIC messaging service has been operationalized to provide safety of life alerts to fishermen who undertake deep sea fishing, where there are no means of terrestrial communication. In this service, alerts related to high sea wave, cyclone and tsunami are broadcast by Indian National Centre for Ocean Information System (INCOIS) using the NavIC satellites IRNSS-1A and IRNSS-1G. Additionally, messages related to potential fishing zones are also sent using this system. Trials have been carried out at various locations in Kerala, Karnataka and Tamil Nadu coast. An updated app has been released and operationalised. ISRO has transferred the technology to six Indian industries for mass productionisation. Fisheries Departments of relevant States have been linked to the industries for their bulk requirements.



ISRO has designed a two-way system in which fishermen can initiate distress signal (such as fire on board, health issues, boat sinking) which is transmitted to the Coast Guard; in return, acknowledgement of receipt of the distress signal and initiation of rescue is conveyed to the distressed fishermen through NavIC messaging service.

Maritime:

NavIC has been recognized by International Maritime Organization (IMO) as a component of Worldwide Radio Navigation System (WWRNS). This enables the incorporation of NavIC based receivers in maritime domain. NavIC is incorporated in Radio Technical Commission for Maritime Services (RTCM) standard. This enables NavIC in differential GNSS applications in the maritime sector.

Surveying and geodesy:

Efforts are underway for introduction of high accuracy NavIC-enabled GNSS receivers in surveying and geodesy. The availability of dual-frequency NavIC receivers with geodetic grade antennas, multi-GNSS support and high precision positioning engines will pave the way for utilization in these sectors.

Critical Infrastructure and Flagship programmes:

Efforts are being made to induct NavIC in other critical infrastructure and flagship programmes such as IST dissemination and time synchronization across various sectors, smart city, UAVs, precision farming, assets monitoring, automation systems requiring high position accuracy.

f. Users' Perspective

The application of NavIC in India is increasing progressively. The perspective of some of the users of NavIC in India is highlighted below.

The fishermen have been using NavIC Messaging Receivers (NMRs) meant for receiving the useful information like potential fishing zones (PFZ) data, disaster warning messages like high wave, rough sea, cyclone and tsunami, distance from international maritime boundary. All these messages are being broadcasted using IRNSS-1A/IRNSS-1G satellite. Among these messages, the PFZ data is nominally transmitted from 5:00pm to 8:00pm daily and the disaster warning messages are transmitted as soon as one of the disasters are detected. For this reason, the fishermen are advised to keep power on and pair with the mobile to receive the alerts and messages as soon as they are transmitted. Based on the feedback from the fishermen who have used these services, a two-way messaging system is being rolled out in which fishermen can initiate distress signal (such as fire on board, health issues, boat sinking) which is transmitted to the Coast Guard; in return, acknowledgement of receipt of the distress signal and initiation of rescue is conveyed to the distressed fishermen through NavIC messaging service.

The fishing vessel tracking terminal developed by ISRO, is a low data rate two way MSS (Mobile Satellite Service) terminal used for tracking of sub-20m boats. This system is used to monitor large number of vessels at coast for the purpose of coastal surveillance and security applications under Ministry of Home Affairs.

The ground system is under Ministry of Home Affairs. This system also supports other applications such as disaster warning dissemination, asset tracking, messaging services, etc. The users are effectively utilizing the services for coastal tracking. Indian Railways has fitted similar system in the locomotives for Real-time Train Information System which not only provides the location of the trains but also been instrumental in minimizing accidents.

NavIC is being inducted in transportation infrastructure like e-tolling, satellite based billing, etc. depend upon real-time tracking of the vehicles and associated telematics. The vehicles are equipped with GNSS based tracking devices. The tracking device computes real-time location of the vehicle and transmits it via cellular network to a central office. The location and time data is processed at the central office to produce the bill. The same architecture can also be extended to provide safety-of-life service to passengers.

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26. NAVIC APPLICATIONS FOR VEHICLE LOCATION AND TRACKING

a. Objectives:

Vehicle tracking system is of very crucial importance particularly for the logistics and transportation industries, in a big Country like India for the efficient management of their fleet systems. For big companies, where the number of trucks and passenger vehicles plying on road is large. Vehicle tracking system helps vastly to improve the business and to reduce the operating costs. Similarly where the number of trains plying across the nation is huge and when the aircraft and ships being operated between cities/countries are large, then their tracking will be highly advantageous and indeed becomes one of the prerequisites. The main objective of these tracking systems using Global Navigation Satellite System (GNSS) is essentially to ensure safety of goods as well as drivers, provide timely assistance in case of breakdown or an emergency and make the system efficient. The vehicle location is one of the most important components. The location and time information anywhere on earth are provided by using GNSS technology. Most of the vehicle tracking systems are designed by using GNSS and Global System for Mobile applications (GSM) * technologies

GSM (Global System for Mobile communication) is a digital mobile network that is widely used by mobile phone users in Europe and other parts of the world. GSM digitizes, compresses data and then sends it down a channel with two other streams of user data, each in its own time slot.

b. Expected Benefit to Society:

If we consider the overall expenses in a vehicle fleet operation the expense on payroll is maximum to the transport companies. Next larger expense is essentially on fuel cost. Using NAVIC tracking it is possible to track the vehicle operation, speeding behaviour of drivers and unauthorised vehicle usage etc. Utilising the tracking data, one can keep proper surveillance on all these factors which helps to initiate suitable actions to minimise the fuel usage and costs. Unauthorized usage of the vehicle can also be effectively controlled. NAVIC tracking in addition ensures proper definition of direct routes to places which in turn helps in large fuel savings. As one has access to all routes in tracking through navigation, it is possible to plan very efficient and optimal routes by the fleet management officer and assign the jobs to one of the vehicles which is nearer to the location.

The access of data in real time enables the officer in charge to take more informed business decisions thus reducing the operational costs. The instant access to data helps businesses to identify the problems quickly and implement the necessary solutions to mitigate costs, that would have been incurred if the problem persisted for a longer period. The trackers also support the digitization of processes, simplify the data collection and make it easily accessible to all required team members. This will vastly help in streamlining the administrative processes. Further the fleet tracking provides digital maintenance alerts based on speedometer readings and helps in maintaining the vehicle safety. With NavIC tracking installed on the vehicles, the company can easily monitor the location and with the help of calendar template, it is possible to quickly identify any unusual or unauthorized use. The productivity improves substantially as the tracker helps to monitor the time and days spent at each site and optimally utilising its services.

c. Implementation mechanism:

Indian NAVIC system is used very effectively for the vehicle tracking. The implementation of the system is carried out using;

1. Tracking device, where GNSS module is used to compute its location and a GSM module is used to relay the location information of the vehicle, and,

2. Backend system to acquire, store and manage the signals relayed from the tracking devices; transmit the vehicle's location information to the end user and displayed on the user's system.

A block diagram for the implementation of vehicle tracking is explained in Figure 1.

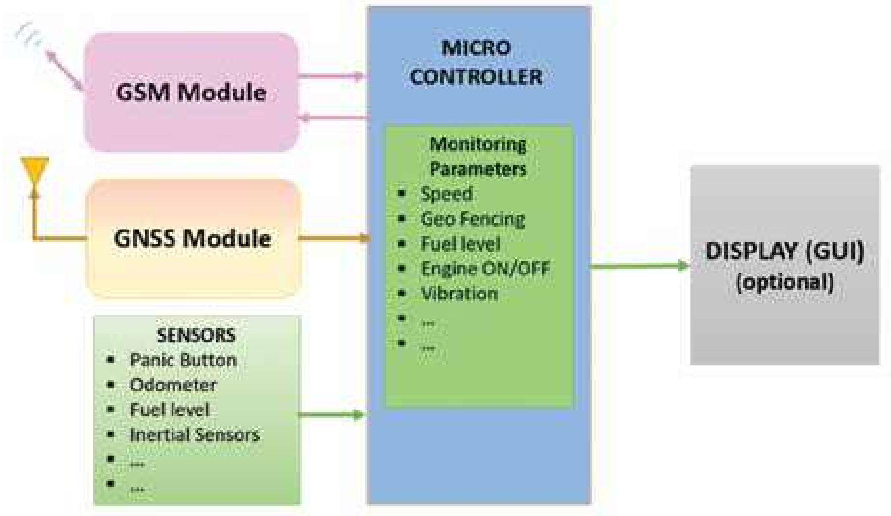

Fig. 1 A block diagram of the vehicle tracking device

The GNSS module comprises of GNSS chipset and antenna which receives the signals from GNSS. The position of the receiver is computed in the GNSS chipset and provides the details to the micro-controller.

Various receiver chip manufacturers (viz., SkyTraQ, Quectel, Allystar, Telit, U-TraQ) have released NavIC enabled GNSS chipsets in the market. GNSS receivers are built on these chipset (which is vital to receive GNSS signal). These receivers are used for location based applications, such as Vehicle trackers, NavIC messaging Receivers, drones, etc. Each GNSS receiver has one chipset. Fig. 2 shows a few NavIC enabled receiver chips manufactured by some of the chip manufactures.

Fig. 2: A few NavIC enabled receiver chips

During the initial phase ISRO developed Vehicle tracking devices using the above chipsets. The field trials carried out in the urban locations of Ahmedabad have shown significant improvement in the availability of signal with hybrid NavIC+GPS mode as against GPS alone mode.

The backend system is developed by the telematics service provider to track the vehicles as per the end user requirement. The typical system block diagram is given in Fig 3.

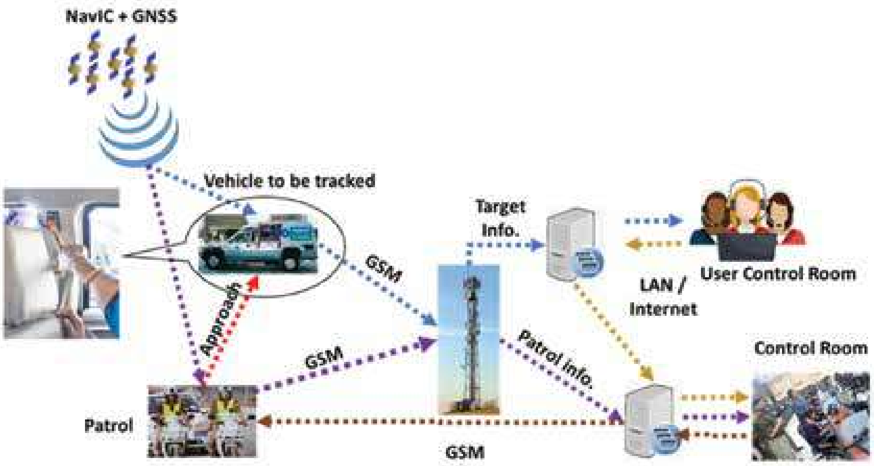

Fig 3. A Typical back end system

The vehicle trackers, installed in public vehicles push the location of vehicle to server deployed in respective state in standardised format (AIS 140) * continuously using cellular network.

