CEN 201
Geospatial Engineering - II

1. Introduction

Dr. Prakhar Misra
Assistant Professor
Geospatial Engineering Group
Department of Civil Engineering
IIT Roorkee
prakhar.misra@ce.iitr.ac.in

*CE4-6 Batch

Course objective: advanced surveying

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: Civil Engineering

1. Subject Code: CEN-201 **Course Title: Geospatial** Engineering II

2. Contact Hours: **L:**2 **T:** 0 **P:** 2

3. Examination Duration (Hrs): **Theory:** 3 **Practical:** 0

4. Relative Weight: CWS: 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0

5. Credits: 5 **6. Semester:** Autumn **7. Subject Area:** PCC

8. Pre-requisite: Nil

9. Objective: To impart knowledge on advanced surveying, photogrammetry, remote sensing, and Geographic Information Systems (GIS).

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Introduction of Geospatial Engineering and its applications in Civil engineering	1
2.	**Photogrammetry:** aerial and terrestrial, types and geometry of aerial photograph, scale and flying height, relief (elevation) displacement, parallax, stereopair and stereovision, stereoscopes, 3D mapping, height determination, photogrammetric mapping, applications of photogrammetry.	5
3.	**Remote Sensing:** Basic/ Ideal remote sensing, interaction mechanism with atmospheric and earth surface, atmospheric windows, multi concept of remote sensing, spectral signatures, various platforms and sensors; visual data interpretation	6
4.	**Sensor & its Data Products:** Various remote sensing sensors & its products (optical, thermal, microwave, hyperspectral, LiDAR)	3
5.	**Digital Image Processing:** Digital image, introduction to digital image processing, preprocessing, enhancement, transformation, indies, image classification for mapping, accuracy assessment.	6
6.	**GIS:** Introduction of geographic information system, vector and raster data, database creation, digital elevation model (DEM), buffering and overlay analysis, spatial analysis in GIS, applications.	6
7.	Introduction to Unmanned Aerial Vehicles (UAV)	1
	Total	**28**

List of Practicals:

1. Familiarization with different types of data products, such as maps, aerial photographs, Mosaics, satellite imagery. Study the information content and suitability of these data products in Civil Engineering applications.
2. Study the difference between a topographic map and aerial photograph of an area. Determine the average scale of the photograph. Also compute the flying height of the aircraft taking observations on minimum 10 points.
3. Study and test of stereovision using the Stereo Test Cards and Pocket Stereoscope. Demonstration of Mirror Stereoscopes to create 3D Model.
4. Base lining of a pair of stereo photograph and creation of 3D Model. Study and use of Parallax Bar.
5. Determination of elevation of minimum 10 points on a stereo pair using Parallax Bar measurements. Determination of corrected elevation by drawing error Contours.
6. Study of photo-interpretation Keys for extraction of Thematic and Topographic information from Aerial Photographs and Satellite Imagery. Preparation of Thematic map such as land cover, drainage pattern of area.
7. Study the Image Processing Systems. Carry out Digital Image Processing of remote sensing image for:
   a. Initial Statistics Extraction
   b. Image Enhancement
   c. Image Transformation (vegetation indices)
8. Sites for free download of satellite images. Geo referencing of remote sensing image with GCP data. Demonstrate the utility of Geo referenced temporal satellite images.
9. Carry out Supervised Landuse and Land Cover Classification of Remote Sensing data and its accuracy assessment.
10. Practice on GIS software, Data input to GIS from various sources.
11. Creation of Digital database (Spatial and Non-spatial) in GIS.
12. Spatial analysis (including buffer and overlay analysis) in GIS.
13. Demonstration on UAV.

12. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication
1.	Bossler, J.D., "Manual of Geospatial Science and Technology", Taylor and Francis.	2002
2.	Burrough, P.A. and McDonnell, R.A., "Principles of Geographic Information System", Oxford University Press.	2000
3.	Chandra, A.M. and Ghosh, S.K., "Remote Sensing and Geographical Information Systems", Alpha Science.	2005
4.	Garg, P.K. Theory and Principles of Geoinformatics, Khanna Book Publishing Co. Delhi	2019
5.	Lillesand, T.L., Kieffer, R. W. and Chipman, J., "Remote Sensing and Image Interpretation", John Wiley and Sons, 6th Ed.	2007
6.	Vosselman, George and Maas, Hans-Gerd, Airborne and Terrestrial Laser Scanning, Whittles Publishing.	2010
7.	Valavanis, K and Vachtsevanos, G.J. (Eds) Handbook of UAV, Springer	2018
8.	Paul Fashlstrom and Thomas Gleason, Introduction to UAV Systems, John Wiley & Sons	2018

Marking schema and house rules

	%
Attendance: (N-14)/14*100	10
Practical (viva, report)	15
Surprise Quiz (2)	15
Mid-Term	20
Final Exam	40
Total	100

1. **Be honest**
2. **Respect others' time**
3. **Be attentive/interactive**
4. **Be considerate to your friends**

.

What could have prevent this?

https://www.livemint.com/news/india/following-google-map-for-fastest-route-you-may-end-up-on-stairs-suv-driver-tamil-nadu-11706581263350.html

What could have prevented this?

https://www.indiatoday.in/india/story/kerala-tourists-drive-into-stream-navigating-google-maps-2543717-2024-05-25

Road detection from satellite imagery

(a)

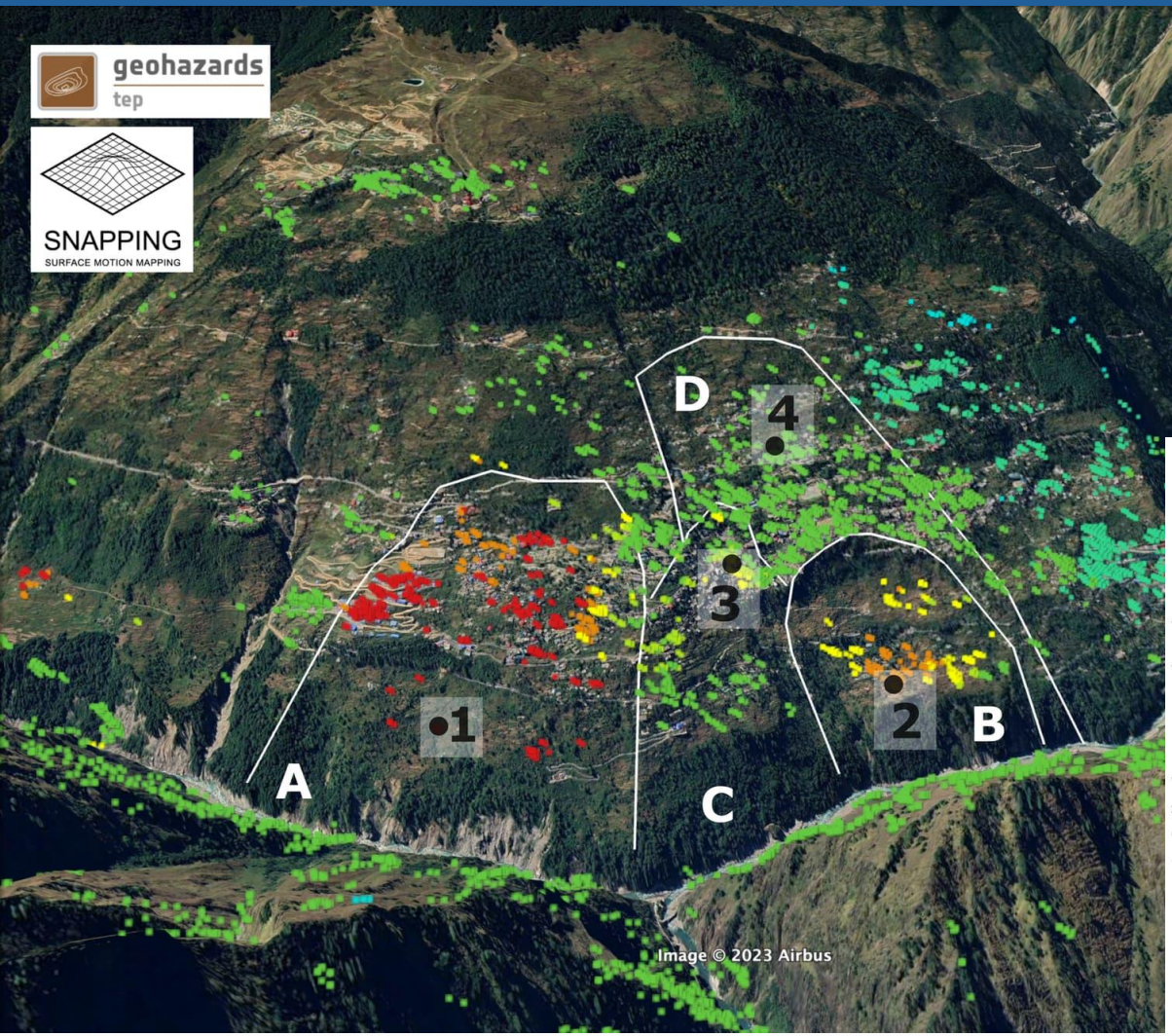
(b)

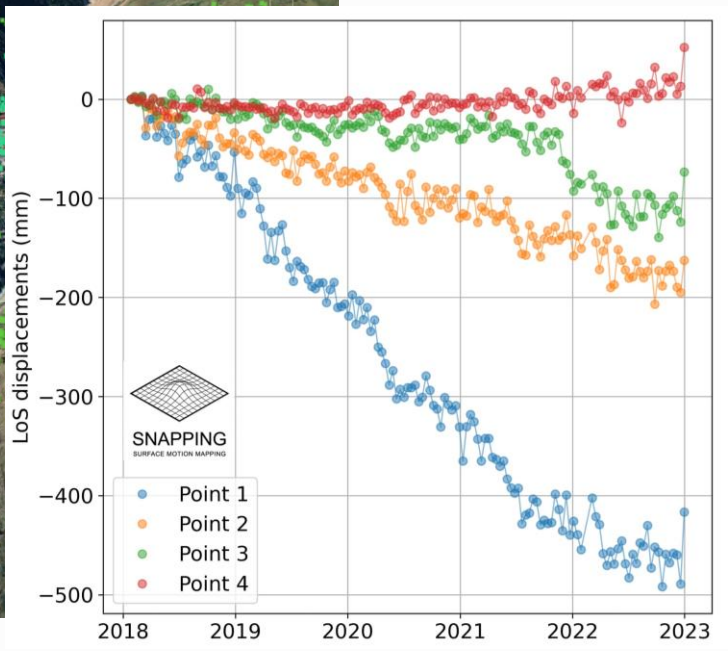
https://www.researchgate.net/publication/330155422_Road_Information_Extraction_from_High-Resolution_Remote_Sensing_Images_Based_on_Road_Reconstruction?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6Il9kaXJlY3QiLCJwYWdlIjoiX2RpcmVjdCJ9fQ

Poor construction or poor foundation?

https://www.india.com/news/india/joshimath-officially-declared-landslide-subsidence-zone-around-60-families-evacuated-top-developments-5844259/

Joshimath: active deformation zone





- 65% houses impacted, Rs 565 cr damage

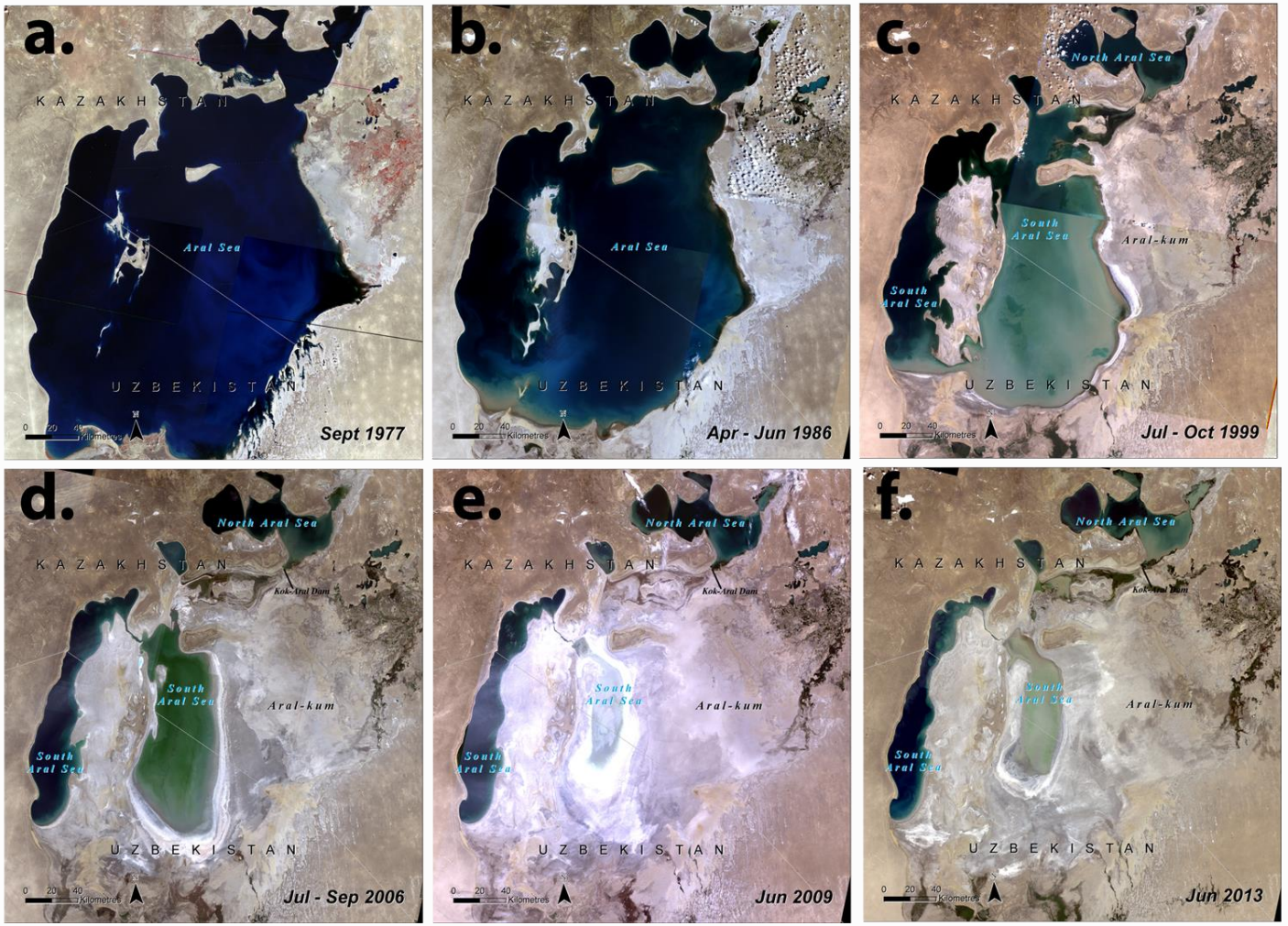
https://blogs.agu.org/landslideblog/2023/01/18/joshimath-new-insar/

Desert or ocean? 3rd largest ‘X’

https://www.nationalgeographic.com/environment/article/aral-sea-climate-change-desert-laboratory

https://www.unccd.int/news-stories/special-feature/witnessing-environmental-catastrophe-reflections-dried-aral-sea#:~:text=Once%20the%20fourth%20largest%20freshwater,disasters%20on%20a%20global%20scale