***[Automotive Industry Standard 140 (AIS 140) is a set of regulations published by Automotive Research Association of India (ARAI) for all public transportation systems to build an Intelligent Transportation System in India}.**

The AIS 140 enabled devices have provision to send location information to both state and central agencies and also to the device manufacturer for vehicle tracking and analytics. In case the network connectivity is poor in some remote palaces, there is provision to store the location in the vehicle tracker and recover the data by server once connectivity is established. The server maintains the log of all vehicle trackers and archive the log of all the vehicles in storage. Telematics developer provides GUI interface for state agencies for easy monitoring of vehicles and allied analytics.

SOS button is also mandated along with AIS 140 compliant vehicle trackers in all public and commercial vehicles. In case, a SOS button is pressed during any emergency, the state and central monitoring agencies are immediately alerted. The monitoring agencies can track the vehicle remotely and in turn alert the local personnel to cater for SOS request of the vehicle.

Ministry of Road Transport and Highway, Government of India, vide Gazette Notification dated 25.10.2018, has mandated that vehicle location tracking (VLT) devices fitted on the vehicle should be type approved as per AIS:140". The amendment No.2 for AIS-140 Intelligent Transport Systems (ITS) – Requirements for Public Transport Vehicle Operation dated 05.12.2018 under §3.1.1.1 (a) further mentions that "device should be capable for operating in L and/or S band and include support for NavIC/IRNSS (Indian Regional Navigation Satellite System) for devices installed on vehicles on or after 1st April 2019. However, VLT devices shall be compliant as per other GNSS constellation in the interim period".

ISRO has interacted with the device manufacturers and the certifying agencies (ARAI and ICAT*) through the initial phase of NavIC implementation and AIS-140 certification in the vehicle location tracking devices.

***[International Centre for Automotive Technology (ICAT) is an automotive testing and R&D center located**

at Manesar, Haryana, India. It has facilities for vehicle homologation and also testing laboratories for Noise, Vibration and Harshness (NVH) and passive safety.]

ISRO offered support to this initiative through joint trouble-shooting exercises, particularly for ephemeris upgradation of the tracker firmware. As on September 2021, up to 139 models of AIS-140 compliant devices are available on the market, as per information available in the ICAT and ARAI website.

The transport authority of respective Indian state is tasked with ensuring that all stipulated vehicles abide by the guidelines laid down by the AIS-140

a. Area Coverage: National / State / District

The NavIC system provides accurate position information service to users in all over India as well as the region extending up to 1500 km from its boundary, its service area. Seven satellites are present for the users that will support stand-alone NavIC solution or provide assistance to supplement multi-GNSS operation. Thus this system ensures the full coverage all over India.

e. Results Obtained: (compare with item b above)

Vehicle tracking systems (VTS) are presently being used by many users in India, like big truck operators, car rental companies, school bus operators and even individual users. The small VTS device (the size of a mobile phone) using GPS/NavIC and Global Pocket Radio System (GPRS) have helped the operators to digitally track their vehicles by simple operation of the device. Logistics companies have been using the system to track the status of consignments and the applications are further increasing. Car rental firms have already adopted the system in several towns and cities to maintain schedules and also for tracking the vehicles. Some of the State Road Transport Corporations have also been planning to use VTS in its day-to-day functioning. In addition there are plans on the anvil by the Government to regulate, coordinate and control interstate traffic between states by deploying such a system. With wider usage, the cost of the tracking systems would further reduce and the technologies would improve substantially. With these advantages, the logistics and transportation industries also would opt for deploying more and more of these systems thus trying to Improve the efficiency and cut down the costs. SATCOM & SATNAV Network was used to test the real-time Position, Velocity & Time (PVT) solution for monitoring, efficient management of rail network & emergency communication. The various operations were, generation of the warning siren in Loco, navigation aid for loco pilot, near-real-time train tracking, emergency messaging to & from locomotive, to control station and emergency voice communication by gang men. Coastal vessel monitoring system has been developed on similar lines with that of VTS for tracking of small boats and presently more than 1000 boats of Tamil Nadu and Gujarat are being tracked in real time.

f. Users' Perspective

Many companies have been satisfactorily using the tracking system and are happy with the advantages of deriving the safety of goods, as well as drivers, and in receiving the timely assistance during the breakdown or an emergency. It is estimated that delays from congestion on highways, roads and transit systems throughout India result in huge productivity losses apart from, over-speeding vehicles cause property damage, personal injuries and inefficient fuel consumption and the users are able to cut down the losses in each of these areas. The fleet operators and logistics firms who have been using the information about the position of vehicles in scheduling, have greatly benefitted in meeting the realistic deliveries and the number of NavIC based tracking system users are also increasing in the Country considering the benefits they derive from the usage of the system..

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5. List of ICAT approved Vehicle Tracking Systems as per AIS 140 Amd. 1:2017 & 2018, as on 28.09.2021 https://icat.in/storage/app/public/uploads/certificate_form_1564983033.pdf

6. List of ARAI APPROVED Vehicle Tracking Systems (GPS + IRNSS) as per AIS 140 as on 05th AUG 2021 https://cms.araiindia.com/MediaFiles/List%20AIS%20140%20as%20on%2005th%20Aug%202021_11629.pdf

27. NAVIC IN SMART PHONES

a. Objectives:

Over past two decades (since 2000), with the advent of several technological evolutions, there has been significant growth in commoditisation of GNSS. The GNSS devices were initially bulky, heavy, power hungry, complex user interface and expensive. Recently, there has been significant improvement in the design of GNSS receiver and embedded in the myriad of consumer devices. The GNSS devices are so cheap that it is practically a commodity available as a standard feature across all the ranges of consumer products. A growing number of mobile phones, personal navigational devices, trackers and tablets are equipped with GNSS receiver's chips and navigation software. Nowadays, almost everybody possesses at least one smartphone. There are scores of applications in a smartphone that use GNSS based location to navigate to destinations. The positioning accuracy of a GNSS module on a smartphone is typically between 3 and 5 m under good multipath conditions and over 10 m under harsh multipath environments.

The consumer products using GNSS are also equipped with other navigation sensors (like accelerometers etc.) to ensure continuity of services for a short duration in the event of poor or blockage of GNSS signals due to high rise buildings or indoors. Additionally, the smartphone or devices can obtain the required position information from other GNSS permanent stations set up by the telecom service provider or from an internet-connected server. This is called assisted GNSS.

Relevant applications in commercials are location-based billing, location-based advertising, and proximity-based notification. In law enforcement, interesting applications are search and rescue, geo fencing, crime scene recovery, and more. Other fields are intelligent transport systems, health care, and teaching. Some challenges regarding the noisy smartphone GNSS observations, the environment effect and smartphone holding modes, restrict the users to achieve high-precision smartphone positioning.

Another method of increasing the availability of GNSS, is by incorporating multiple constellations. NavIC being a Geo based regional constellation provides higher elevation angles for users in primary coverage area. Round the clock visibility of the satellites and higher elevation angles improve the availability in urban canyons.

b. Expected Benefit to Society:

A standalone GNSS receiver provides basic information about coordinates and a few other data. But when this information is combined with other technology, such as maps, it becomes a very powerful tool. US Department of Defence first developed GPS for military use, but now widely available for commercial use by the public, often incorporated into products such as standalone or built-in navigation devices for road vehicles and boats, as well as apps for smartphones. Likewise, Galileo was developed by European Union, Beidou by China, Glonass by Russia, QZSS by japan and NavIC by India are independent navigation constellations and are being incorporated more and more into electronics devices with time. Main advantages of GNSS is given below in detail.

1. Navigation

Perhaps the most common use for GNSS is in navigation systems. Combined with map technology, it becomes a powerful tool for road vehicles and boats. GNSS can pinpoint a device's location with accuracy and by comparing coordinates, the statistics can be used to calculate a device's direction of movement and speed. This information can be used to provide step-by-step directions from Point A to Point B in real time.

2. Low Cost

The GNSS constellations are paid for, maintained and upgraded from respective Government funding. That means that the system is essentially free, although you may have to pay for a device and software to utilize it. Smartphone apps, such as Google Maps, that use GNSS are also typically free.

3. Crime and Security

GNSS can be used as a valuable tool by law enforcement to track criminals or terrorists, using devices they attach to vehicles, or through tracking the perpetrator's smartphone. GNSS tracking devices can also be used to deter theft by employers or ordinary people.

4. Easy to Use

Navigation using GNSS is generally very easy and requires minimal skill or effort, certainly when compared to traditional methods and technologies, such as map-reading. In most cases, the user just has to input the destination and the device will do the rest.

5. Safety

GNSS tracking can be used by parents to keep tabs on their children and make sure that they're safe. As well as GNSS tracking being useful for keeping staff members and others safe in certain jobs, it can also be used to monitor the whereabouts of key workers in case they're urgently required to deal with an emergency.

6. Neighbourhood Search

As well as navigation, GNSS can also be used to provide information on the local area. For instance, finding out where the nearest hotel or gas station is, or discovering nearby restaurants that are open for business. This is convenient when you are on a long road trip and need to find a place to stop for food, gas, sleep, and so on.

7. Traffic and Weather Alerts

One of the great things about GNSS is that it is all happening in real time. That means that you can be notified if there is a traffic accident, or another type of hold-up ahead, or if you are approaching an area where there is a severe weather event occurring. Not only can this shorten your journey time, but also improve safety.

8. Updated and Maintained

The GNSS is a critical service, hence updated and maintained in very good shape by respective providers. Most software, apps, and devices that use GNSS are also regularly updated, normally free. Therefore, unlike a traditional printed map, which goes out of date after a while, GNSS and related technology normally stays very accurate.

c. Implementation mechanism:

In May 2016 and during the “Google I/O” conference, Google announced that the raw GNSS measurements, i.e., the pseudo range, carrier-phase, Doppler shift and carrier-to-noise density ratio (C/N0) observations, would be accessible through the Android Nougat (version 7) operating systems. In August 22, 2016, the Android 7 (Nougat) was officially released by Google, which can be regarded as a breakthrough for the GNSS community. Since then, many researches have been conducted to develop new algorithms to improve the performance of GNSS positioning using these mass-market devices.

Early smartphones only provided single-frequency and mostly GPS-only observations. In 2017, the Samsung S8 and Huawei P10 smartphones were released as the first multi-GNSS devices, which are able to track carrier-phase measurements. However, in May 2018, the Xiaomi Mi 8 equipped with the new Broadcom BCM47755 GNSS chipset was released as the world’s first dual-frequency GNSS smartphone, i.e., added with L5 for GPS and QZSS and E5a for Galileo (European GNSS Agency, GSA, 2018a) and L5 for NavIC. It can be also regarded as a great milestone in smartphone positioning as it provides the users with an opportunity to make ionospheric-free linear combination between observations of two frequencies to eliminate the ionosphere effect.

Following the release of the BCM47755 by Broadcom, other key chipset manufacturers have also developed the dual-frequency chipsets such as Qualcomm with the Snapdragon X24 LTE modem and HI Silicon with the Kirin 980 system-on-a-chip (GPS World, 2018). In late 2019, Qualcomm Technologies, Inc. collaborated with Indian Space Research Organization

(ISRO) to provide chipset platforms, which support NavIC for the first time. Broadcom has also introduced the BCM47765 in May 2020 as the second-generation dual-frequency GNSS solution capable of tracking the new BeiDou Navigation Satellite System (BDS-3) constellation's B2a signals. The BCM47765 simultaneously supports Global Positioning System (GPS), Global Navigation Satellite System (GLONASS), Navigation with Indian Constellation (NavIC), BeiDou Navigation Satellite System (BDS), Galileo Navigation Satellite System (Galileo), Satellite-Based Augmentation Systems (SBAS), and Japanese Quasi-Zenith Satellite System (QZSS) in both the L1/ B1/E1 and L5/E5a/B2a frequency bands. This has led to improved availability (30 new L5 signals which is about 60% more) and accuracy (Cozzens, 2020b).

d. Area Coverage: National / State / District

The NavIC system provides accurate position information service to users in all over India as well as the region extending up to 1500 km from its boundary, its service area. NavIC signals are broadcast in two frequencies: L5 band (1164.45 – 1188.45 MHz with center frequency 1176.45 MHz) and S band (2483.5 – 2500 MHz with centre frequency 2492.028 MHz). There is a plan of augmenting the service with L1 band (1563.42 – 1587.42 MHz with center frequency 1575.42 MHz) in the near future. Seven satellites are present for the users that will support stand-alone NavIC solution or provide assistance to supplement multi-GNSS operation. Thus this system ensures the full coverage all over India.

e. Results Obtained: (compare with item b above)

Currently there are several smartphone models on the market capable of supporting NavIC, a few of them are listed below available at the time of writing.

NavIC Supported Mobiles		
Poco m2 pro	Real me X50 pro 5G	iQOO 7 Legend
Redmi Note 9 Pro	Mi 10	Vivo X60 & pro
Redmi Note 9 pro max	Huawei P40	Nokia XR20
Real me 6 pro	Asus Zenphone 7 pro	Vivo X70 pro

Mi 10i	Huawei p40 pro	Asus Rog Phone3
Vivo v20	Huawei mate 40 Pro	Asus Zenphone 7
One plus nord	Real me 7 pro	Mi 11 Ultra
Vivo v20 pro	Mi 11x	Asus Rog Phone 5
Mi 10T	Xiaomi 11 Lite NE 5G	Vivo X70 pro+
Mi 10T pro	One Plus Nord 2 5G	

Dual frequency GNSS supporting NavIC has become a standard feature in medium and high-end mobiles. A number of processors for mobile phones are already available in market supporting NavIC. Mobiles having these processors are likely to support NavIC subject to the availability of dual band RF chain for GNSS.

NavIC supported in Qualcomm mobile processors

800 Series (High End)	700 series (Semi High end)	600 series (Mid-Range)	400 Series (Low Range)
SD 888	SD 768G	SD 690	SD 460
SD 870	SD 765G	SD 662	
SD 865+	SD 750G		
	SD 720G		

NavIC enabled processors	
Mediatek	Dimensity 1200,1000c,700
Huawei	Kirin 9000,990 5G
Samsung	Exynos 980

f. Users' Perspective

Many users expressed satisfaction for having the indigenously developed NavIC in their mobile phones. Location availability in urban canyons has improved due to incorporation of multiple constellations.

The NavIC reception in one of the mobile phones is shown in Figure

Fig 1. The NavIC reception in one of the mobile phones

Accuracy of position has also improved because of dual frequency measurements. Industry also supported the implementation of NavIC but they are concerned with increase in cost for low end mobiles by addition of extra RF hardware to support one more band of frequencies. With more and more adoption, low end mobiles will also have dual band capability and eventually support NavIC. ISRO is planning to incorporate signals in L1 band with upcoming NavIC satellites which will help ISRO to address the concern for cost sensitive segment.

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28. REAL TIME TRAIN INFORMATION SYSTEM (RTIS) IN INDIA

a. Objectives:

With a network of 67,000km, Indian Railways operate around 13,000 passenger trains and around 9,000 freight trains, touching almost every nook and corner of the country. Indian Railways play a very major role in the socio-economic development of the country. In such a complex system proper tracking, monitoring and regulating of the traffic in the entire network have to be done quickly and more efficiently, with real-time information. In addition, the Indian Railways had several unmanned crossings across the Country and time to time they have been facing severe problem of accidents at these un-manned level crossings due to lack of reliable communication system across the entire network of railway system. It is also necessary to have a reliable and robust real-time train tracking system and effective communication system during emergencies. Therefore, the objective of the Real-time Train-tracking Information System (RTIS) system for Indian railways was to establish a robust hybrid (terrestrial with SATCOM) communication link which can service the entire network of the Railways in the Country. To meet this objective, ISRO developed a country-wide hybrid network for real-time train tracking system and emergency communication system.The project was carried out through a joint partnership between ISRO and Indian Railways to address these problems with the help of space technologies.

b. Expected Benefit to Society:

Real Time Train Information System (RTIS) has allowed the Indian Railways to determine the train location in almost real time, thus helping the concerned railway controllers to make near real-time scheduling of trains and publish more accurate passenger service information. The timely information about the arrival and departure of trains, has vastly helped the passengers in reducing the waiting time. This in turn has helped railways to improve the overall satisfaction of passengers. The vital information of a train running late has also enabled the commuter to rearrange their time which in turn has helped to Improve the overall passenger satisfaction. With the RTIS system, the railway controllers are able to track, monitor and regulate the traffic of the entire network more accurately which enables full & efficient utilization of railway resources.During an emergency, knowing the exact location of the train has helped to generate the speedy response by rescue teams, saving precious lives. Another advantage of RTIS system is minimizing the dependency on station masters for train scheduling. The two-way small messaging between network controllers and loco pilots brings higher efficiency in emergency management.With these advantages, RTIS has enabled the train controllers to focus more on controlling and managing train routes in a better and efficient way thus enhancing the punctuality of all the trains. Complete work on train scheduling on various routes are automated using RTIS which has enabled the railway management to have more time ondecision-making, coordination, control, analysis, and also on visualization for planning the future of railways. The RTIS system has helped in identification of unscheduled stoppages and to address the reason behind it making traffic routing more efficient. The system provides railway authorities with large amounts of data. It is estimated that it generates more than 14 million daily updates on train locations, which helps the railways to develop better modules for train operations. (ref. 4).It also helps to regulate traffic when increased number of trains, especially during the festive season.

c. Implementation mechanism:

The system used for implementation is a Mobile Satellite Service (MSS) based SATCOM network to function in tandem with a satellite based navigation system. In MSS network for Indian Railways, all locomotives have to be fitted with a S-Band transceiver terminal for providing SATCOM connectivity & GPS/GAGAN receiver for precise navigation. This S-band transceiver unit has also built-in GPRS/LTE based terrestrial communication mode in redundant configuration for addressing all issues of system availability related to real-time positioning of locomotives. Real time information system (RTIS) deals with the widespread mobility of remote terminals /

locomotive devices connected through MSS links as the train moves from one geographical location to another. Locomotive device comprises of indoor and outdoor units. The Indoor unit, is installed in Locomotive Cabin, and it consists of a ruggedized processor module with RTIS application software, Primary Display, Primary GPS (Global Positioning System)/GAGAN receiver, 2 x GPRS/3G/4G modem, RF transceiver and associated interfaces for connectivity to outdoor unit. The outdoor unit includes MSS transceiver module, secondary GPS/GAGAN receiver and antennae for all modules (MSS, 4G, RF, GPS etc.). They are all located on locomotive roof top. The schematic diagram of the MSS Network used for Real-time Train Information System is explained in Figure 1.

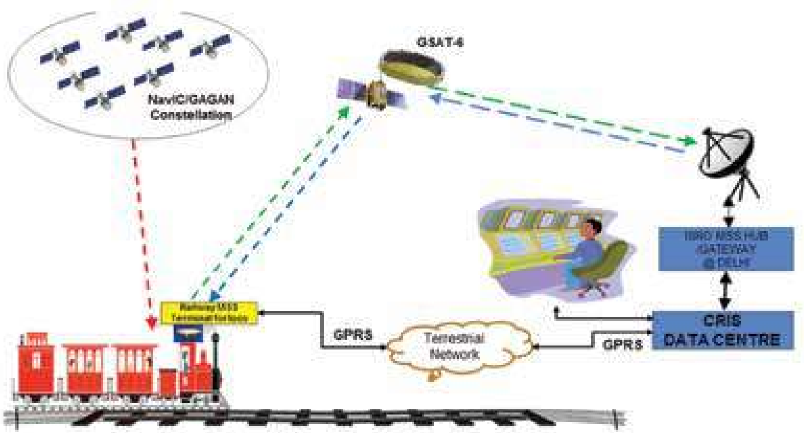

Fig 1. MSS Network for Real-time Train Information System

The S-Band terminal periodically transmits the position & speed information of locomotive to central control station via MSS satellite and simultaneously receives the control. Emergency messages are transmitted from control station. The L-band GPS/GAGAN receiver in the locomotive device determines spatial co-ordinates and speed of the moving locomotive at regular intervals. An application software located in the train determines the movement events of the train i.e. Arrival, Departure, Run-through stations, etc. based on predefined logic applied to spatial coordinates. There is also be a GPRS based communication module which reports events like arrival to a station, departure to a station etc.