One of the planet's worst environmental disasters: Aral Sea



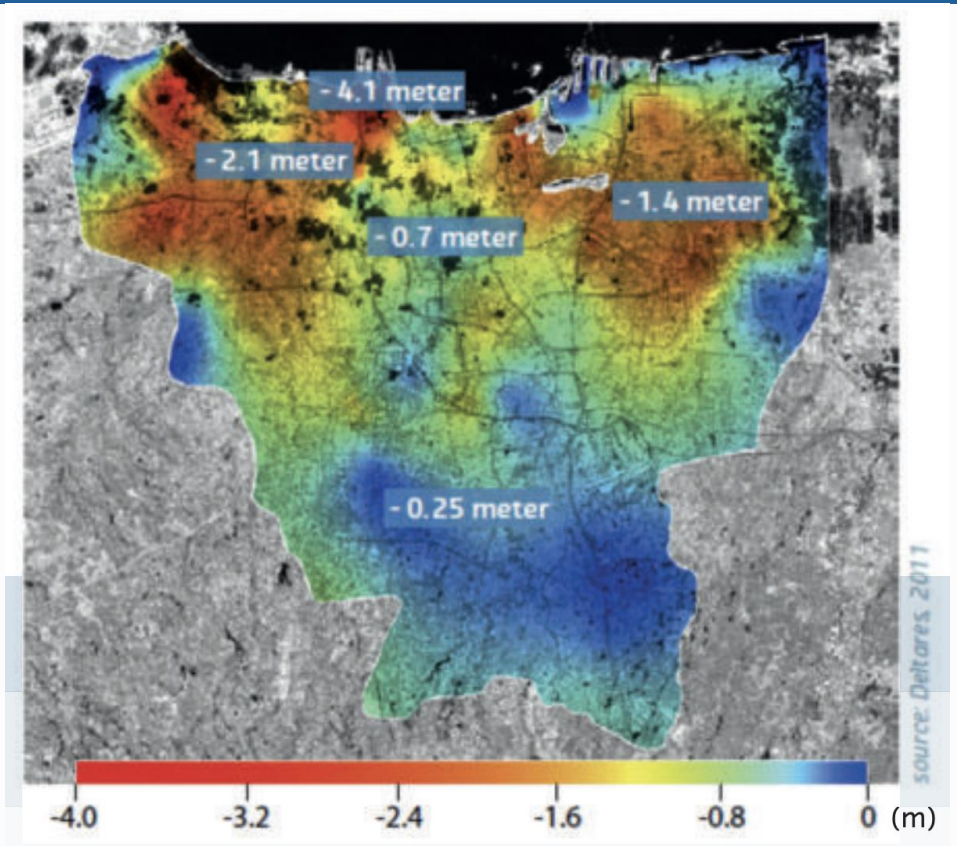
Aral Sea began shrinking in the 1960s after the rivers that fed it were diverted by Soviet irrigation projects. Satellite images by NASA in August 2014 revealed that for the first time in modern history the eastern basin of the Aral Sea had completely dried up.[7][8] The eastern basin is now called the Aralkum Desert.

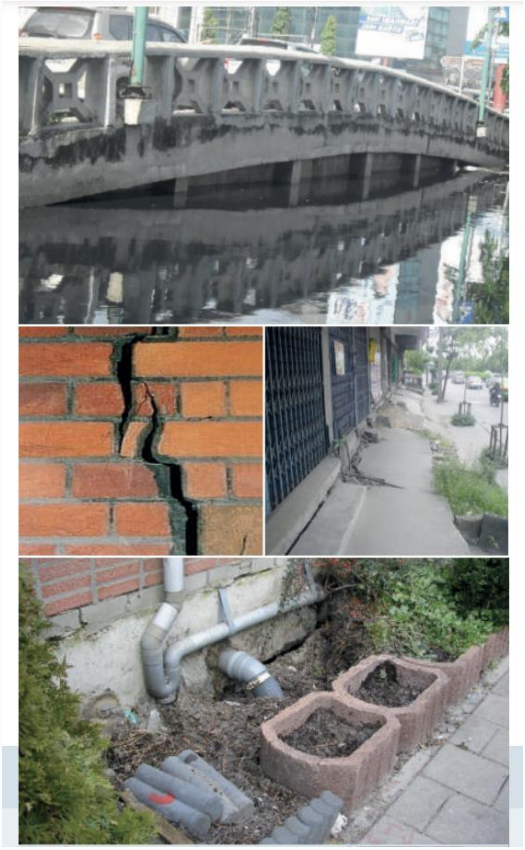
Displaced more than 100,000 people and affected the health of more than 5 million people

Jakarta: Flooding only due to heavy rainfall?

- https://indonesiaurbanstudies.blogspot.com/2013/05/jakarta-annual-flooding-in-january-2013.html

Where to build sea wall? How tall?

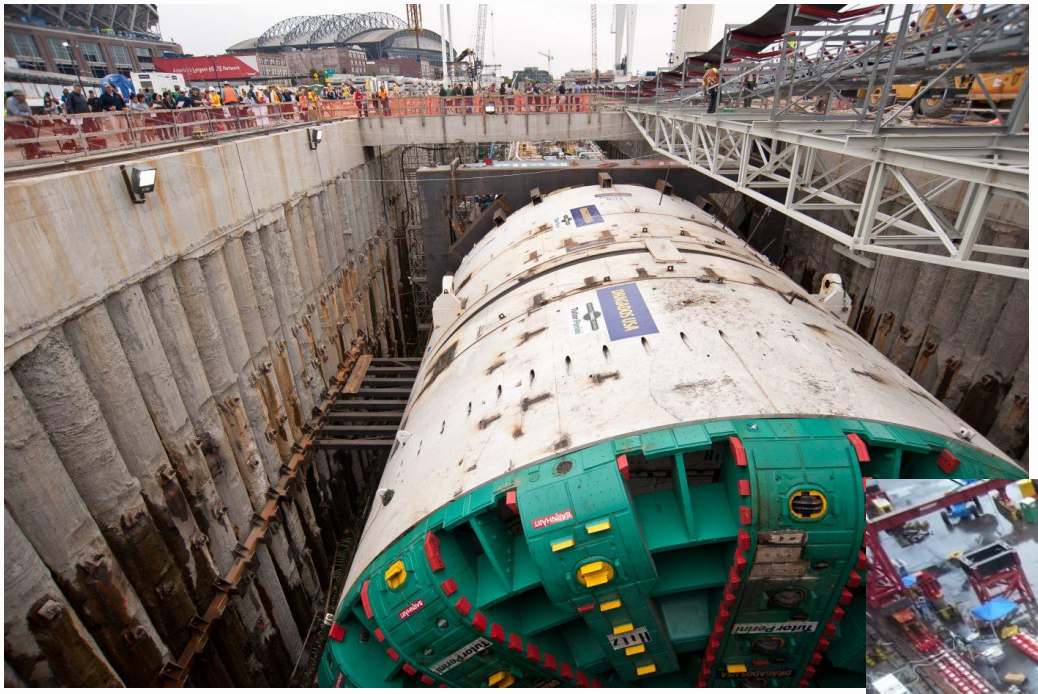




- North Jakarta has sunk 2.5m in 10 years and is continuing to sink by as much as 25cm a year in some parts, which is more than double the global average for coastal megacities.
- Dramatic rate at which Jakarta is sinking is partly down to the excessive extraction of groundwater
- Groundwater is pumped out, land above it sinks as if it is on a deflating balloon - land subsidence
- Shift to new capital at cost $35billion (15% Indonesia's annual budget)

https://cms.deltares.nl/assets/common/downloads/Sinking-cities-1.pdf
https://www.bbc.com/news/world-asia-44636934

Tunnel boring machine breaks down



World's largest tunnel boring machine (~6 storeys tall)

Access hole dug to repair TBM

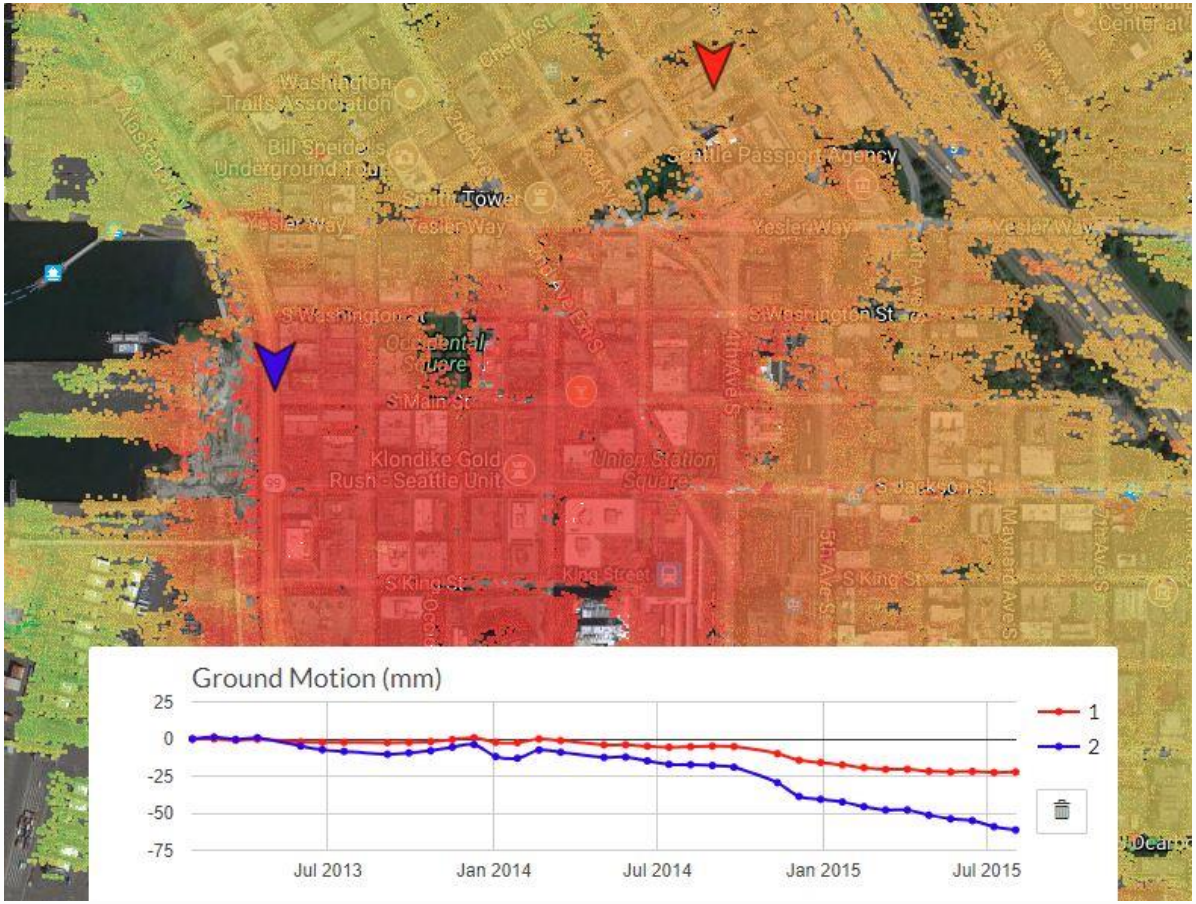
https://3vgeomatics.com/citywide-subsidence-monitoring/

How big is the impact?

Large Sinkhole appears close to access hole

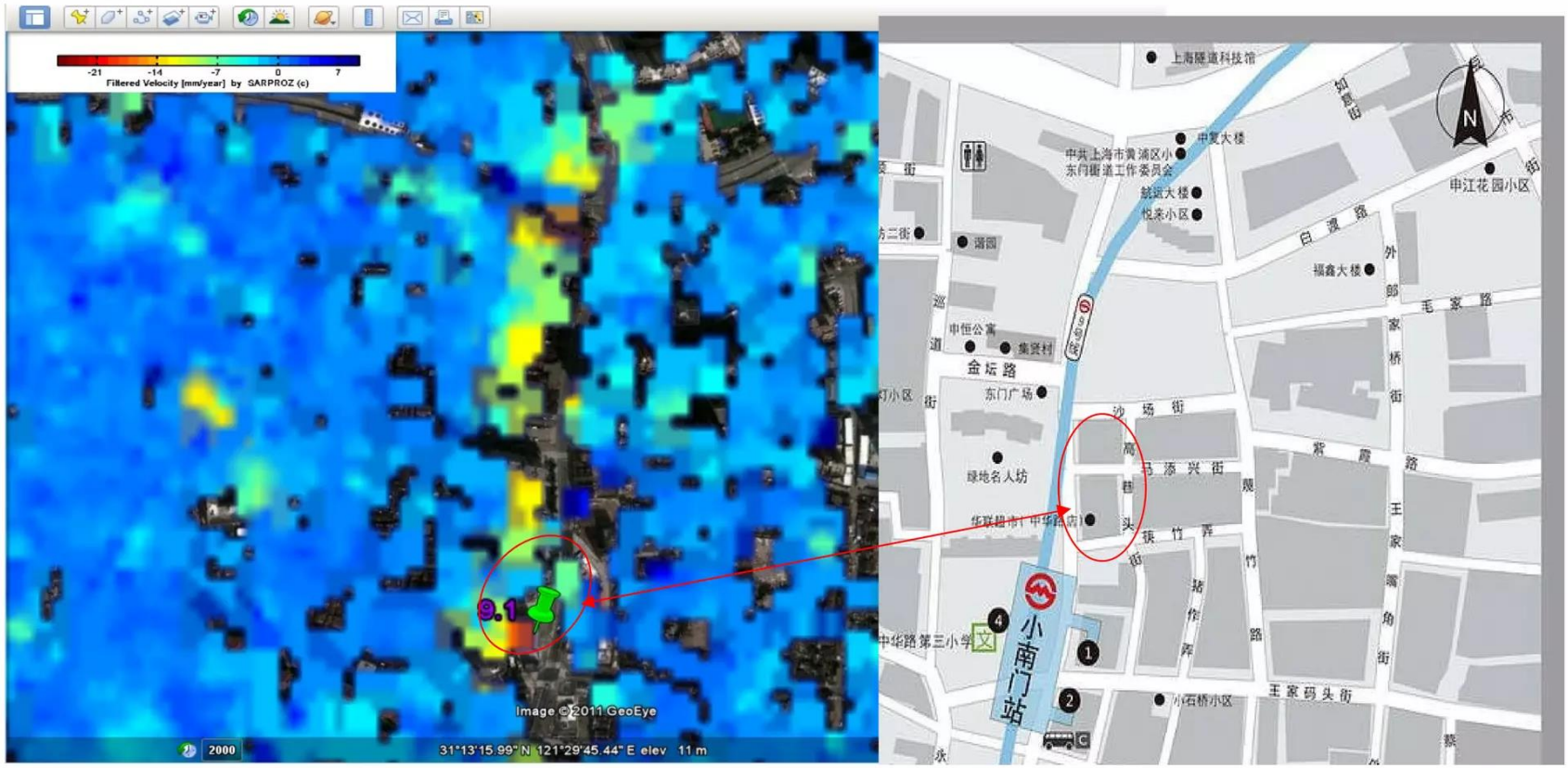
Ground settlement, cracking

TBM Subsidence using satellite



- Traditional surveying methods could not detect the displacement, due to its size resulting in misleading measurements
- intelligence on initial signs of movement to prevent or minimize significant visible damage.

Subway deformation in Shanghai

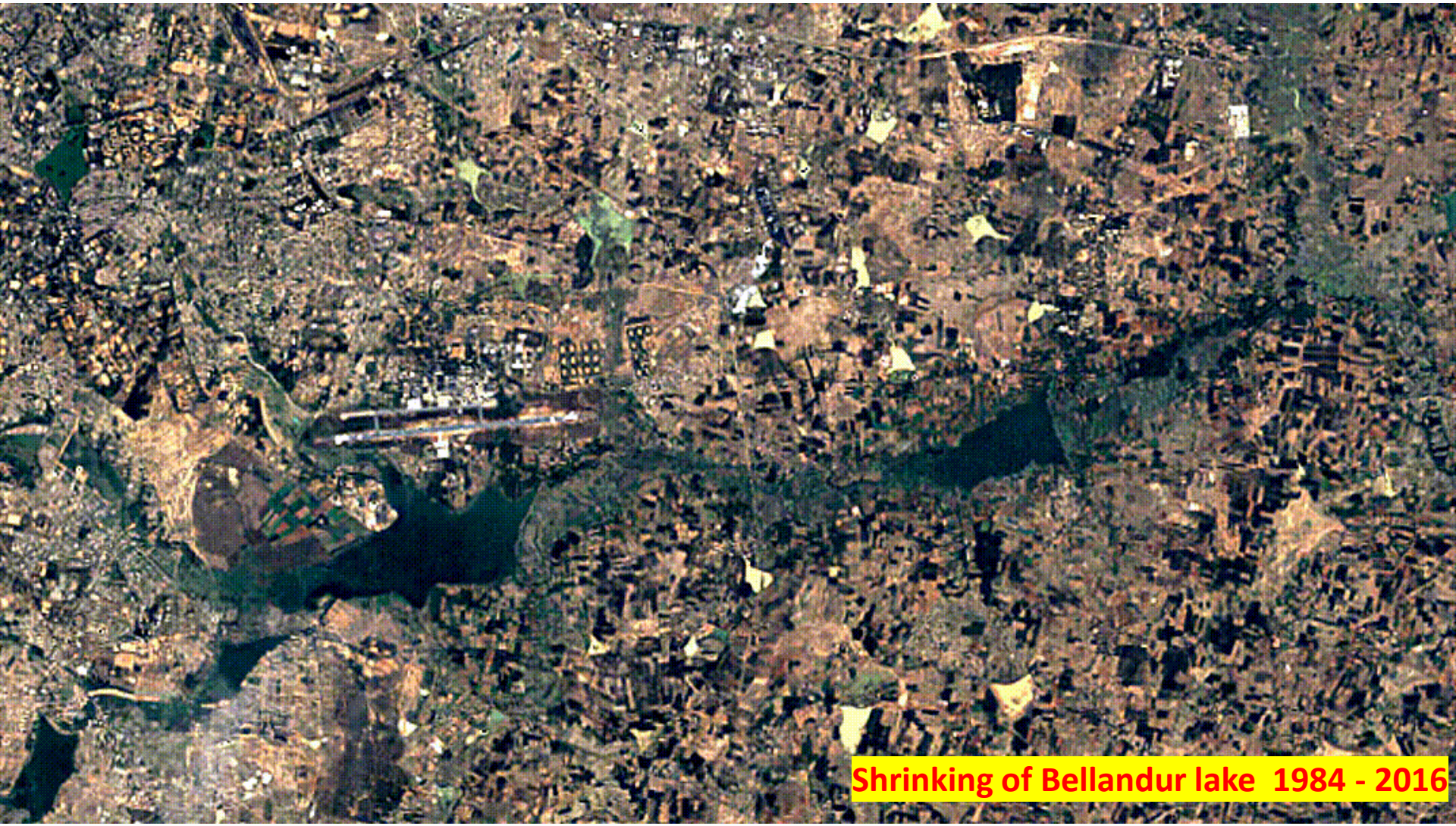


The precise location of the subway tunnels is not public. With radar data, through the surface deformation, we can precisely track the new lines built recently.

Floods in Bengaluru

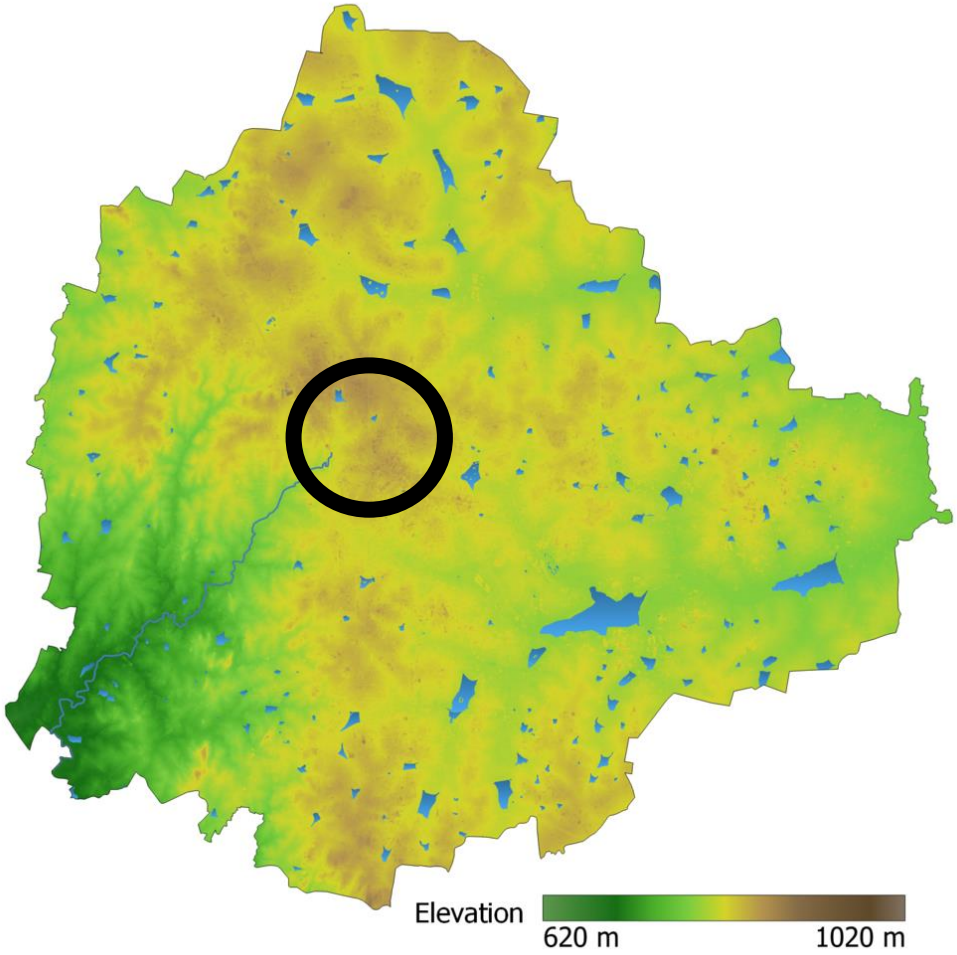
https://tfipost.com/2022/09/those-crying-about-bengaluru-floods-had-a-part-to-play-in-it/

Bengaluru: encroached floodplains

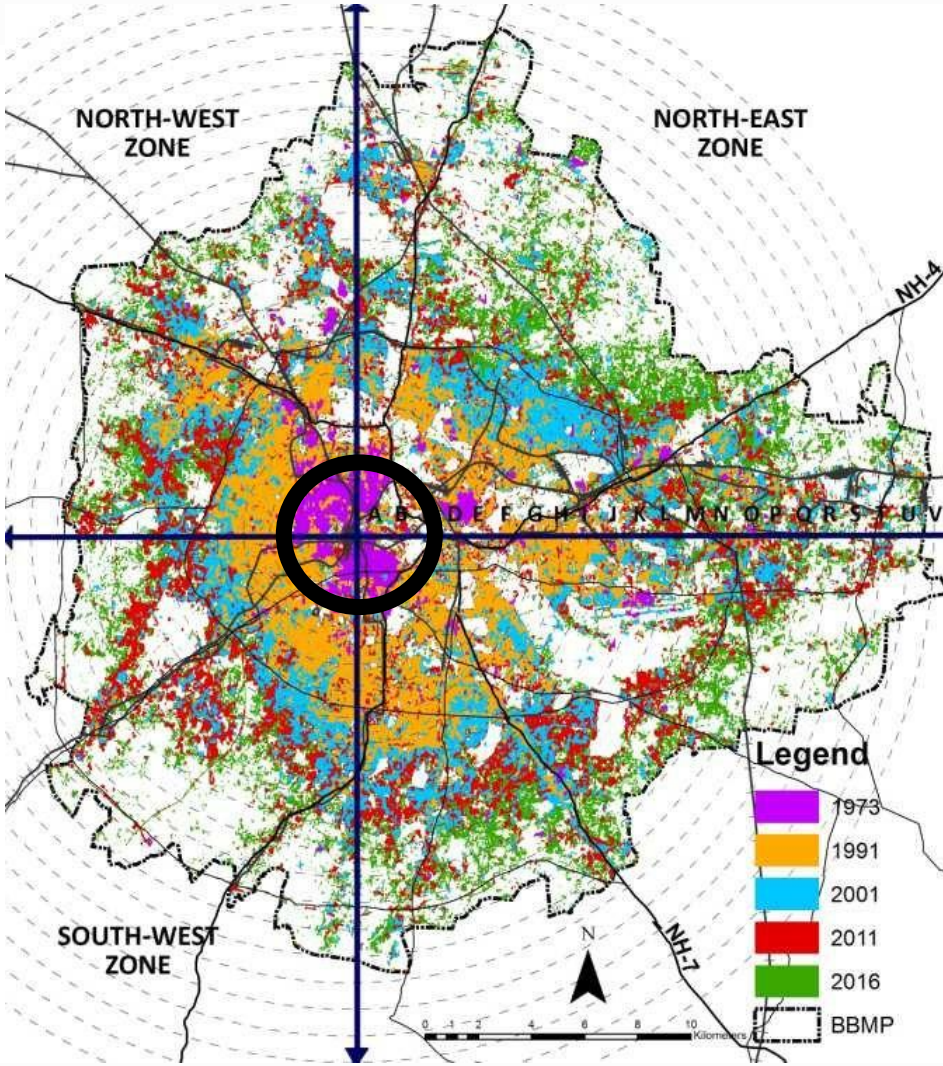


Ridge and valley style planning no longer followed

Recent urbanization along low lying areas



Bengaluru elevation

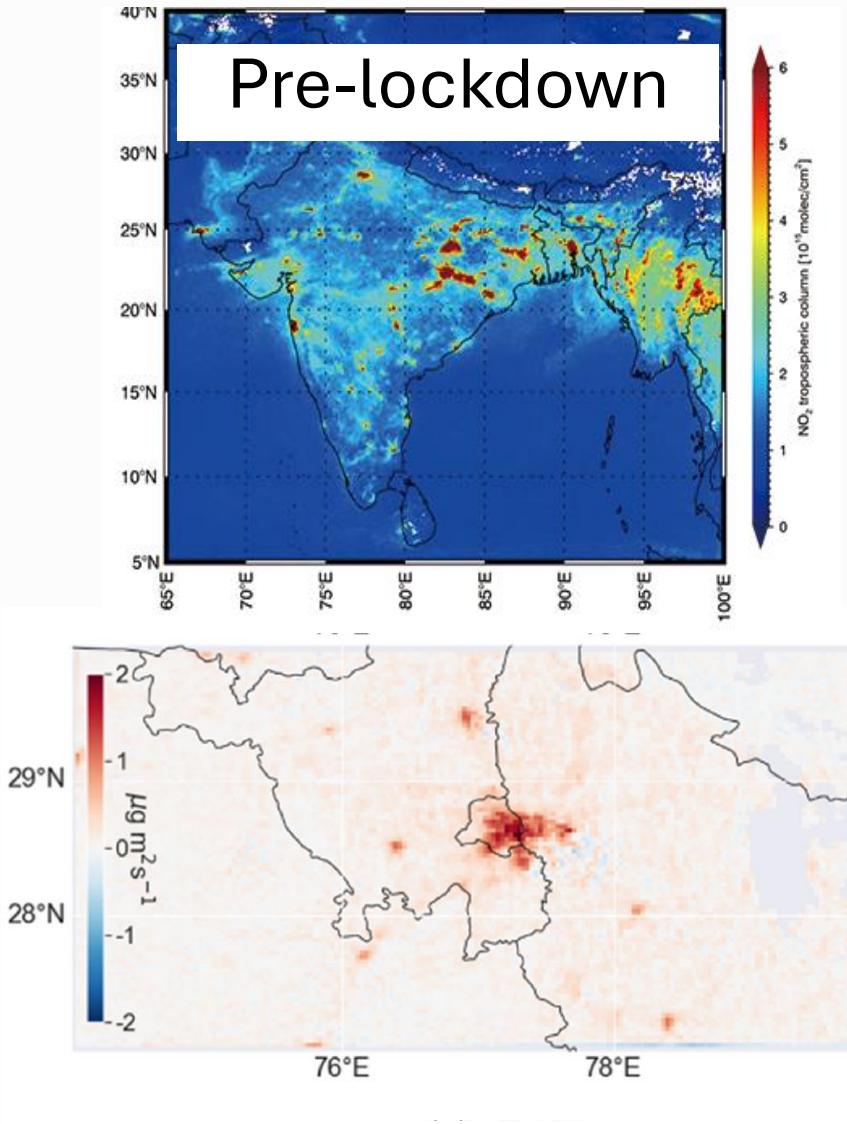


Bengaluru urbanization

Air pollution in North India

https://www.businessinsider.com/before-after-photos-show-less-air-pollution-during-pandemic-lockdown?IR=T#before-venice-italys-high-traffic-waterways-were-generally-murky-3

Decreasing NOx emissions during lockdown



Misra, P., Takigawa, M., Khatri, P. *et al.* Nitrogen oxides concentration and emission change detection during COVID-19 restrictions in North India. *Sci Rep* **11**, 9800 (2021). https://doi.org/10.1038/s41598-021-87673-2

Geospatial Engineering

Geospatial Engineering: discipline is a field that combines principles of engineering, geodesy, and surveying to collect, distribute, store, analyze, process, display, manage geospatial data or geospatial information

Geospatial data/information: data/information related to features of location(s) on earth (land, water, and underneath)

Fields/Technologies of geospatial engineering:

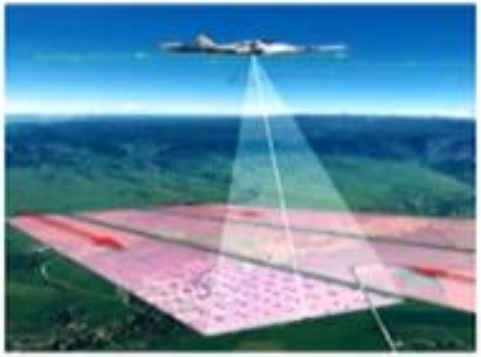
- **Land surveying**
- **Global navigation satellite systems**
- **Photogrammetry**
- **Remote sensing**
- **Geographic information systems (GIS)**
- **Cartography**
- **Geodesy**

.