Further these events are relayed to the Central Location Server (CLS) of Central Railway Information System(CRIS) using S-MSS and 4G/3G mobile data service, along with position / location updates. The CLS processes the received data and sends it to the Control Office Application (COA) for plotting the control charts. As COA is integrated with the National Train Enquiry System (NTES), it automatically generates the accurate real-time passenger information. If the passengers have the NTES app download, they can get precise train location through the app. The flowchart of RTIS functioning is given in the Fig. 2

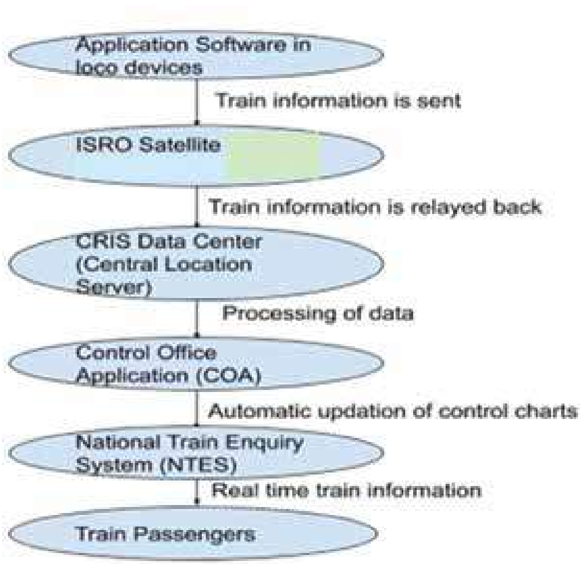

Figure 2. The flowchart of RTIS functioning

Another variant of an S-band transceiver with a modified firmware is fitted at Un-Manned Level Crossings (UMLC's) and it is interfaced with an audio/visual alarm system. This alarm automatically triggers on receiving warning command from control station based on the proximity of locomotives from that UMLC. The control station calculates the distance of locomotives from the pre-defined UMLC's location in real-time by using the reported position from locomotives and generates the command for UMLC terminals to trigger the audio-visual alarm. The central control station also manages communications with all locomotives & provide real-time position information about running locomotives on GIS Map. In case of any emergency this network provides a fast communication link between affected locomotives & control station for exchanging the support information. The indoor unit also has a provision to send SOS message which helps in effective accident management. In case of SOS message, the control station relays the message along with position of affected locomotive to all trains in vicinity so that they are aware of accident avoiding further damage. Figure 3 explains the MSS Network used for warning at un manned level crossing (UMLC) in railways.

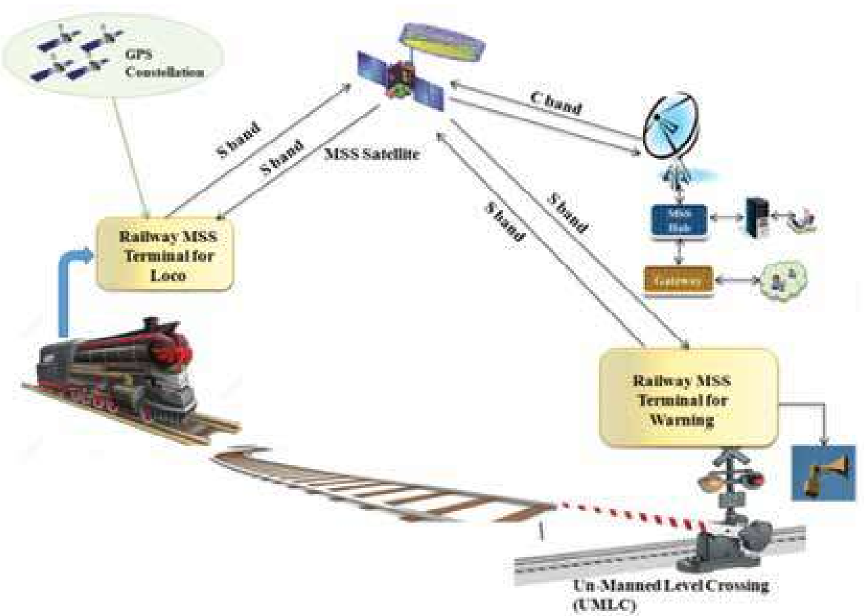

Figure 3. MSS Network for warning at un manned level crossing (UMLC)

The augmented Real Time Train Information System (RTIS) is effectively utilized for real time rail monitoring, automatic warning generation at un-manned level crossings and emergency communication. Presently this RTIS network has been implemented in all limited trains in collaboration between Indian Railways, ISRO & industry partners and the efforts are being continued to extend the network to all trains of Indian Railways as part of nation-wide rollout.

d. Area Coverage: National / State / District

The area coverage is all through the Indian continent to cater to the entire railway network across the Country. The existing space services for Mobile Satellite Service (MSS) based SATCOM network and also for the satellite based navigation system in the Country have capability to serve the entire region of the railway networks.

e. Results Obtained: (compare with item b above)

In early phases of development, the proof of concept demonstration of this network was successfully conducted usingHigh Power MSS satellite link on a local railway track between Ahmedabad-Botad route. The field trial of automatic warning at UMLC was carried out in a scaled down network of 10 locomotives & 5 UMLC's in Hajipur sub-division of Indian Railways. Further as part of pilot project demonstration, the RTIS system was implemented for real-time tracking of 6 electric locomotives on New Delhi-Guwahati (NDLS-GHY) and New Delhi-Mumbai (NDLS-BCT) Rajdhani trains, on trial basis, proved the feasibility for network-wide roll out on Indian Railways. The locomotive device is ruggedized enough to withstand the varied environmental conditions during the trial period. As part of the Phase I implementation of RTIS, Bharat Electronics Limited (BEL) commissioned the RTIS network deploying over 2700 MSS terminals on locomotives of Indian Railways as per the data released by Ministry of Railways, Government of India on Real Time Train Information System as on 18 MAR 2020, through PIB Delhi.

The overall percentage of successful transmission of event triggered updates using both MSS and GPRS mediums was found to about 99.3%. During the trials, significant optimization/fine-tuning was done in the RTIS system. Bharat Electronics Limited (BEL) with Saankhya Labs was selected as the Satcom technology partner of Space Applications Centre, ISRO for RTIS project, who have developed Mobile Satellite Service (MSS) terminals and hub-side equipment for RTIS. Under RTIS initiative, GPS devices have been already mounted in fairly large number of trains. The expansion of this scheme to install GPS in all the trains to know the real-time position of the trains is underway by Indian Railways. The second phase of RTIS implementation is underway to cover 6000 more locomotives.

f. Users' Perspective

Government of India has plans to increase the implementation of RTIS in a phased manner. In the first phase, passenger trains serving the golden quadrilateral and diagonals except the Mumbai – Chennai corridor are planned. For freight traffic, electric locomotives serving the Delhi – Mumbai and Howrah – Chennai corridors are identified.

The successful network-wide implementation of RTIS certainly improves safety and operational efficiency of the entire Indian railway network has made big impact on improving the communication in times of emergencies. The partnership between Indian Railways and SAC-ISRO has already demonstrated the system and has started providing the effective solutions to many of the problems faced by the large network of Indian railways thus improving the overall efficiency of the system.

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29. GNSS BASED HIGH ACCURACY APPLICATIONS

a. Objective:

Satellite navigation systems have become integral part of all applications where mobility plays an important role. Standalone GNSS signals enable the calculation of the receiver's position, however ionosphere variations and measurement inaccuracies in orbit determination and timing synchronisation cause limited accuracy of the order of approximately 5 meters. Emerging applications such as drones, augmented reality and autonomous vehicles are driving the demand for high accuracy (<1m) and high precision real-time positioning in the mass-market. To achieve real-time high accuracy positioning using GNSS, a network of continuously operated reference stations is established to provide accurate reference measurement data and several signal augmentation techniques such as Real-Time Kinematic, RTK (the technique that eliminates errors as much as possible to give you accurate results and enhanced positional data), Precise Point Positioning, PPP (a positioning technique that removes or models GNSS system errors to provide a high level of position accuracy. A PPP solution depends on GNSS satellite clock and orbit corrections, generated from a network of global reference stations) and hybrid variations combining PPP and TRK (e.g. PPP-RTK) have been developed.

b. Expected Benefit to Society:

Technological advancements in GNSS signal augmentation services are opening the door to many new and innovative high-accuracy applications. High accuracy positioning systems offer huge benefits in precision agriculture, surveying, mining, transportation and scientific studies.