Geospatial engineering

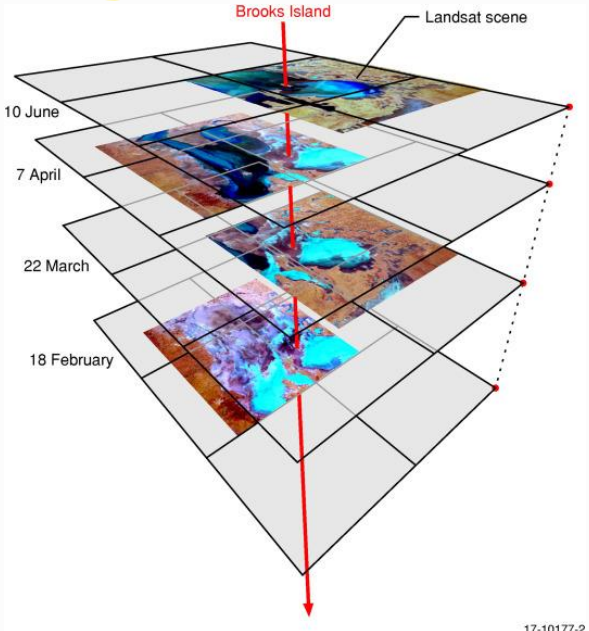
- Understanding and managing spatial aspects of world, for better planning, resource allocation, problem-solving.
- Understand complex problems and provide answers to: What, Where, When, Who, How, Why
- Geospatial engineers' work: land surveying, mapping, urban planning, environmental assessment, infrastructure development, disaster management, and natural resource management.
- Create accurate maps, models, and databases that help in decision-making processes for various industries including transportation, agriculture, telecommunications, and urban development.
- Integrate data from various sources such as ICT, IoT to geospatial datasets to create information, knowledge and value

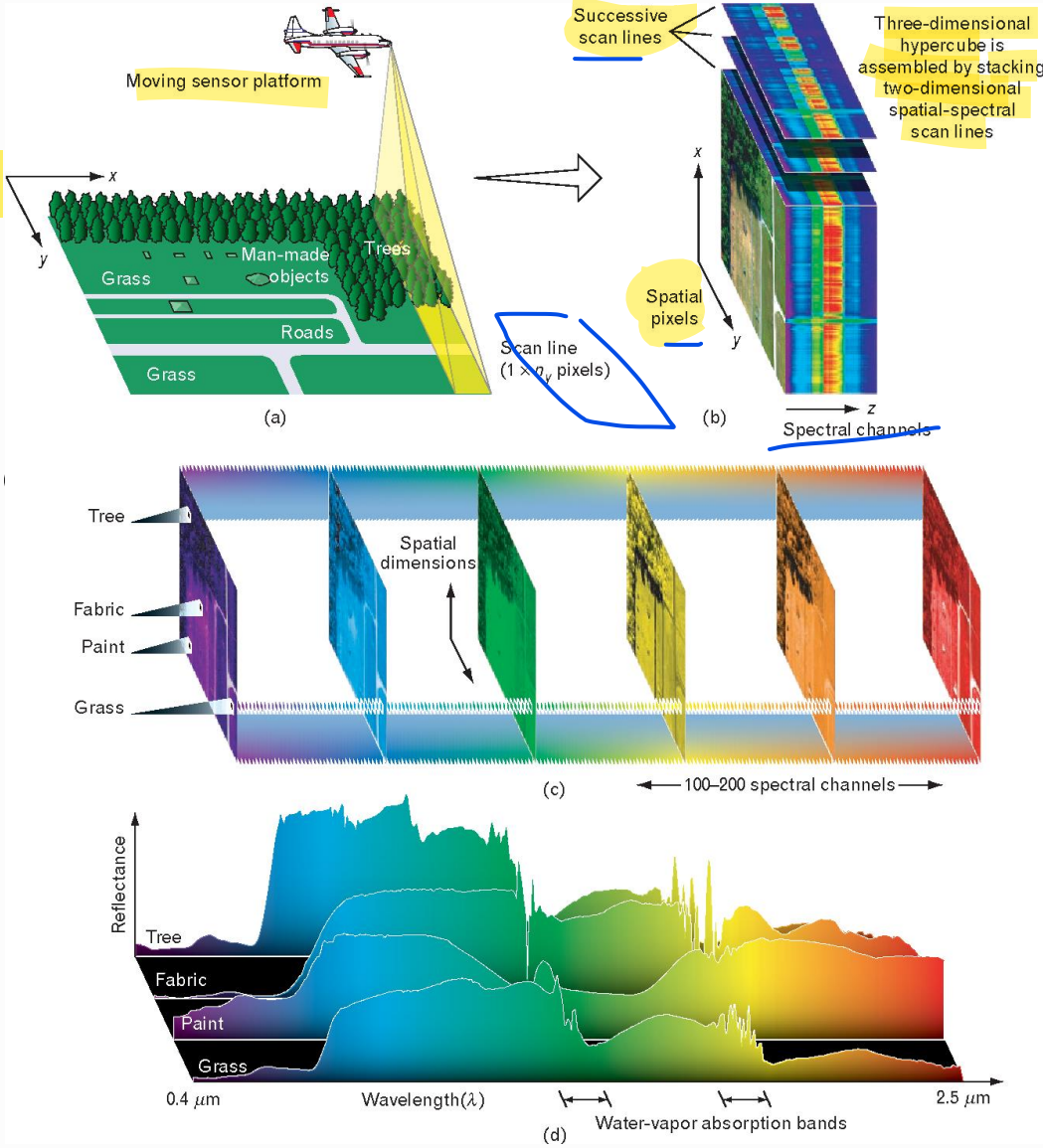
Categorize by tools for geospatial technology



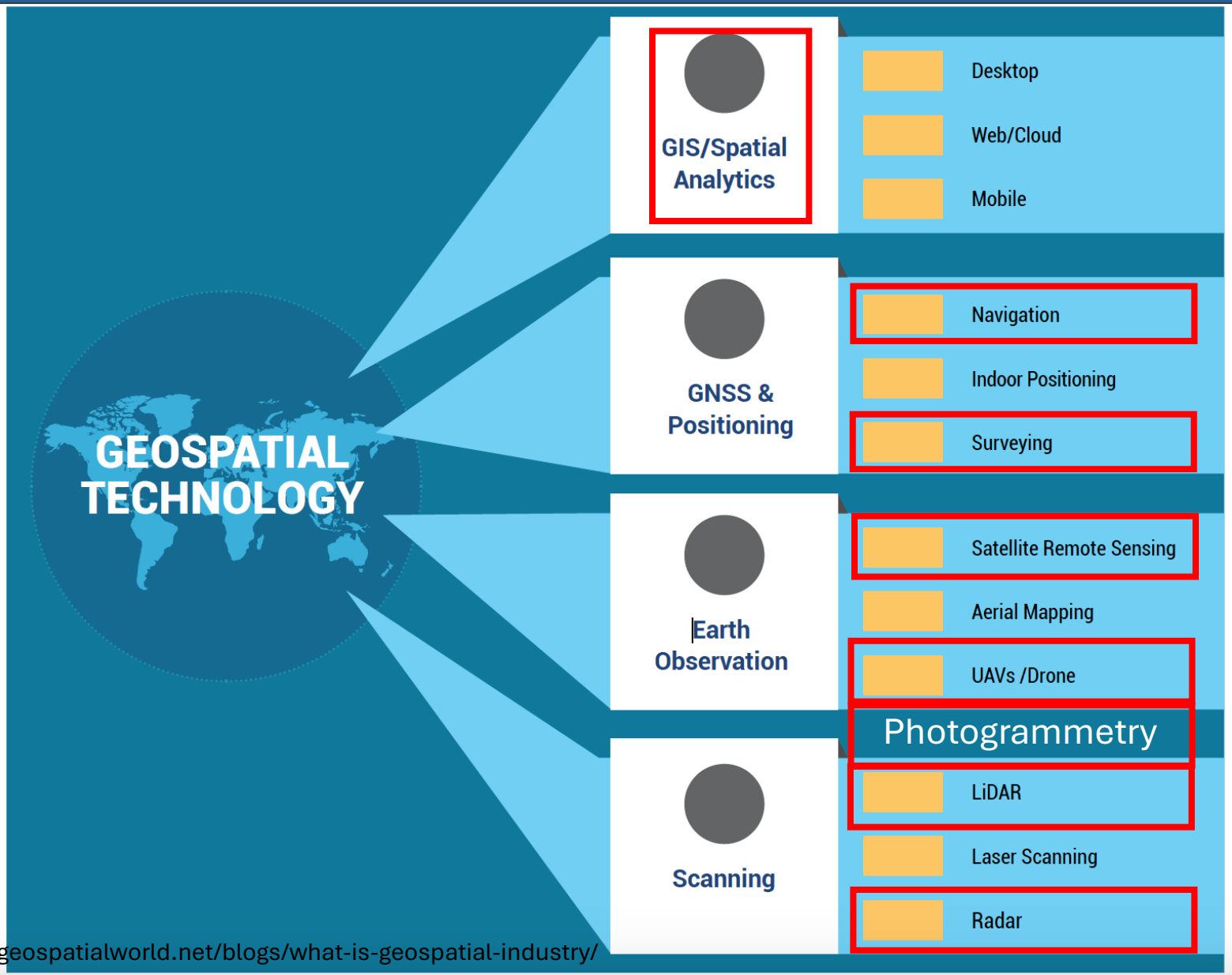
Categorize by main tasks

1. Collection of raw data
2. Processing to geodata
3. Development and manageme of geodata-database
4. Analysis and modelling of geodata
5. Development and integration geodata





Categorize by Major components



https://www.geospatialworld.net/blogs/what-is-geospatial-industry/

Global positioning system (GPS)

- *GPS provides three-dimensional position of objects on the Earth anytime, anywhere and in any weather condition.*
- Today, it is considered as the most advanced and popular system of navigation.
- The technology has benefitted various applications like, highways, railroads, mining, surveying and mapping, power, agricultural, environmental management, telecommunications, health, law enforcement, emergency response, crustal movement, disaster response, aviation, automobile navigation, tracking objects, sports, construction, recreation, etc.

GPS survey

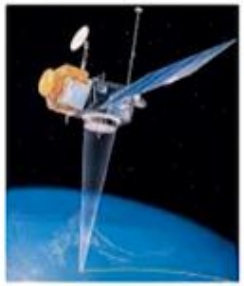
- GPS is a worldwide radio navigation system that allows users to determine their exact location, velocity, and time 24 hours a day, in all weather conditions, anywhere in the world.
- The system provides highly accurate position and precise time on a continuous global basis to properly equipped users.

Photogrammetry

- *Photogrammetry is the art, science and technology of obtaining reliable information about physical objects and the environment, through the processes of recording, measuring, and interpreting photographic images.*

- The output from the photogrammetric process can be the coordinates of ground points, a graphical representation of the ground surface (topographic map, thematic map, 3D maps, etc.), or a rectified image with map-like characteristics (ortho-photos) which can be further used in GIS.

Remote Sensing

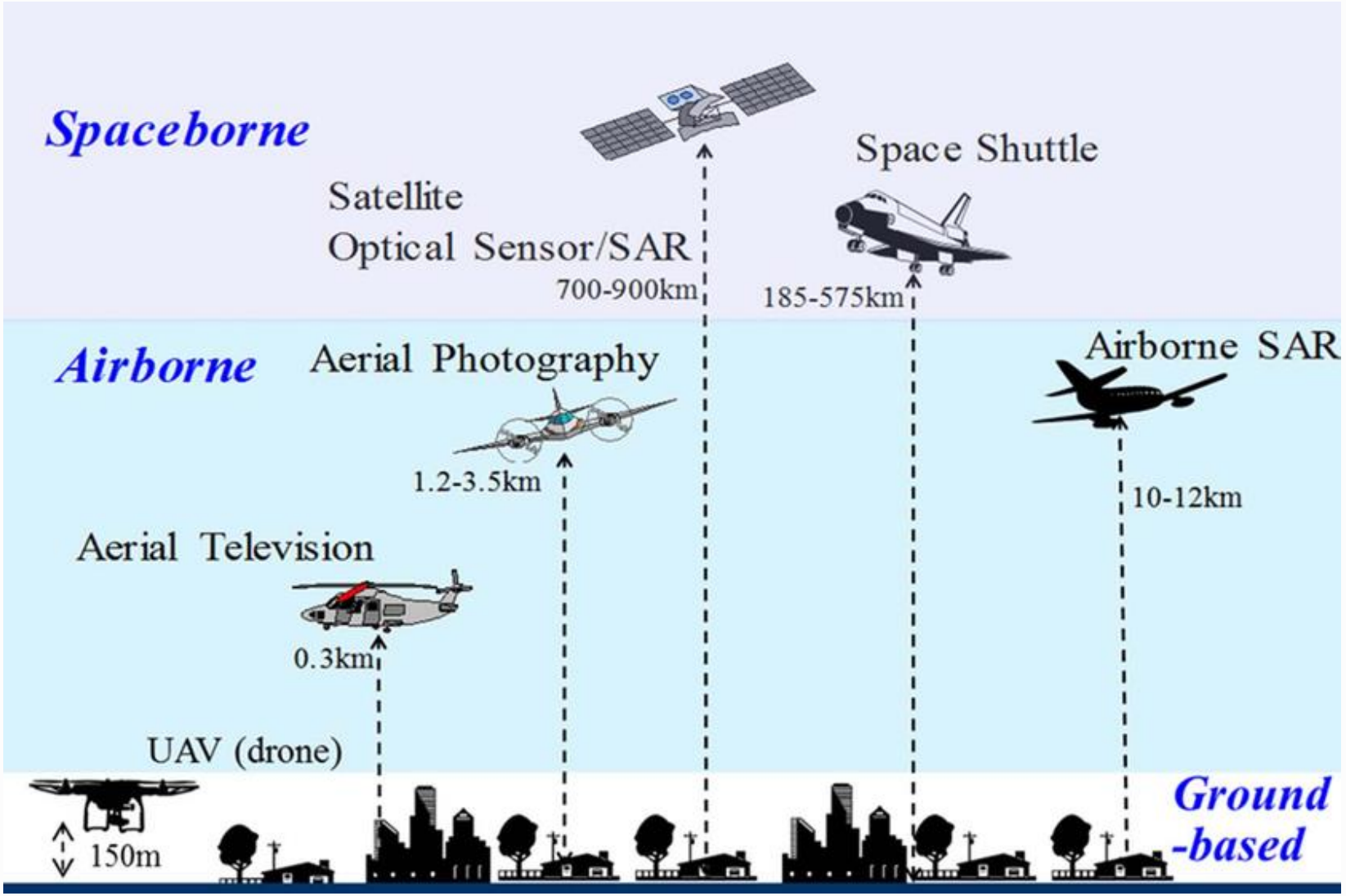


- *Remote sensing refers to obtaining information about the objects, or area, or phenomenon through the analysis of data obtained remotely by sensor systems.*
- It provides an important source of information of Earth surface, including land use, vegetation, surface temperatures, digital elevation models, soils, water, geology, roads, habitation, forestry, surface elevation and snow, at different scales
- Sequential images are very useful in monitoring dynamic activities, such as flood, water pollution, deforestation, forest fire, snow cover, urban sprawl, drought monitoring and assessment etc.

UAV/Drone

- *An unmanned aerial vehicle (UAV) is an aircraft used for Earth surface data collection that carries no human pilot or passengers.*
- UAVs, also called "drones", can be fully or partially autonomous but are more often controlled remotely by a human operator.
- UAVs are fast becoming popular, and are being used for various applications, including logistics, agriculture, remote sensing, wireless hotspot services, smart city applications, disaster management, etc.

Platforms: Satellite, Aerial, UAV



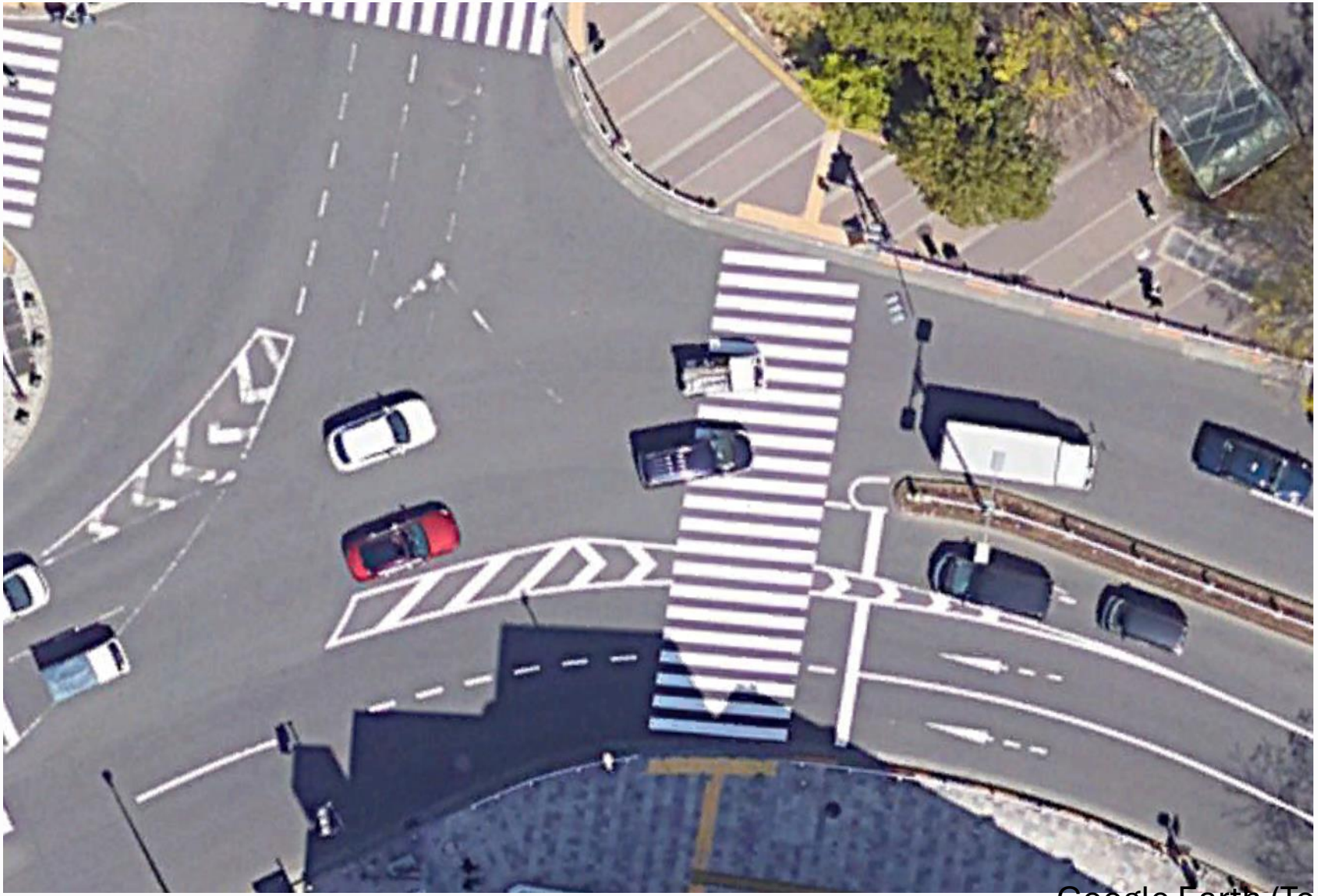
https://www.researchgate.net/publication/370131847_Free_and_Low-Cost_Aerial_Remote_Sensing_in_Archaeology_An_Overview_of_Data_Sources_and_Recent_Applications_in_the_South_Caucasus

https://www.researchgate.net/publication/329798838_Mini-UAV-based_Remote_Sensing_Techniques_Applications_and_Prospectives

Satellite platform image

Google Earth (Delhi)

Aerial platform image

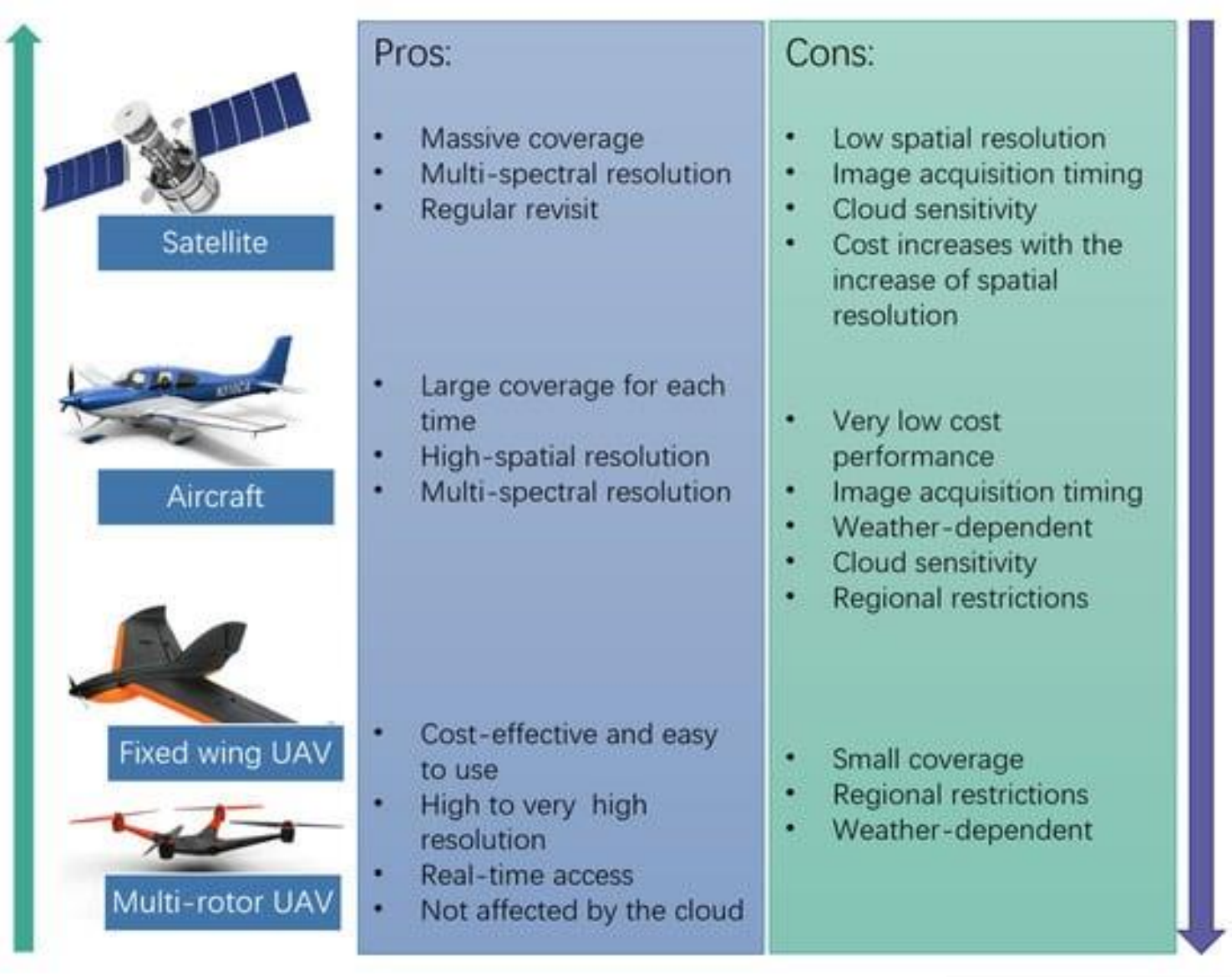


Google Earth (Tokyo)

UAV platform image

- Zhao, Y.; Zhou, L.; Wang, X.; Wang, F.; Shi, G. Highway Crack Detection and Classification Using UAV Remote Sensing Images Based on CrackNet and CrackClassification. *Appl. Sci.* **2023**, *13*, 7269. https://doi.org/10.3390/app13127269

Platforms: Satellite, Aerial, UAV

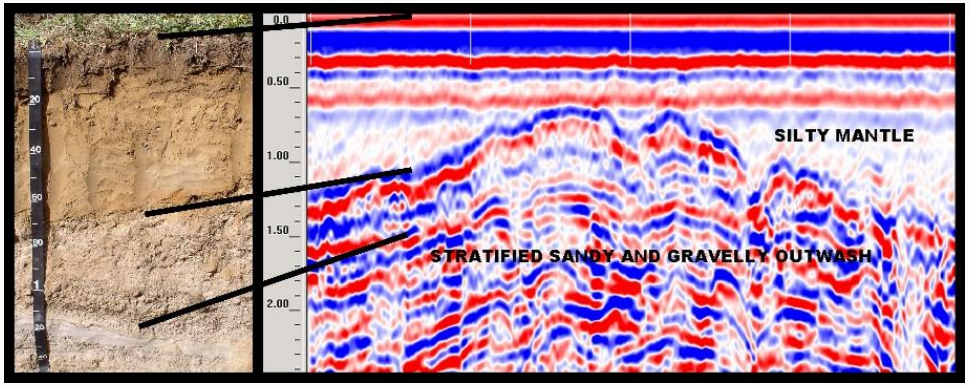


Zhang, X.; Han, L.; Han, L.; Zhu, L. How Well Do Deep Learning-Based Methods for Land Cover Classification and Object Detection Perform on High Resolution Remote Sensing Imagery? *Remote Sens.* **2020**, *12*, 417. https://doi.org/10.3390/rs12030417

Needs define/design specifications

Ground penetrating radar (GPR)

The GPR provides high-resolution coverage of the survey area, detecting even small objects underneath ground.



Light Detection and Ranging (LiDAR)

Measures distance to surfaces by timing a laser pulse and its corresponding return providing X,Y,Z positions of each return.

Used for mapping topography, structure geometry

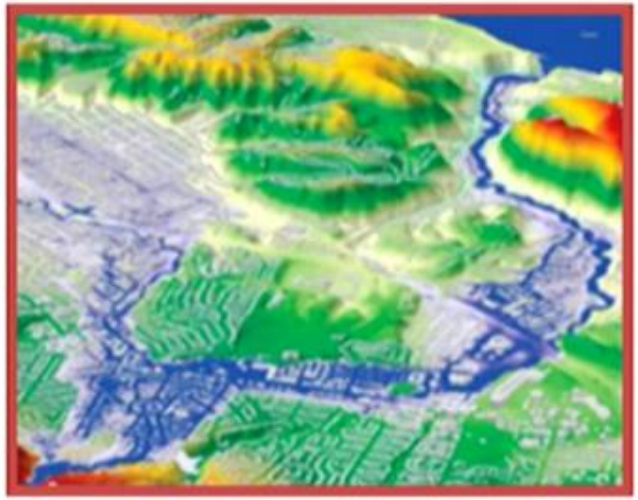
LIDAR has high accuracy of –

10- 15 cm in height and

30 cm to 60 cm in the horizontal

It has high productivity of around 300 square kilometers of coverage per hour, and

It can operate day and night.

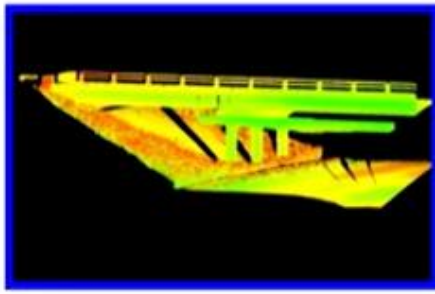


Terrestrial laser scanner (TLS)

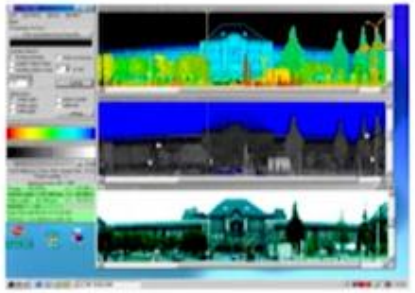
LiDAR point cloud of another bridge

Uses of TLS

- It collects 3-D data (X, Y and Z) of the objects, such as dams, bridges, towers, structures and building in a faster way.



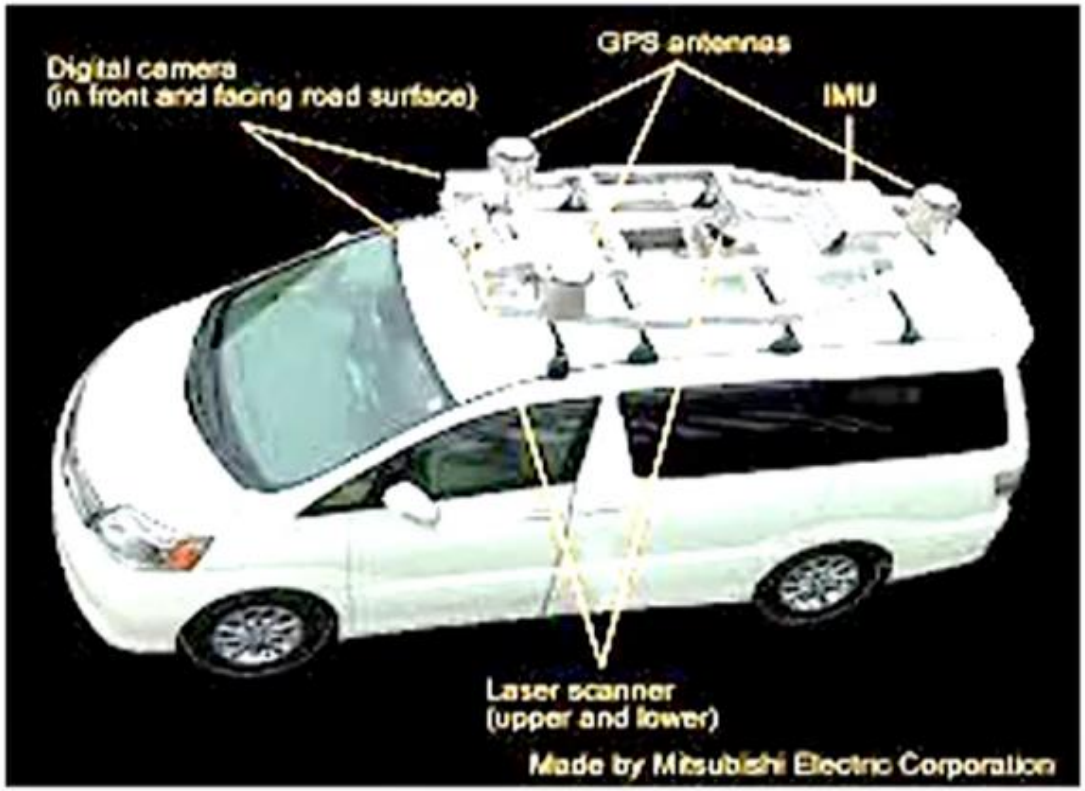
- It is used to carry out 3D modelling and analysis of structures for measurement studies, like deformation, sinking, inclination, and cracks in the structures.