Some of the Application Areas:

i. **Precision Agriculture:** Agriculture is a well-established application for GNSS data, with many tractor manufacturers incorporating

GNSS receivers within their models to enable tracking and in some cases automated control. With improved GNSS accuracy automated ploughing, and seeding can be done without the intervention of humans. High accuracy GNSS positioning can improve the precision of seeding, allowing for crops to be planted closer together to improve the efficiency of land and pesticide use. UAVs can also be used to monitor and work on crops.

ii. **Surveying:** GNSS was rapidly adapted for surveying, as it can give a position (Latitude, Longitude and Height) directly, without the need to measure angles and distances between intermediate points. Surveying can be done almost anywhere using high accuracy GNSS systems with a clear view to sky so that signals from GNSS satellites can be received. Surveying using GNSS saves lot of effort and time compared to traditional techniques. Even a centimetre level differences can cause huge monetary losses across huge swaths of land measured.

iii. **Mining:** The monolithic scale of open-pit mining requires huge fleet of machinery, creating a significant logistics challenge for operators. GNSS data is often used to enhance these operations; the availability of enhanced GNSS data can support the automated control of drills which increase safety and productivity as a single operator in a secure control room can operate and monitor up to five automated drills. High accuracy GNSS positioning offers greater flexibility in mine exploration and growth.

iv. **Marine**: High accuracy positioning will help wide variety of marine applications such as navigation, seafloor mapping, underwater exploration, dredging, search and rescue operations, offshore drilling and pipeline routing services through improved accuracy and reduced convergence times. An increase in positioning accuracy can lead to improved fuel and time management reducing carbon footprint of vessels. Whilst autonomous capabilities are typically associated with the automotive industry, it is widely anticipated that marine shipping will also become increasingly automated. Increased positional accuracy will directly support the evolution of marine autonomy.

v. **Rail:** Railway transportation is a critical aspect of mass transportation and must maintain high safety standards within tight time constraints. The introduction of automatic train control systems has improved the efficiency of railways, complemented by the use of GNSS to track trains even on low density line networks. High accuracy services improve the safety of signalling applications and can reduce the need for additional sensors on low traffic density lines, reducing maintenance costs.

vi. **Autonomous driving:** Autonomous vehicles require the combination of highly specialised sensors to navigate without the aid of a human pilot. The inclusion of GNSS will be essential to their ability to navigate through the open-ended environment of the world.

vii. ***Ge*odynamics:** Precise positioning can be used for determining very minute position shifts. By establishing Continuously Operated Reference (CORS) stations and processing the data can yield crustal deformation measurements. This helps in understanding geodynamics and earthquake processes. CORS stations are positioned along possible seismic fault-lines. Time-series of the position data is used to detect strain accumulation, thereby indicating possible seismic hazard. CORS is also being used for monitoring deformation in the plate interior regions. Study of the signature of total electron content (TEC) variations due to earthquakes is emerging as a big research topic for enabling early warning of earthquakes.

viii. ***A*tmospheric research:** Ionosphere variation is a major source of error in high accuracy GNSS measurements. The same high accuracy GNSS measurements can then be used for studying ionosphere variations if the receiver is placed at a surveyed point. The main climatological models for mean stable part of the electron density in the ionospheric layers are well established. However, the inhomogeneous part, responsible for scintillation effects, still remains to be modelled accurately. This is a major and interesting topic of research that utilises the capability of CORS network data.

c. Implementation mechanism:

The accuracy of standalone positioning systems can be improved using the observations from reference sources and differencing out the common errors like atmospheric and ephemeris errors. Continuously Operating Reference Stations (CORS) have become the de facto choice for high accuracy applications and studies globally.

CORS network consists of four building blocks: reference stations, data processing centre, data communication network, and user application systems. Typical architecture of CORS network is shown in Fig. (1).

Data processing centre consists of high performance servers for processing the measurement data. Data communication network carries out communication between the reference station, data centre, and rovers. User application system is the end user of the CORS. It also consists of GNSS receiver, antenna, and communication network.

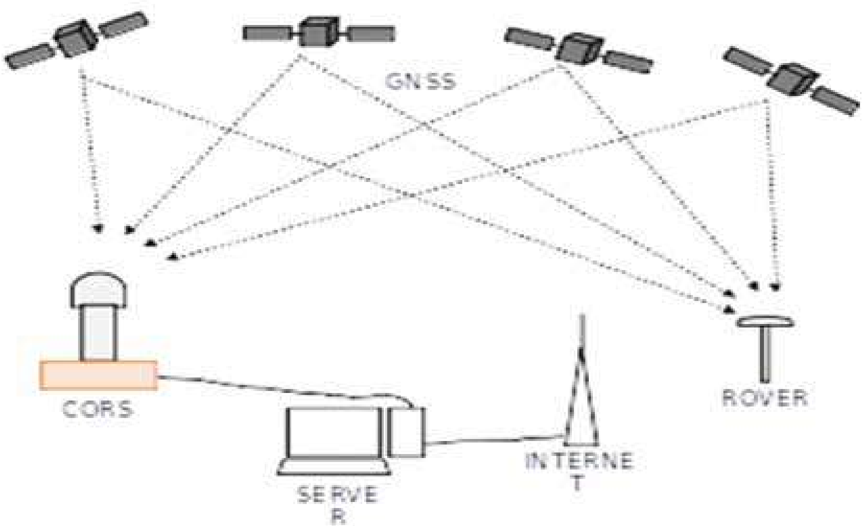

Fig. 1: Continuously Operating Reference Stations (CORS) architecture

CORS operate as a part of a larger network. Hence, each station should have the capability of storage, archival and communication of measurement data. The recommended format for data archival isReceiver Independent Exchange Format (RINEX). RINEX is a data interchange format for raw satellite navigation system data. The final output of a navigation receiver is usually its position, speed or other related physical quantities. The recommended protocol for real-time communication of correction data is based onRadio Technical Commission for Maritime, RTCM standard. (RTCM standard, is a communication protocol for sending differential GPS (DGPS) to a GPS receiver from a secondary source like a radio receiver). Adherence to these standards ensures compatibility with the greatest range of equipment and processing software. Data can be communicated using the existing means of communication, including the internet.

Data processing is the most important step in High accuracy positioning. The GNSS measurements, whether from a single station or from a range of stations, need to be processed to refine the position information. Lot of processing is needed to obtain an accurate position. Currently, such processing is being done through scientific software like Gipsy Oasis (from Jet Propulsion Laboratory), Gamit / GlobK (from Massachusetts Institute of Technology), or Bernese (by Astronomical Institute of the University of Bern). The highly accurate GNSS positions and the error residuals are then utilised in the relevant model to derive parameters of scientific interest.

d. Area Coverage: National / State / District

NavIC covers Indian landmass and a region extending up to 1,500 km beyond Indian mainland (primary coverage area). NavIC signals are broadcast in two frequencies: L5 band (1164.45 – 1188.45 MHz with center frequency 1176.45 MHz) and S band (2483.5 – 2500 MHz with center frequency 2492.028 MHz). There is also a plan to augment the service with L1 band (1563.42 – 1587.42 MHz with center frequency 1575.42 MHz) in the near future. NavIC system is thus functional and fully geared up to meet the demanding requirements of CORS. In India too, the need for CORS networks has been felt and Survey of India, Department of Science and Technology is taking the lead in establishing across the country. Already, a few of the CORS have been established by Andhra Pradesh & Tamil Nadu state governments research and development organisations, and academic institutes for their own application/research objectives. Currently, these CORS are being operated using GNSS (GPS, GLONASS, Galileo). It is proposed to adopt India's own navigation system NavIC within the Indian CORS infrastructure.

e. Results Obtained: (compare with item b above)

CORS is an integral part of the geodetic infrastructure of India. Many governmental agencies, research and development organisations, and academic institutes have established CORS for their own applications and research objectives.

Survey of India (SoI) has taken up the establishment of CORS in India in a systematic manner. Already more than 200 stations have been established. Efforts are underway to expand it to around 900 stations covering the entire country. SoI plans to offer services like network real-time kinematics (NRTK), corrections for differential GNSS, and online processing services through these networks. Government of India has launched the "स्वामित्व" ("Swamitva") scheme, which aims to provide an integrated property validation solution for rural India using surveying and mapping techniques. This scheme is based on the CORS network.

Indian Railways has implemented automated level crossing at unmanned gate crossings, wherein the gate is closed whenever a train is approaching the unmanned gate from either side. Also Indian railways equipped all trains with GNSS receiver for real time tracking and signalling,

There is also an initiative to bring out an Indian Geodetic Reference Frame (IGRF) with the integration of horizontal and vertical datum, tidal gauge network, and an Indian geoid model. CORS forms a critical component of this architecture.

A number of other organisations like National Geophysical Research Institute (NGRI), Indian National Centre for Ocean Information Sciences (INCOIS), and Indian Space Research Organisation (ISRO) have established CORS in the country.

India is also contributing to the IGS network. There are four IGS stations in India, one each at Bengaluru and Hyderabad, and two at Lucknow. There are plans to increase the number of these stations in the coming years.

f. Users' Perspective

The combination of L5 and S band signals provides a new set of frequencies which is not available in other GNSS. The fact that NavIC satellites are in GEO/GSO orbit rather than MEO orbit means that they provide diversity in the vertical direction. The ionospheric corrections broadcast by NavIC are based on real-time grid based measurements carried out in the monitoring stations located in tropical and equatorial region. Such ionospheric model is not available in the other GNSS. Due to these factors, NavIC has the potential to become a very interesting and invaluable component of the CORS networks. Some of the technologies related to wide-band geodetic grade antennas covering L5 to S band, processing of signals in S band, and precise positioning algorithms for NavIC signals are yet to be fully established.

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30. POTENTIAL ADVANCED NAVIC APPLICATIONS

a. Background

To provide position information in the Indian region and 1500 km around the Indian Mainland Navigation with Indian Constellation (NavIC), an independent regional navigation satellite system has been designed. It is a regional system and consists of seven satellites. It provides the real time information for a) standard positioning service for civilian use and b) restricted service with encryption for strategic uses or any other user with authorisation from appropriate authorities. With the commissioning of NavIC, India joined the elite club of 5 other countries having their own navigation system like GPS of USA, GLONASS of Russia, Galileo of Europe and BeiDou of China. With this there is no need to have dependence on other countries for navigation services. European Union and Japan are trying their own full-fledged or partial constellations. Due to its extensive coverage, it is possible to share the services with SAARC nations as a diplomatic goodwill gesture from India towards countries of the region. The applications of NavIC are in several areas, like personal navigation, rail transport, road transport , civil aviation, high sea and inland waterway navigation, precision agriculture, search & rescue, surveying, monitoring of tectonic plate movement for prediction of earth quakes, etc. A separate write up on NavIC is given in sectionN3, Navigation with Indian Constellation (NavIC) giving various essential details.

b. Objectives:

The usage of signals of Global Navigation Satellite Systems (GNSS) is growing rapidly in all sectors of civilian applications. This growth is simulated by the initiatives of digitalisation, smart cities, big data and AI/ML. The objective is to integrate the Navigation technologies with other technologies like communication, IoT and mapping. This provides a great potential for proliferation of applications. Already a good number of applications are in use in the Country and many of them have been discussed in this report in the earlier sections. This section details many of the potential applications of NavIC which will enhance several applications for the benefit of the society and the Country. The details are given in the following section

c. Various potential applications and their benefits to Society

1. Unmanned aerial vehicles:

An unmanned aerial vehicle (UAV) is a vehicle that is unoccupied but under human control, whether radio-controlled or automatically guided by a GNSS-based application. Initially, unmanned vehicles were used primarily by the defence industry. However, as the unmanned vehicle market has grown and diversified, the commercial use of unmanned vehicles has also grown and diversified. Some of the current civilian uses for unmanned vehicles are: logistics delivery, medical organs and emergency medicines supply, farming, crop monitoring, aerial videography, infrastructure mapping, search and rescue, and disaster management.