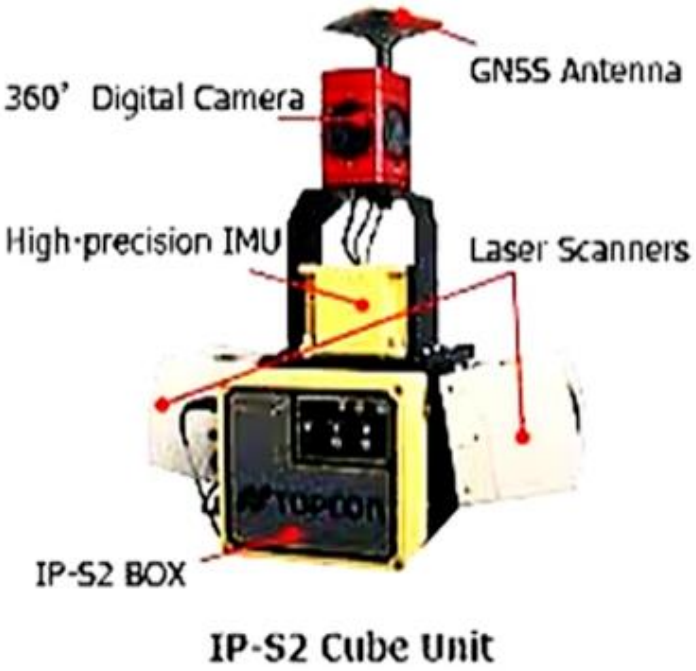


Mobile mapping system (MMS)

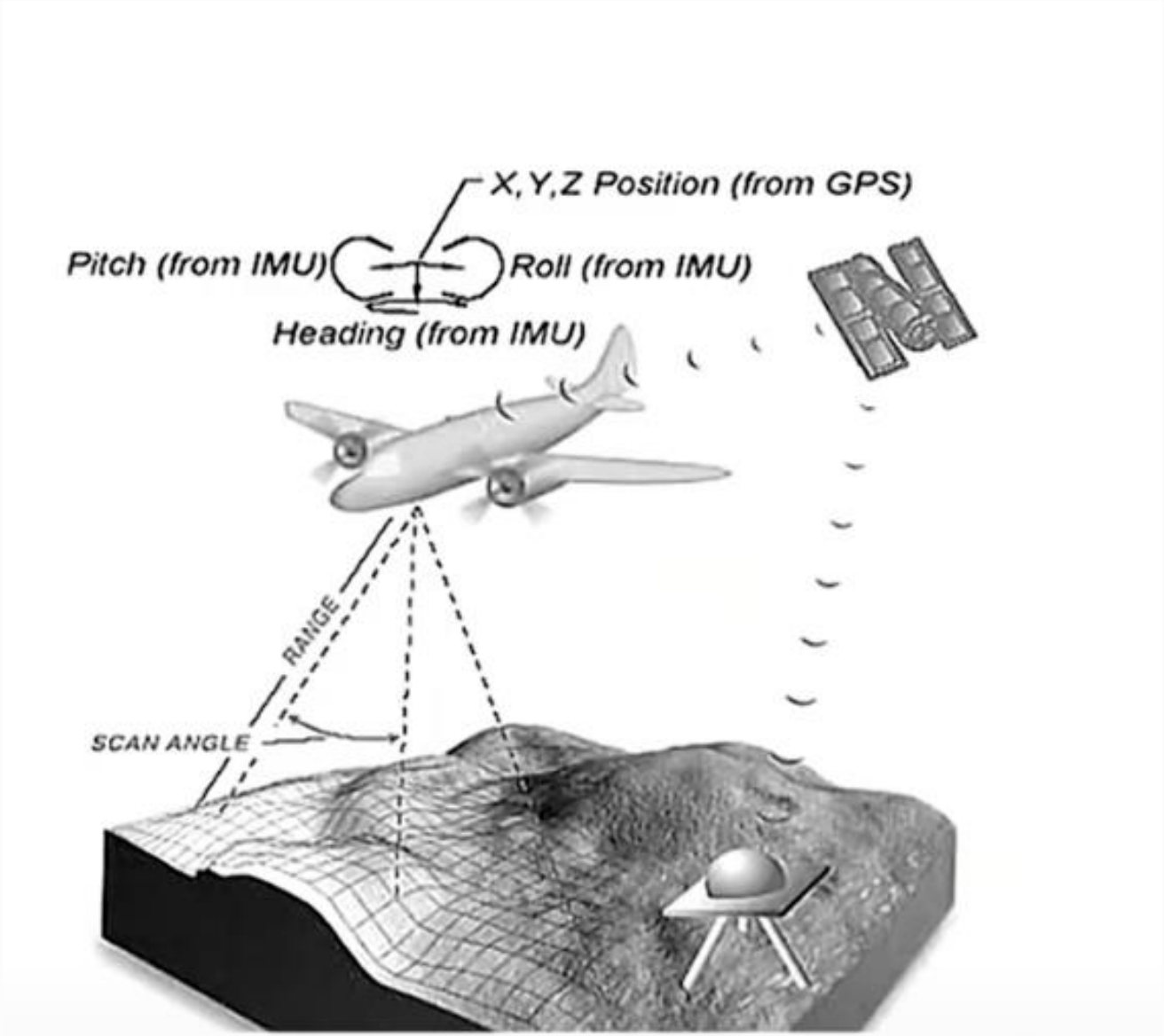
Mobile Mapping System is a vehicular based imaging and LiDAR data collection

MMS Components

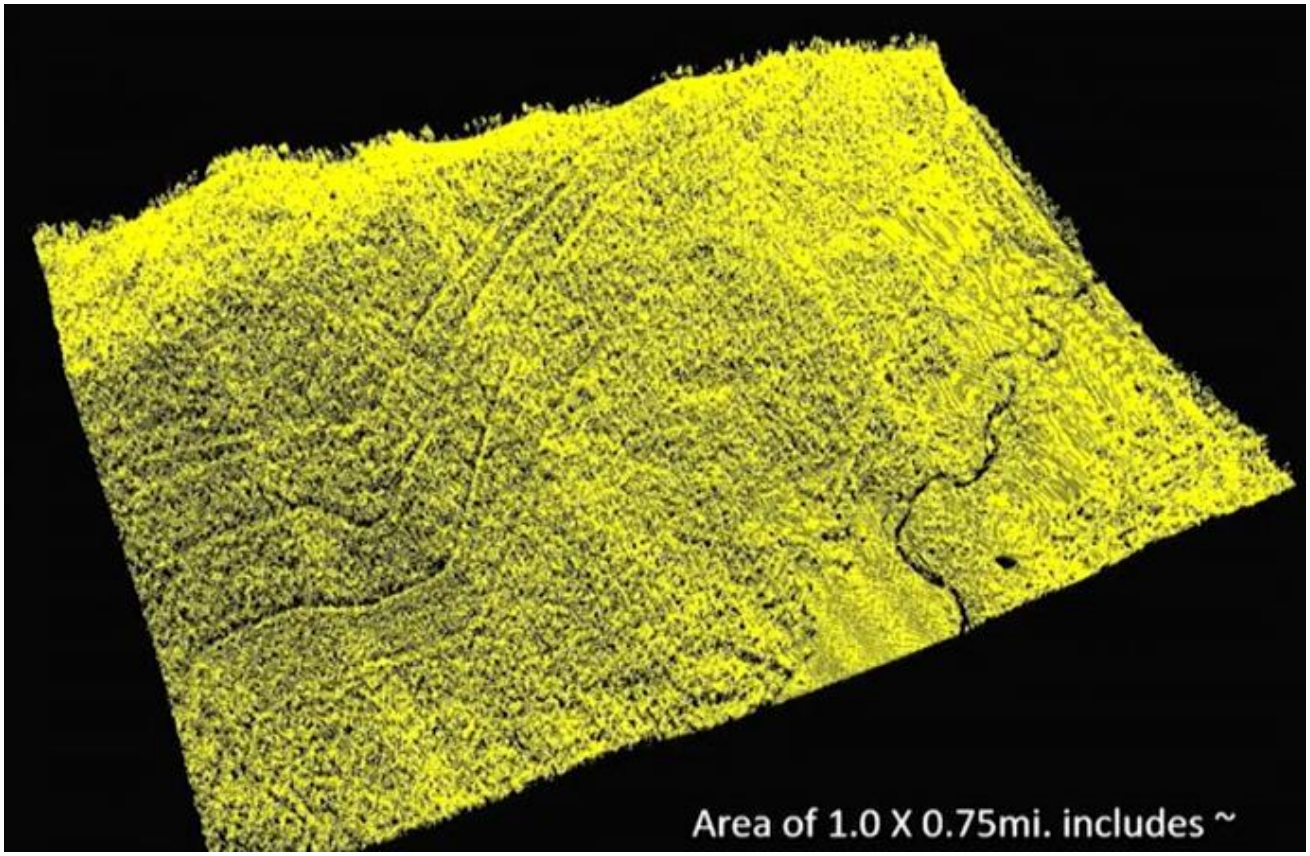




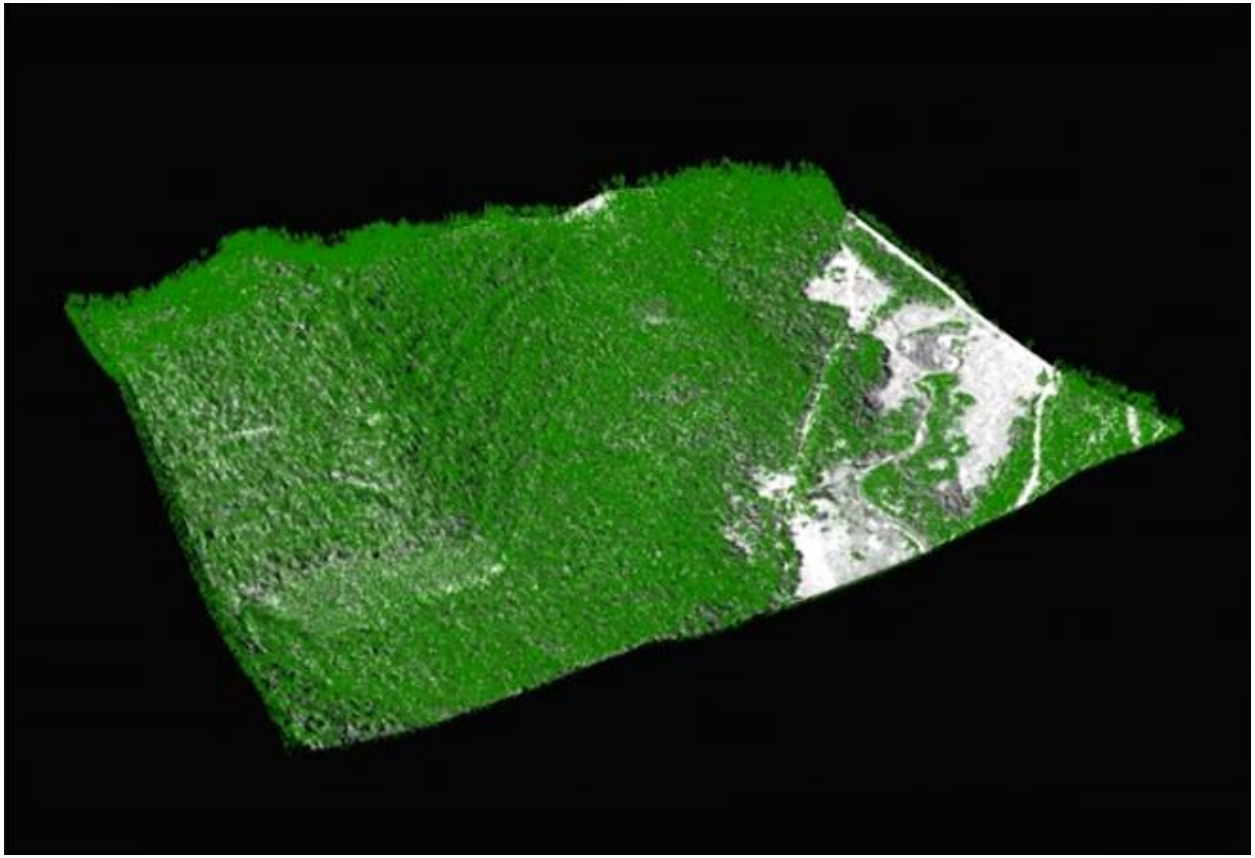
Airborne laser scanner (ALS)