Fig 1. Unmanned Aerial vevicles

The UAVs are generally equipped with a navigation system consisting of inertial navigation systems (INS) and GNSS (Fig 1). This hybrid GNSS+INS system records the UAV location and attitude for each measurement. An accurate UAV location and attitude is necessary for the measurement to be useful.

UAVs utilise chipsets that operate on multi-GNSS signals. The availability of chipsets with NavIC support has opened up the utilisation of NavIC in UAVs. Recently, NavIC has been included in the national agricultural drone standard IS 17799. A generic drone standard with similar recommendation is in the works. The availability of reliable and efficient GNSS based avionics is an integral contributor for the development of drone logistics ecosystem. This technology is expected to contribute to various citizen-centric applications including farming and delivery of essentials as mentioned earlier.

2. Timing applications

Time is a by-product of GNSS position determination. As the clock source on board GNSS satellites is highly accurate (nanoseconds), the user receiver also becomes synchronized with the very accurate satellite time. An added advantage is that the same time can be made available over a wide geographical area. This can be utilised for varioustime synchronisation applications. GNSS timing can be relied upon for synchronisation of critical infrastructure like power grids, telecommunication systems, computer networks, banking networks and stock markets. ISRO has initiated the usage of NavIC in some of these applications by developingprototype timing receivers that can be commercially produced by industry. A few of these receivers are being used in power grid synchronisation.

There is also a national-level effort by the Department of Consumer Affairs to provide traceable Indian Standard Time across the country. National Physical Laboratory (NPL) is the time-keeper of the national and maintains primary timescale at New Delhi. NPL, along with the assistance of ISRO, is establishing one primary timescale and five secondary timescales at the reference laboratories of DoCA. These timescales include NavIC timing receiver as a component of the system architecture. Moreover, the time ensemble algorithm developed indigenously by ISRO for the NavIC timing facility will also be deployed in this national project. Once established, this system will provide accurate and traceable IST to various users across India, thereby enhancing cyber security resilience.

1. Precision agriculture:

GNSS-based devices are being used to support farm planning, field mapping, soil sampling, seed sowing, fertilizer application and crop assessment (Fig 2). GNSS applications can automatically

Fig 2. GNSS based device for agriculture

guide farm implements along the contours of the farm in a manner that controls erosion and maximizes the effectiveness of irrigation systems. Farm machinery can be operated at higher speeds, day and night, with increased accuracy. All these factors maximise efficiency of the operations, leading to optimisation of costs and minimisation of environmental impact. NavIC has the potential to be utilised for precision agriculture applications in the country.

2. Mining:

GNSS information is being used to efficiently manage the mining of an ore body and the movement of waste material. GNSS equipment installed on shovels and haul trucks provides position information to a computer-controlled dispatch system to optimally route haul trucks to and from each shovel (Fig 3). Position information is also used to track each bucket of material extracted by the shovel, to ensure that it is routed to the appropriate location in the mine (crusher, waste dump, leach pad). Moreover, GNSS along with high precision techniques like real-time kinematics (RTK) can provide the precision positioning needed to accurately locate the blast holes in mining.

Fig 3. GNSS enabled haul trucks

Multi-GNSS systems are particularly advantageous in a surface mining environment in the presence of various obstructions, as more satellites means more signal availability. NavIC has the capability to support these applications in a multi-GNSS environment. Some state governments in the country have started conducting pilot phase implementation with NavIC enabled devices for mining activities.

3. Radiosonde:

Radiosondes are battery-powered telemetry instrument packages that are carried into the atmosphere typically by a weather balloon (Fig 4). They are equipped with sensors that measure altitude, pressure, temperature, relative humidity, wind (both speed and direction), and cosmic ray influx at high altitudes. A class of radiosonde whose position is tracked as it ascends

Fig 4. Radisonde in a ballon

in the atmosphere to give wind speed and direction is referred to as rawindsonde, which is an abbreviation for radar wind sonde. Another class of radiosondes are the ones that are released from airplanes and fall rather than being carried by weather balloons. This class of radiosondes are referred to as dropsondes. Radiosondes play a vital part in most forms of operational atmospheric data assimilation.

ISRO has realised indigenous GNSS radio sonde enabled with NavIC, known as PisharotySonde. PisharotySonde uses sensors for measuring the atmospheric temperature & relative humidity and GNSS receiver module for acquiring the wind parameters, altitude, date and time.The sonde system also generates the WMO specified 'temp' messages for reporting the data. This indigenous low cost system is compact and light weight. The system has been cleared for meteorological applications. More than 12000 sondes are already realized by ISRO.

The PisharotySonde System is used by scientists for boundary layer studies and upper atmospheric observations. PisharotySonde system provides a low cost solution without compromising the quality for such applications. Data from the system is also used regularly to support satellite launches.

4. Radio occultation studies:

Fig 5. GNSS Radio occultation method

GNSS radio occultation (GNSS-RO) is a type of radio occultation that relies on radio transmissions from GNSS satellites(Fig 5). This technique is used for performing atmospheric measurements. It is used as a weather forecasting tool, and could also be harnessed in monitoring climate change. The technique involves a low-Earth-orbit satellite receiving a signal from a GNSS satellite. The signal has to pass through the atmosphere and gets refracted along the way. The magnitude of refraction depends on temperature and water vapour concentration in the atmosphere. GNSS radio occultation amounts to an almost instantaneous depiction of the atmospheric state. The relative position between the GNSS satellite and the Low-Earth-orbit satellite changes over time, allowing for a vertical scanning of successive layers of the atmosphere. Radio occultation observations can also be conducted from aircraft or on high mountaintops.

NavIC signals being in L5 and S band, gives added measurements w.r.t frequency diversity. High resolution temperature profiles of stratosphere can be obtained using GNSS and NavIC radio occultation. Temperature, pressure and humidity measurements of radiosonde balloon are carried out with 3D position tagging using NavIC Rx which is qualified to withstand thermal, shock and vibrations of radiosonde dynamics. Field trails planned/ carried out with VSSC and the antennas customized for the receiver.

5. Disaster Management:

Navigation system helps in sending early warning to people of country particularly coastal areas about cyclones, tsunamis, heavy storms etc. and supports the authorities in monitoring & rescue operations during disaster times. The assistance provided to mitigate the disaster effects by giving the information of disaster timing, safe location and the disaster relief management to make earlier plans and save the lives of people in the Country as well as up to 1500 km around it.

6. Security and Defense:

The system helps in enhancing India's security by better monitoring of any terrorist activity in border areas, surveillance of strategic infrastructure etc. In terms of Military Application, this system no doubt functions as a force multiplier for the Indian Defence Unit. The wide spectrum of utility it serves from target fixing, missile and weapon delivery, avoiding civilian causalities, unit location and direction, vision clarity in bad weather etc. will enhance the capacity of defence in both war and peace time.

7. Launch Vehicle Tracking:

NavIC and NavIC + GPS based 3D positioning is supported. The receiver is ruggedized and qualified to withstand thermal, shock and vibrations of Launch vehicle dynamics. This is used in the prediction of preliminary orbit determination (POD) of newly launched satellites. These receivers are flight tested in PSLV, GSLV-MK-II, LVM3 HSP-PAT Missions. Two Antennas and LNA customized for the receiver are used.

d. Area Coverage: National / State / District

NavIC service area covers the Indian landmass and an area up to 1500 km beyond Indian landmass. In terms of latitude and longitude, the service area is bounded approximately by the rectangle of latitude 5°S to 50°N and longitude 55°E to 110°E.Since it covers an area of 1500km beyond Indian region, it can be used by the neighbouring countries as they are all falling within the NavIC service area. It is important to use appropriate NavIC receiver to utilise the NavIC services. In case the user crosses the coverage area, navigation service can be seamlessly utilised by using other global navigation satellite system by having a multi-constellation user receiver.

e. Technical details:

Indian regional navigation satellite system (IRNSS), is a constellation of 7 satellites made operational in 2018/19 with 7 satellites, with two types of services like Standard Positioning Service (SPS), to all the users and Restricted Service (RS), an encrypted service provided only to the authorised users. Position accuracy expected is better than 20 m (2σ) in the primary service area. NavIC provides navigation signals in two frequency bands: L5 band with centre frequency of 1176.45 MHz and S band with centre frequency of 2492.028 MHz. A new civilian signal is also introduced in L1 band with centre frequency of 1575.42 MHz. NavIC has a provision for one-way broadcast of short messages which is being used for example for providing emergency warning alerts to fishermen venturing into deep sea, where there is no terrestrial network connectivity. Application-specific receivers are available commercially off-the-shelf in the market. Also, a few mobile handsets in India are having NavIC capability and anybody can obtain these devices and use NavIC. Currently (mid-2022) there are about two dozen mobile handsets in India with NavIC capability. The number is progressively increasing because all the major mobile chip set manufacturers have incorporated NavIC in their latest chipsets.

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31. SATELLITE BASED FISHERY SERVICES

a. Background

India has a coastline of over7500 km and an exclusive economic zone (EEZ) of around two million square km. It is estimated that about seven million people along the coast are dependent on fishing. Over the ages, fishermen have been following conventional and traditional methods to identify the fish stock in the high sea. It has been studied that scientific method of fish forecasting employing space technology considerably reduces the time and effort of fishermen for finding the fish shoal location and also is economically beneficial.

The satellite-based fish forecast system helps to identify the location of rich fishing shoals in the sea on the basis of satellite measurements of sea surface temperature (SST) and chlorophyll concentration. This information is effectively utilized to identify the Potential Fishing Zones (PFZ). The PFZ provides the probable locations of fish aggregation in the seas.

Indian National Centre for Ocean Information System (INCOIS) under Ministry of Earth Sciences is identified nodal agency to derive PFZ information using satellite images. This PFZ information is currently being disseminated by INCOIS through their website. A number of mobile apps have been developed viz., “PFZ Advisory”developed by INCOIS, “Machli” developed by Reliance foundation, “Thoondil” developed by Govt. of Tamil Nadu, mKRISHI developed by Central Marine Fisheries Research Institute, Fisher Friend Mobile App (FFMA) developed by M S Swaminathan Research Foundation (MSSRF). All of them display the PFZ information sourced from INCOIS. The fishermen using their smart phones with any of the above mobile applications along with the GNSS location findtheir way to fishes. However, the limitation of these mobile applications is that they depend on terrestrial mobile data network whose range is around 3-4 km from the shore.

Another important aspect of space based services is to provide the timely emergency warnings. Using satellite data, a suitable system is configured to issue the distress alert messages and two-way small messages at the time of emergency to fishermen in small boats to ensure the safety of their life at sea. In addition the alerts on sea storms and cyclones to fishermen are also essential, while they are at deep sea. The communication with fishermen,before the space based services were introduced, was limited to mobile networks and very high frequency radio with a maximum range over 20 km. However the fishingboats in the Arabian Sea, Bay of Bengal and the Indian Ocean move as far away as 300nautical miles from the coast.

b. Objectives:

The objective of the space based fishing services is to forecast the Potential Fishing Zones (PFZ) almost on a daily basis to all fishermen in India using Remote Sensing (RS) and Geographic Information System (GIS) techniques. This forecast on the potential zone of fish aggregation using the space technologies vastly benefits the fishing community in minimizing the search time and also their efforts in locating the right fishing groups with the attendant savings in the cost.

Another objective has been to ensure the safety of fishermen under emergency situations by implementing suitable space based technologies to track the position of fishing boats and to provide two- way messaging features andreal-time position information to communicate the needed alerts at the time of emergencies in real time to fishermen who are in deep sea so that they take appropriate measures to return to safety. .

c. Expected Benefits to Society:

The Potential Fishing Zone (PFZ) forecasts helpto bridge the gap between estimated and harvested potential of fishes. It also aids fishermen to increase their catch and to enhance their profit. The application of space based technologies are effectively utilized in economizing the ongoing marine fishing operations and also in reducing the valuable human efforts. The space based fishing services help in identifying the potential fishing grounds on a regular basis, by reducing the search time by 30 to 70 %. This brings in substantial saving in the valuable fuel utilized by fishermen and also in the requirements of manpower. Further the fishing period is also reduced from 3-5 days to 1-2 days. In addition, the traditional fishermen also are benefited by using of PFZ forecast falls near shore.

The development of the satellite based advisory services for disaster warning messages the right information to all fishermen in deep sea in real time and warn them on the likely danger due to rough sea, cyclone or even tsunami, which helps them to take suitable decisions to save the precious lives.

d. Implementation mechanism:

Using data from Remote Sensing (RS) and Geographic Information System (GIS) technique,Indian National Centre for Ocean Information Services (INCOIS) of Ministry of Earth Sciences (MOES) has been generating the needed information/ forecast for Indian fishermen often referred as the Potential Fishing Zones (PFZ) advisories about fish congregation in the sea.

These forecasts indicate the places where possible fish shoals are present. Presence of Chlorophyll and difference in Sea Surface Temperature (SST) arefactors which indicate the fish congregation in the sea. Satellite derived real-time information on the above two factors are used for generating PFZ forecasts. These identified potential fishing zones are derived from the satellite images and then transferred to navigational charts to provide as PFZ advisories. PFZ advisories are brought out by INCOIS, Hyderabad, dailyand are disseminated through FAX/telephone to different fish landing centers and boat owners along the Indian coast.

The OCEANSAT spacecraft of ISRO provides essential data on surface winds and ocean surface strata, observation of chlorophyll concentrations, monitoring of phytoplankton blooms, study of atmospheric aerosols and suspended sediments in the water. The sea surface temperature(SST) is obtained from Advanced Very High Resolution Radiometer (AVHRR) thermal infrared data aboard US-National Oceanic and Atmospheric Administration (NOAA) satellite. The SST charts are generated with an accuracy of 0.5°-2°C and in near real time. The integrated Potential fishing zones (PFZ) charts along the coast of India are generated using the composite of SST (AVHRR), and chlorophyll images (IRS-P4, OCM). The process of generation of PFZ chart using AVHRR and IRS-P4 OCM data is given in Figure 1.

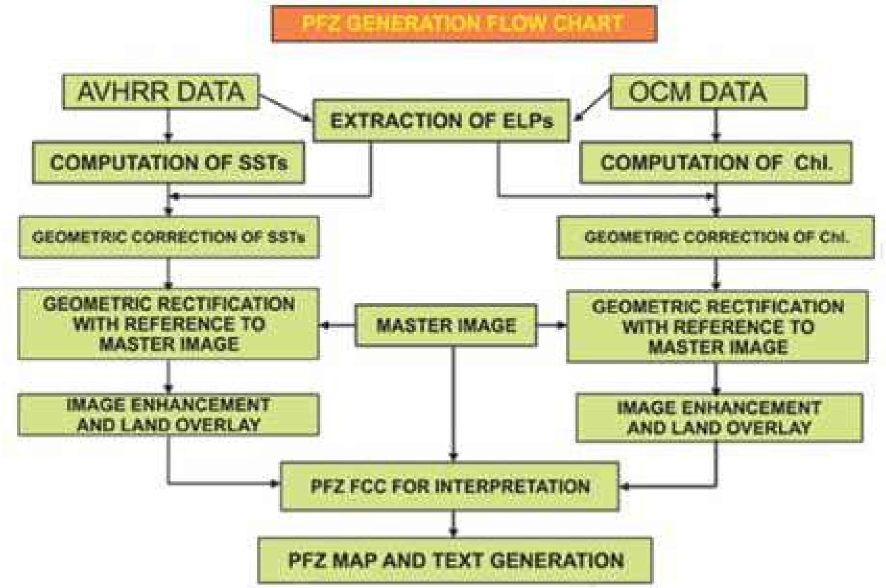

Figure 1.Steps for generation of PFZ chart using AVHRR and IRS-P4 OCM data

India has developed its own navigation system viz., GAGAN and NavIC. In addition to their primary functionality of providing PNT services, these navigation systems also have the capability of broadcasting short messages even in the region where there is no terrestrial communication network.

For seamless and effective dissemination of emergency information and communication on disaster warnings, Potential Fishing Zones (PFZ) and Ocean States Forecasts (OSF) to fishermen venturing high seas, following devices have been conceived:

A. GEMINI: the GAGAN Enabled Mariner's Instrument for Navigation and Information (GEMINI) device, launched by Government of India is used. The GEMINI device receives and transfers the data received from GAGAN satellite/s to a mobile through Bluetooth communication. A mobile application developed by Indian National Centre for Ocean

Information Services (INCOIS) decodes and displays the information in nine regional languages. The architecture of GEMINI is given in Figure 2. Electronic Display Board (EDB) developed for display has been installed at various fish landing centers along the coast. Electronic display board facilitates dissemination of satellite images, ocean state information and also the disaster warning. At present, INCOIS disseminates these fishery prospects charts to around 586 nodes covering the entire coastline of India. This technique is being operationally used at the national level with update of fishery forecast daily.

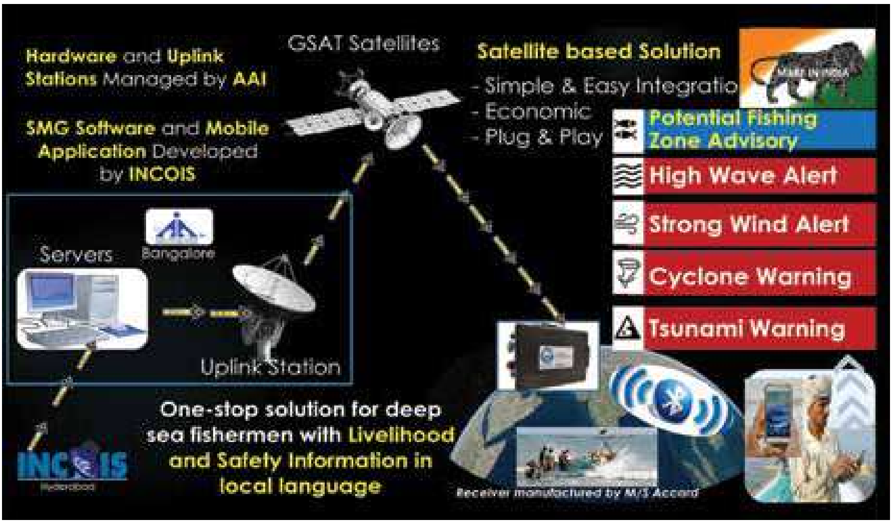

Figure 2: GEMINI Architecture (Credits: INCOIS)

Figure 3 below gives a typical PFZ dissemination along the Indian coast. It can be seen that PFZ Information are disseminated in both western and eastern coasts as shown in the Figure.

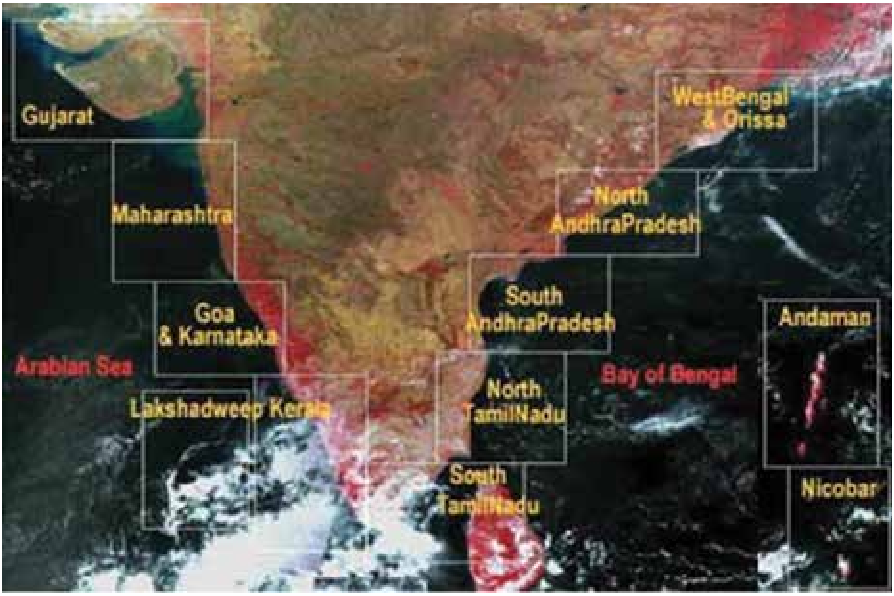

Figure 3 A typical PFZ dissemination along the Indian coast.