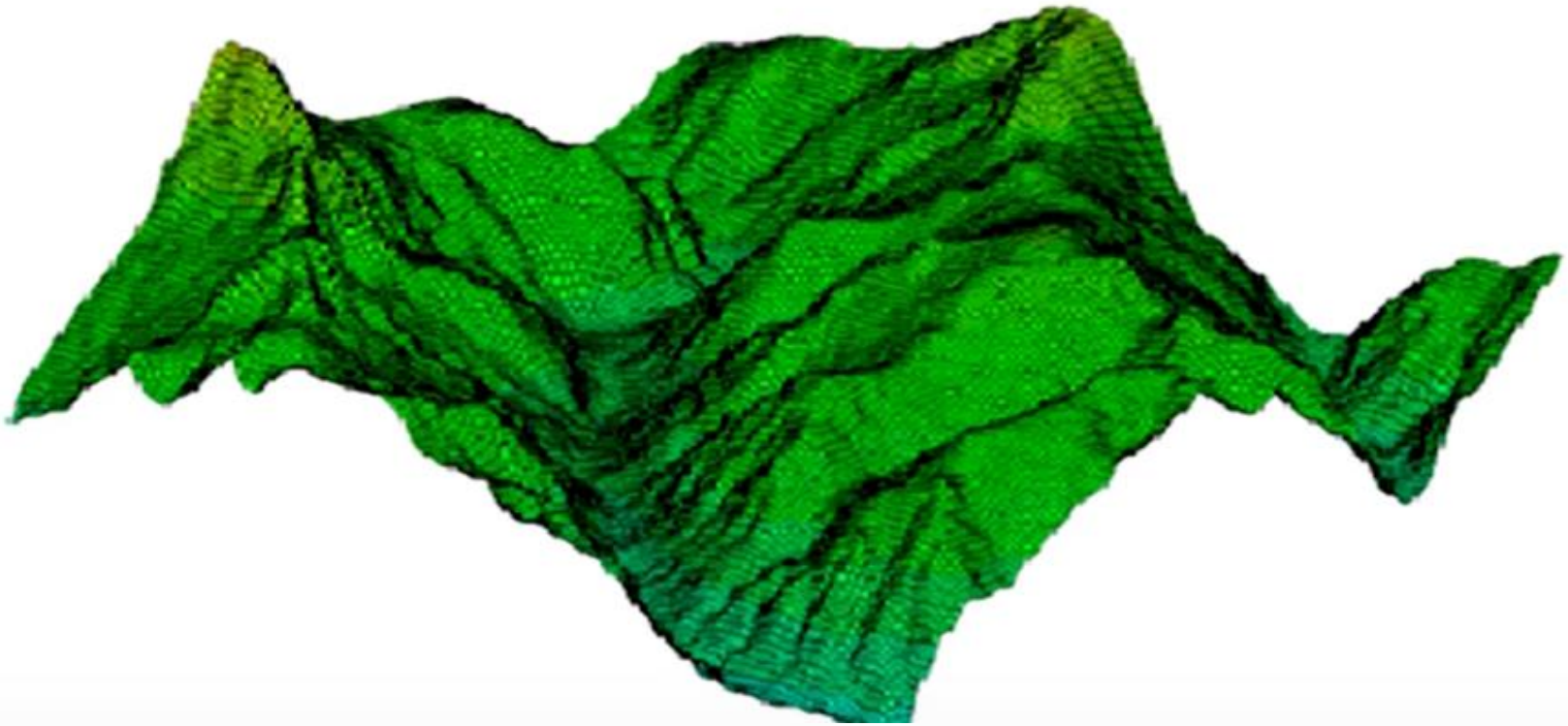
LiDAR data: millions of X,Y,Z points



LiDAR: separating trees from ground



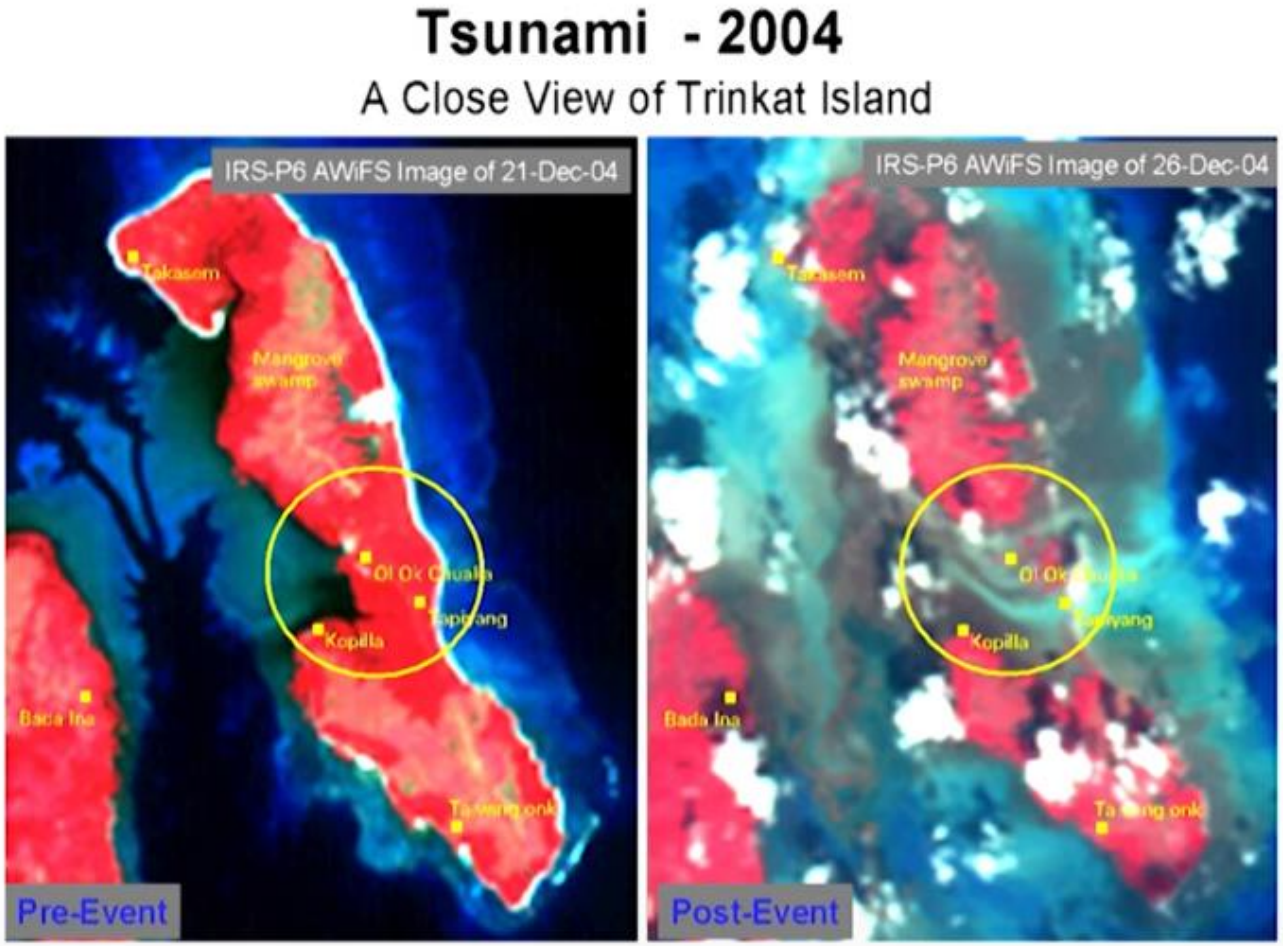
Digital elevation from LiDAR



Various satellite images

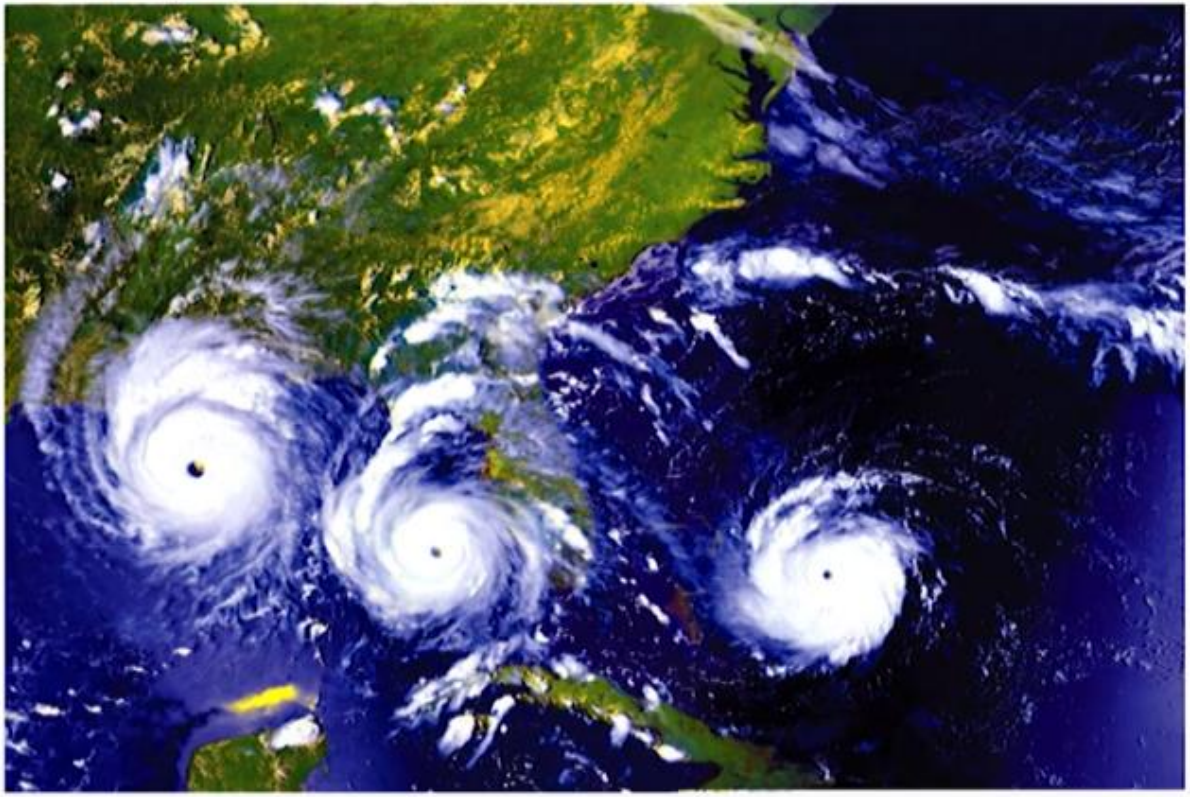
Landsat
IRS
SPOT
ASTER
IKONOS
Quickbird
MODIS
AVHRR
GOES

Damage due to tsunami 2004



Hurricanes viewed through geostationary satellite

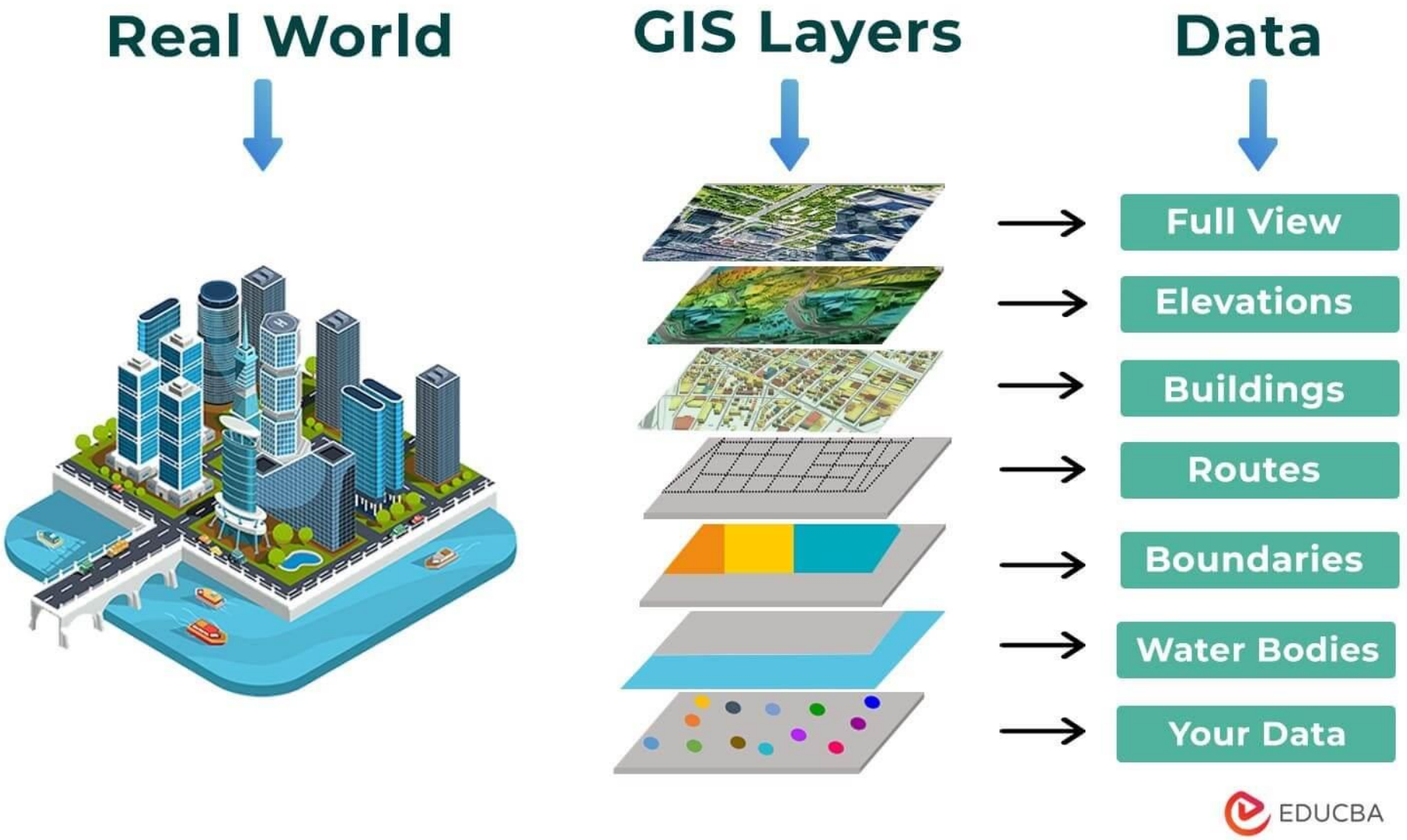
Images of Hurricane *Andrew* (1992) Viewed from Geosynchronous Satellite



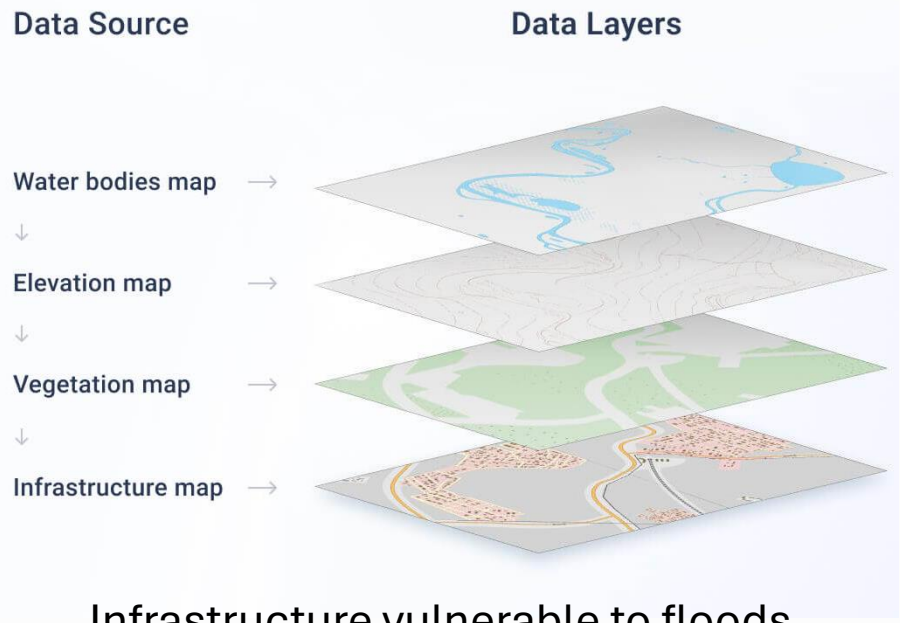
Geographic information system (GIS)

- *A GIS is an information system which is capable of integrating, storing, editing, interpreting, analysing, visualizing, querying, sharing and displaying spatially referenced data of the Earth to understand the relationships, patterns, and trends.*
- GIS consists of images that are geo-referenced to the Earth with *x, y* coordinates, and their attribute values that are stored in the database table.
- The spatial data in the form of maps, such as topography, geology, soil types, forest and vegetation, land use, water, roads etc., are stored as layers in digital form.
- Integrates a database of multiple information layers using a defined criteria and produces new thematic maps.