B. NMR: The NavIC Messaging Receiver (NMR) is conceptualized and developed by ISRO for reception and display of messages related to alerts, forecast and directives on the occurrence of natural disasters like high wave, cyclone, Tsunami etc. The receiver transmits raw data over Bluetooth (BT) link to a pre-configured mobile unit. An application running on a smart device like mobile phone/tablet having Bluetooth connectivity can decode and display the messages for users. This receiver is designed as battery operated low power device. The architecture of NMR is given in Figure 4.

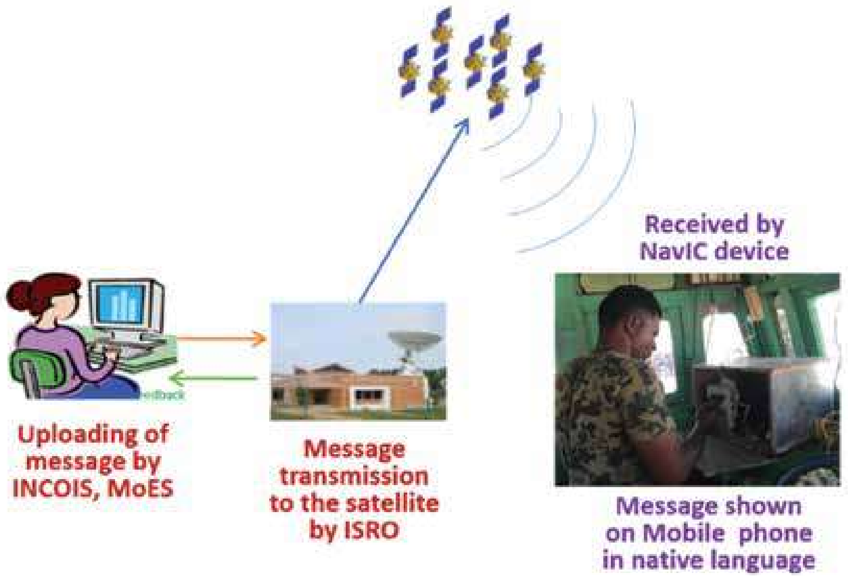

Figure 4: NavIC Messaging System Architecture

Mobile Satellite Services (MSS) in India has been implemented for national disaster management and for strategic & special application needs. High Power multi beam S-band Satellite (GSAT-6) has paved the way for miniaturized terminals for popular MSS applications. Space Application Centre (SAC), Ahmadabad has developed a number of handheld and portable terminals with IP based Hub to support different S-band communication services. The system for monitoring the movement of sub 20m fishing boats in sea consists of a transponder unit fitted in the boat, a Satcom (GSAT-6) satellite spectrum, an earth station hub, network management servers and associated software. ISRO has developed a two way MSS terminal using in-house developed modem ASIC (SDM1.0), capable of tracking 2.5 lakhs boats simultaneously.

The primary objective was to track the position of sub 20m boats and to provide two- way messaging features andreal-time position information to various authorized agencies including, department of State Fisheries and Central fisheries. The system has various features aiding fishermen such as emergency stored messaging (SoS) from boat to hub, emergency broadcast related to weather and disaster warning from control station to boats, two-way small messaging between boat owner and fisherman. A user friendly multilingual Android Mobile App for Connectivity to MSS Terminal using Bluetooth/ Wi- Fi is provided to users. The block diagram of the entire system of vehicle tracking system for sub 20m fishing boats is given in Figure 5. The MSS Hub for two way MSS Network is currently located at Space Application Centre, (SAC) Ahmedabad with 6.3 m C-band antenna to communicate to the satellite.

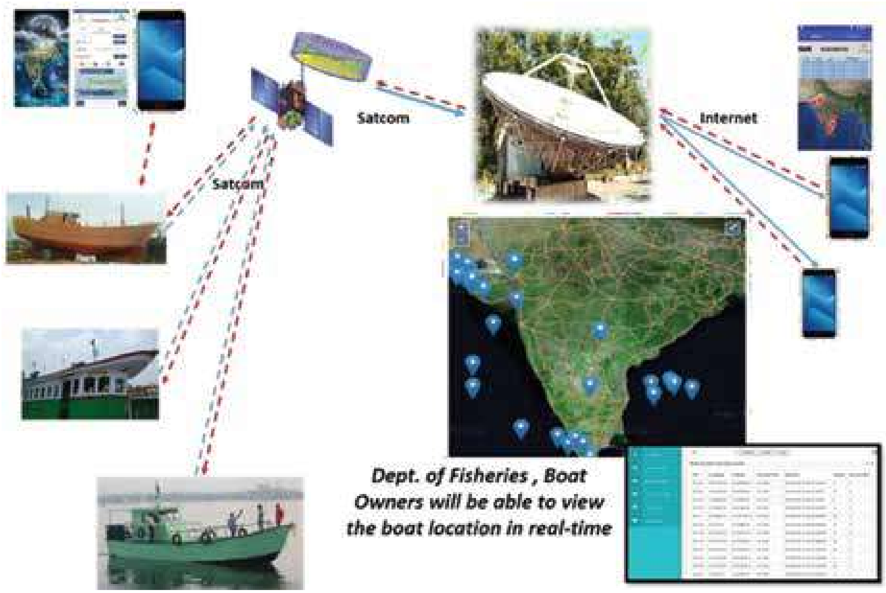

Figure 5: Tracking system for sub 20m fishing boats

MSS terminal hardware was developed at SAC/ISRO with modem ASIC to prove the technology. The terminal comes with an Android Application named as "Nabhmitra (A friend in the sky)" which facilitates fisherman to connect with the terminal via Bluetooth/Wi-Fi for sending and receiving emergency messages/small messages using an android phone. In addition, since data from all the terminals managed at central hub, it allows Dept. of Fisheries / any nodal agency (INCOIS) to send emergency warning or Potential Fishing Zone information to fishermen.

e. Area Coverage: National / State / District.

The space based system gives the full coverage along the entire coastline of India. The satellite (GSAT-6) uses BSS band of frequencies in forward link (C x S) and MSS band in the return link (S x C). The GSAT-6 incorporates C-band feeder link and the downlink is in S-band having five spot beams. West and South beams have large sea coverage, which is utilized for tracking of small boats.

For the purpose of dissemination of PFZ adversary, the entire Indian coastline along several states is divided into 12 sectors for the purpose of generating thePFZ maps in their respective local languages The States are : Gujarat, Maharashtra; Karnataka and Goa;Kerala; South Tamil Nadu; North Tamil Nadu; SouthAndhra Pradesh; North Andhra Pradesh; Orissa and WestBengal; Lakshadweep Islands; Andaman and NicobarIslands. The PFZ maps provide information on themajor landing centers, bathymetry latitude and longitude and the identified fishing zones. Theseintegrated PFZ advisories are prepared in English, Hindiand other local languages (Gujarati, Marathi, Kannada,Malayalam, Tamil, Telugu, Oriya and Bengali).

f. Results Obtained: (compare with item c above)

The results of experiments on PFZ advisories along North Andhra by National Remote Sensing Agency (NRSA) and Fishery Survey of India (FSI), Visakhapatnam base during November 2002, through - February 2004 were quite encouraging. It was observed that during trials the chlorophyll gradients were prominent (moderate to strong) compared to SST (feeble) gradients along theNorth Andhra and Orissa coast. At the same time the fish catches were quite high in the areas where SST and chlorophyll features were strongly coupled.

Regarding the tracking of fishing boats, with more than 500 MSS terminals across five locations in Tamil Nadu, an awareness program was carried outin coordination with Department of Fisheries. The officials of Fisheries Department's officials (Assistant Directors, Inspector, Joint Director) andFishing community along with boat owners & drivers were trained about usage of the terminal. The demonstrations on working of terminal and also hands on training on the user application of the terminal were imparted. In addition, the application software, user manual, and necessary literature were given to number of participants. After successful completion of pilot-project, the national roll-out of MSS network to track 2.5Lakh fishing vessels is being continued.

g. Users' Perspective

The fishermen all across the country are vastly benefitted by the advisories of potential fishing zones. They are quite happy with the information on PFZ's and utilizing these services regularly. The display in the local languages is a big advantage to the locals. The fisher men have been utilizing the information on potential fishing zones, geo-fencing applications etc., through their regional language and easy to use hand held instrument. They are saving a lot of time and also the expenditure since the directions are easily available. The fishermen are greatly benefitted by the alerts on emergencies such as cyclone, high waves, tsunami, etc., which was not available earlier and based on the inputs they attempt to move to the safety. The study carried out on PFZ users in Tamil Nadu and Puducherry in 2012 confirmed that 60 per cent of fishermen usingtrawlers benefited from PFZ. At the same time small craft fishermen too constituteda whopping 40 per cent, indicating that smaller fishermen were makingsignificant use of the PFZ advisories.

The feedback from fishermen is that distress alert system is very user friendly. With press of a distress button on DAT devise it sends its location, time and type of emergency along with its id. It also gets activated automatically when touches the water. This has been of considerable help to fishermen as an aid for search and rescue operation. On activation, the DAT transmits signals every one minute for initial 5 minutes followed by once in every five minutes till the battery lasts (more than 24 hours). The DAT is designed to float on water in sinking situation and functions nominally while floating on the water. Users are greatly benefitted with space aided safety system.

The fishermen have the option of sending emergency messages when at sea. This gives the boat's co-ordinates to the Coast Guard Maritime Rescue

Co-Ordination Centre, at Chennai. Situations like medical emergency, fire on board, sinking or capture of boats are being reported to authorities on shore for immediate action. The ship's location is displayed on a map so that rescue personnel can coordinate an efficient rescue operation.

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"I appreciate the initiative and efforts by Dr.BN Suresh in shaping it up into the present form. I wish the publication gets well-circulated and creates much awareness amongst the masses about India's journey of Diverse Space Applications"

–S. Somanath

Land Use Map 2016-17

"Through this publication; "Diverse Space Applications for National Development", Dr.BN Suresh delves into applications of space technology, that are developed and operationalised in the country, benefitting specific user segments, the society and the nation at large. The author looks at the contributions of Earth Observation, Satellite Communication and Navigation from citizens' perspective and appreciates how these applications are used for bringing tangible or intangible benefits to the country. I am sure that this compilation is an excellent resource on the last mile connectivity of Indian Space Programme, and the reader would definitely gain insight on how Indian Space Programme is relevant and beneficial for the country."

–Shantanu Bhatawdekar