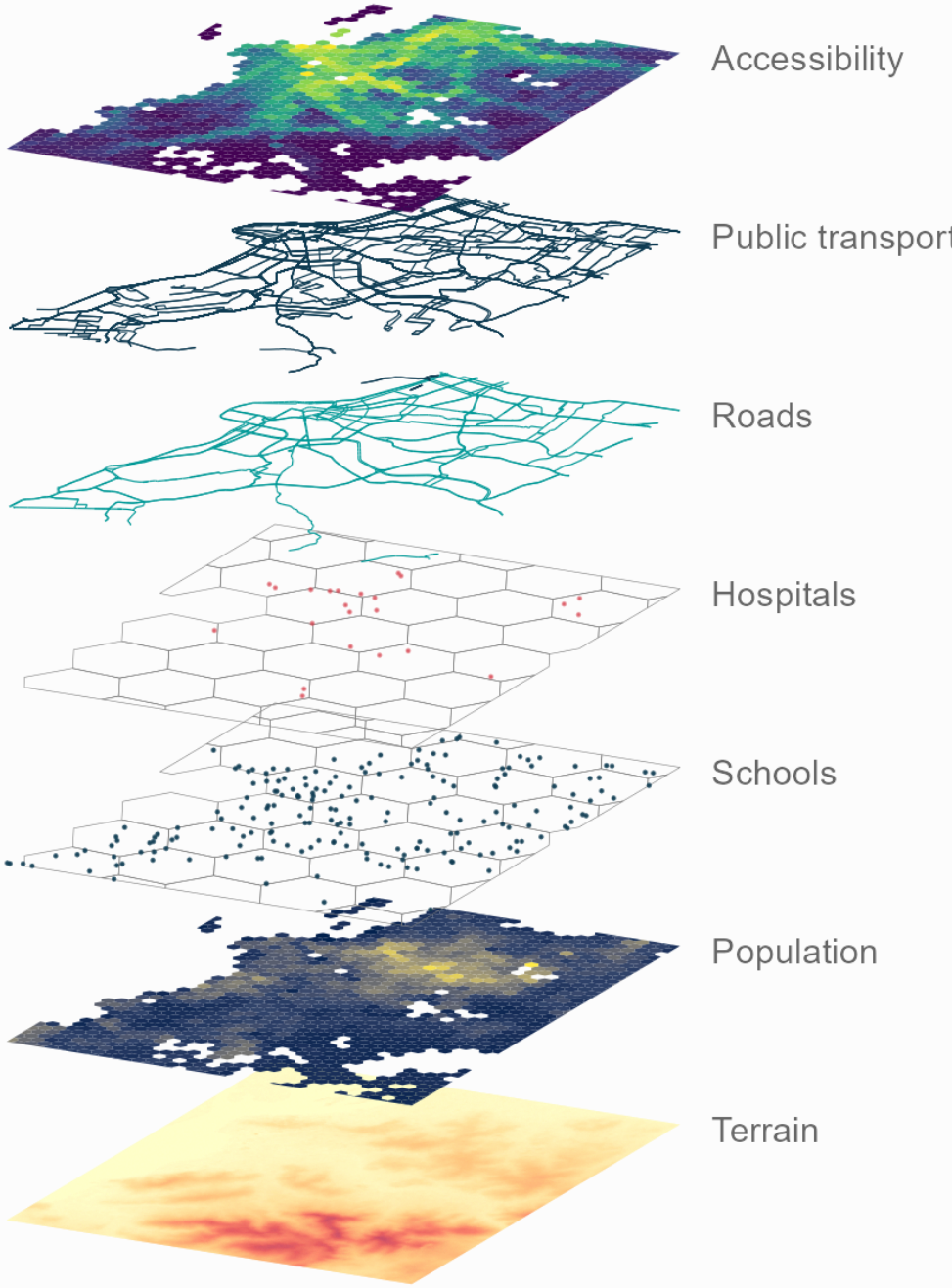
GIS – integration of georeferenced data



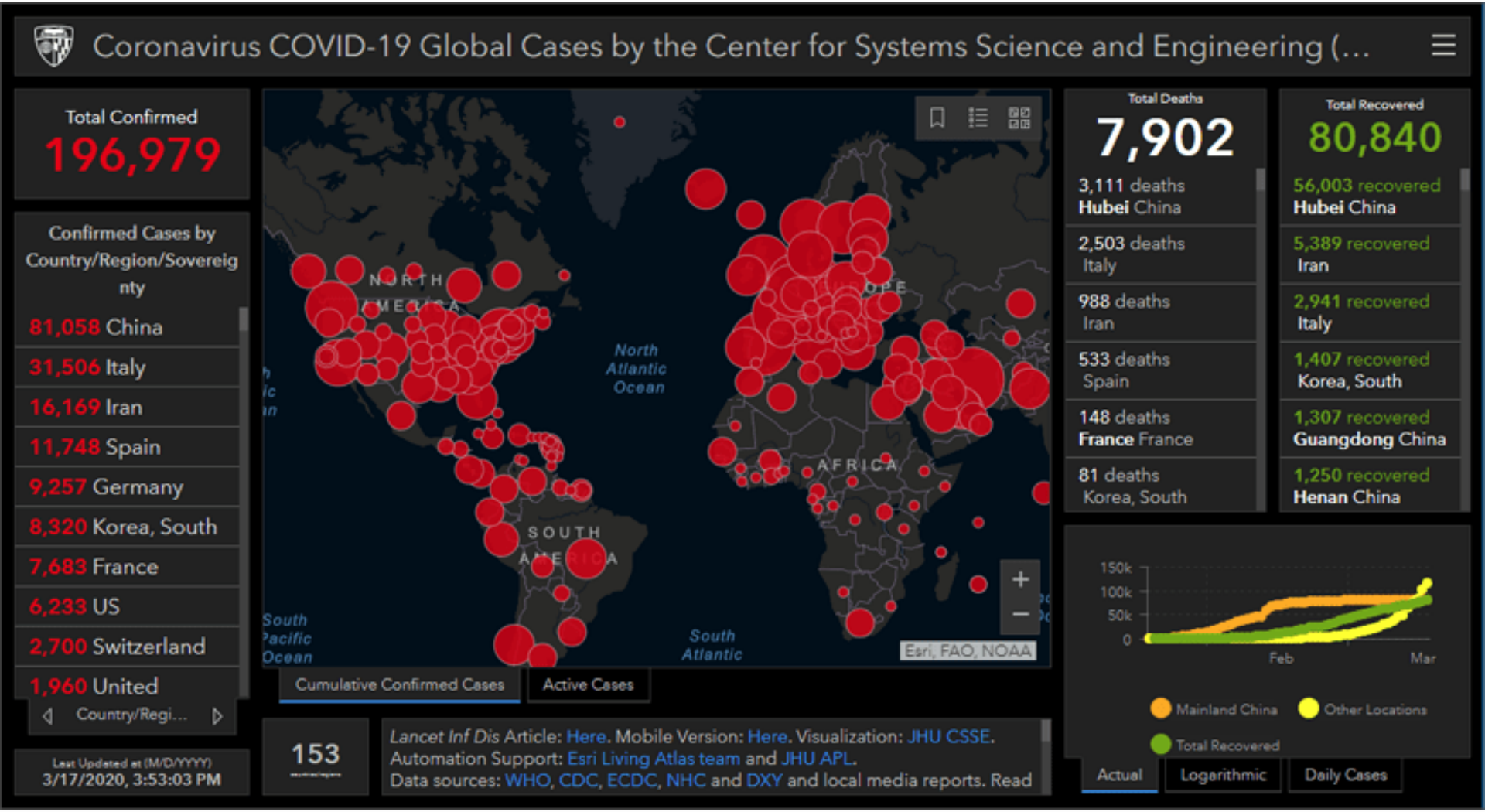
Geospatial data layers for infrastructure planning



Infrastructure vulnerable to floods

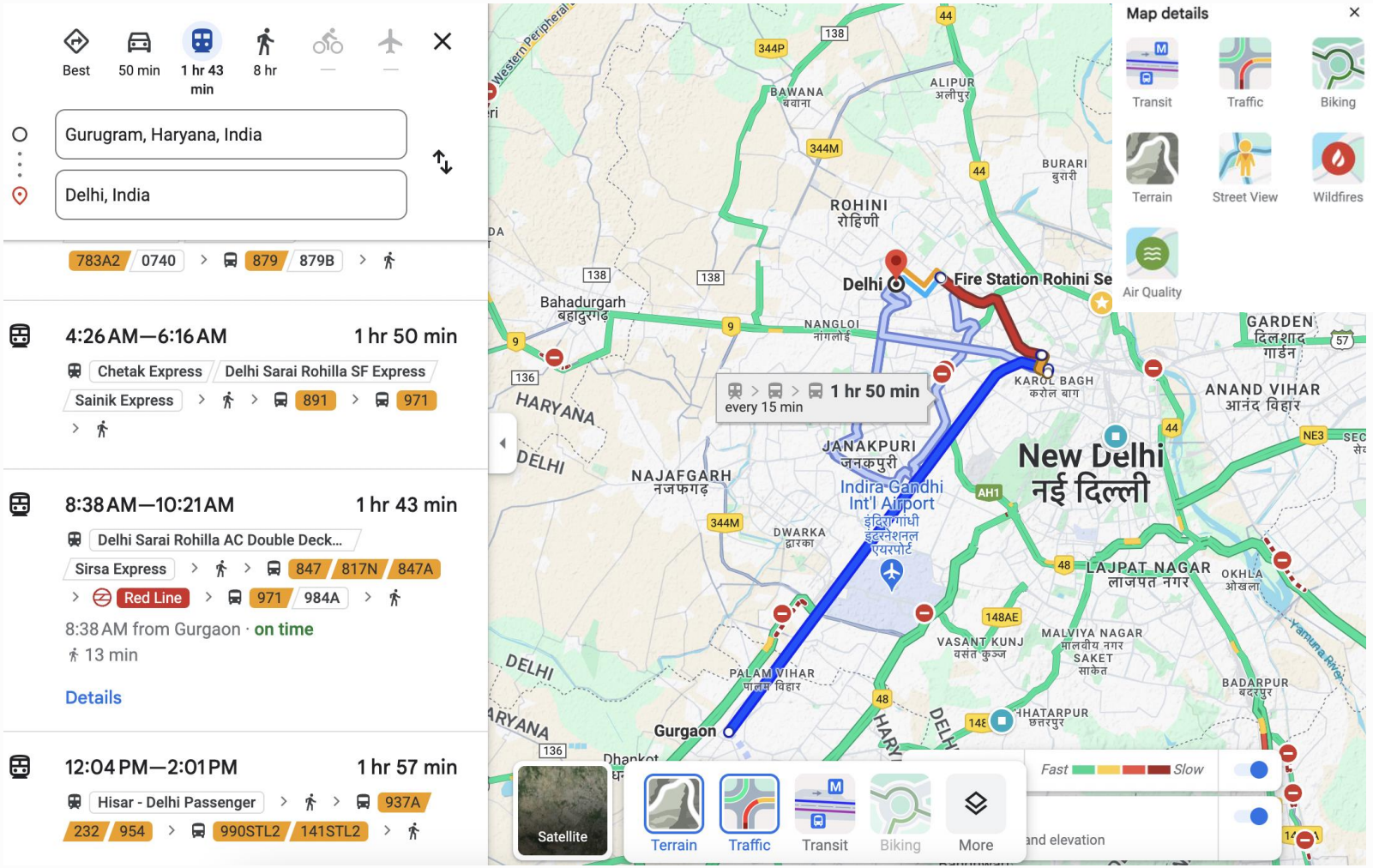


GIS dashboard - COVID incidences



https://www.arcgis.com/apps/dashboards/bda7594740fd40299423467b48e9ecf6

GIS allows expert system/decision support system



Make spatial query, statistical analysis, create maps and visualization

What layers and operations needed for creating Google Maps?

GIS applications

https://shukka.com/gis-application-development-services.php

Geospatial hardware, software

- The major companies that produce **compatible hardware** in India are HP, Trimble, Sokkia, Nokia, Leica and Garmin.
- The **major software** providers in India are ESRI, AutoDesk, Bentley Systems, Leica Geosystems, PIX4D, InterGraph and PCI Geomatics.
- The major companies in **geospatial services** include, ESRI, Rolta, RMSI, Infotech Enterprises, TCS, Google, Microsoft

Various applications

- Emergency services
- Public health
- Traffic & transportation
- Infrastructure
- Mineral and oil exploration
- Urban planning
- Land use
- Watershed management
- Environmental modelling
- Agriculture
- Meteorology
- Climate change
- Oceanography
- Atmospheric modelling
- Business
- Crime mapping
- Location based planning
- Telecommunications
- Navigation systems
- Military etc.

Why study geospatial engineering?

- India is recognised for its IT skills and space programmes.
- It offers good infrastructure and expertise for collection of geospatial data.
- India has shortage of skilled human resource in the field of geomatics, so students can take this as hotspot career.
- Geomatics is not only for the people studying surveying , remote sensing, GPS, GIS or geography, but recently more disciplines, like computer science, civil engineering, architecture, geology, environmental science etc., have also included geomatics Engineering subject.
- The Government has made liberal policies to collect and share geospatial data and information so that geomatics is used for socio-economic development and achievement of sustainable development goals.

14 fundamental themes by Govt of India

1. Geodetic Reference Frame

2. Orthoimagery

3. Functional Areas (Boundaries)

4. Geographical Names

5. Elevation & Depth

6. Water

7. Transportation Network

8. Buildings & Settlement

9. Land Cover & Land Use

10. Physical Infrastructure

11. Land Parcels

12. Addresses

13. Geology & Soils

14. Population Distribution

Status of geospatial engineering in India

India has long been a leader in using geoinformatics technologies since 1980s by having its own Indian Remote Sensing Satellites.

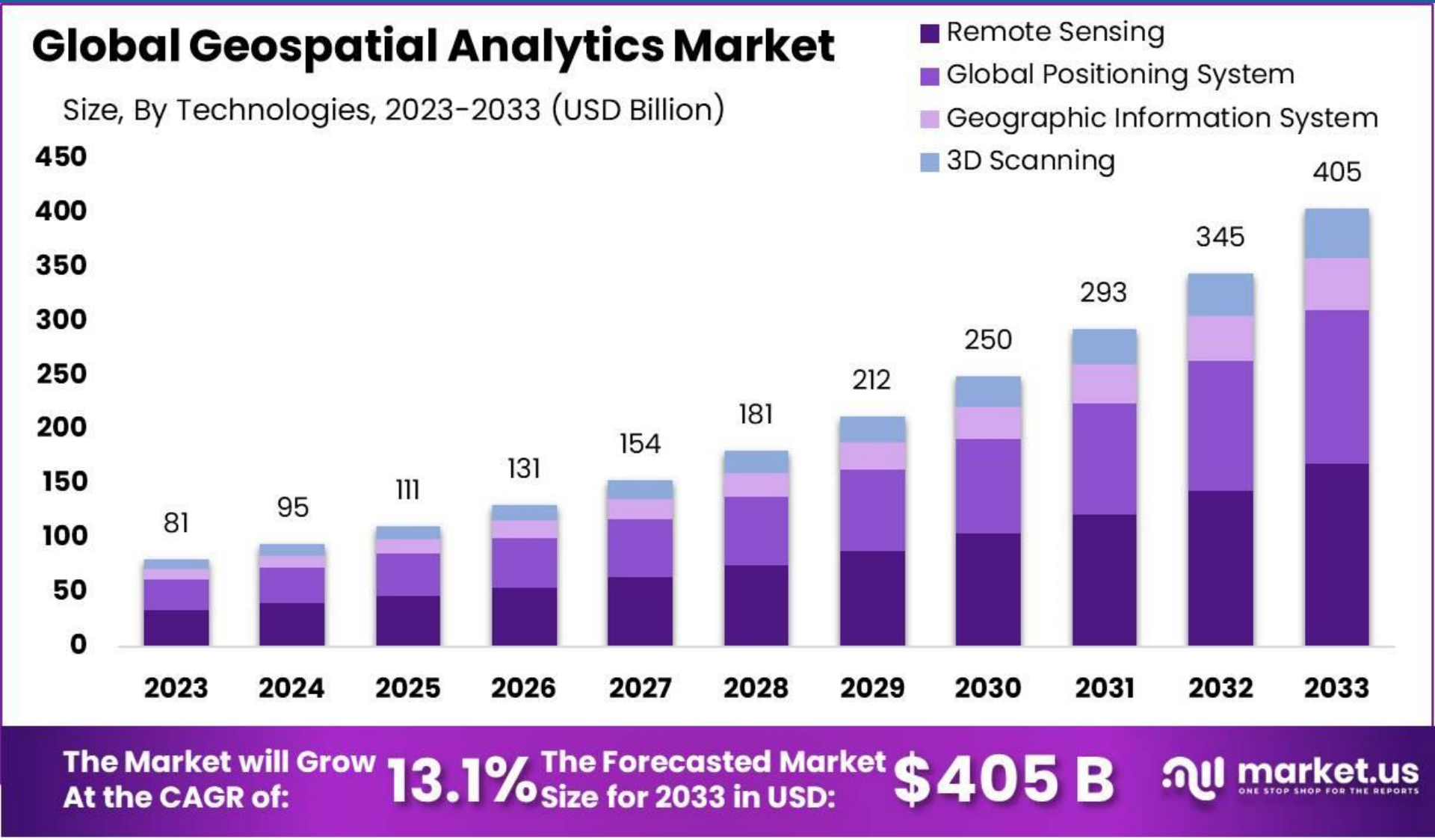
In India, it has become an important component of planning & decision making, such as urban planning, natural resources, infrastructure, agriculture, forestry or location-based services.

In various government programs, such as Digital India, Smart Cities, Skill Development, Start-Up India, Make in India, National Mission for Clean Ganga, Interlinking of rivers, Delhi Mumbai Industrial Corridor, Smart Power, and Smart Agriculture, geospatial technologies are playing a critical role.

Supported by Indian Space Research Organization, Survey of India, Indian Institute of Remote Sensing, National Remote Sensing Center, and others

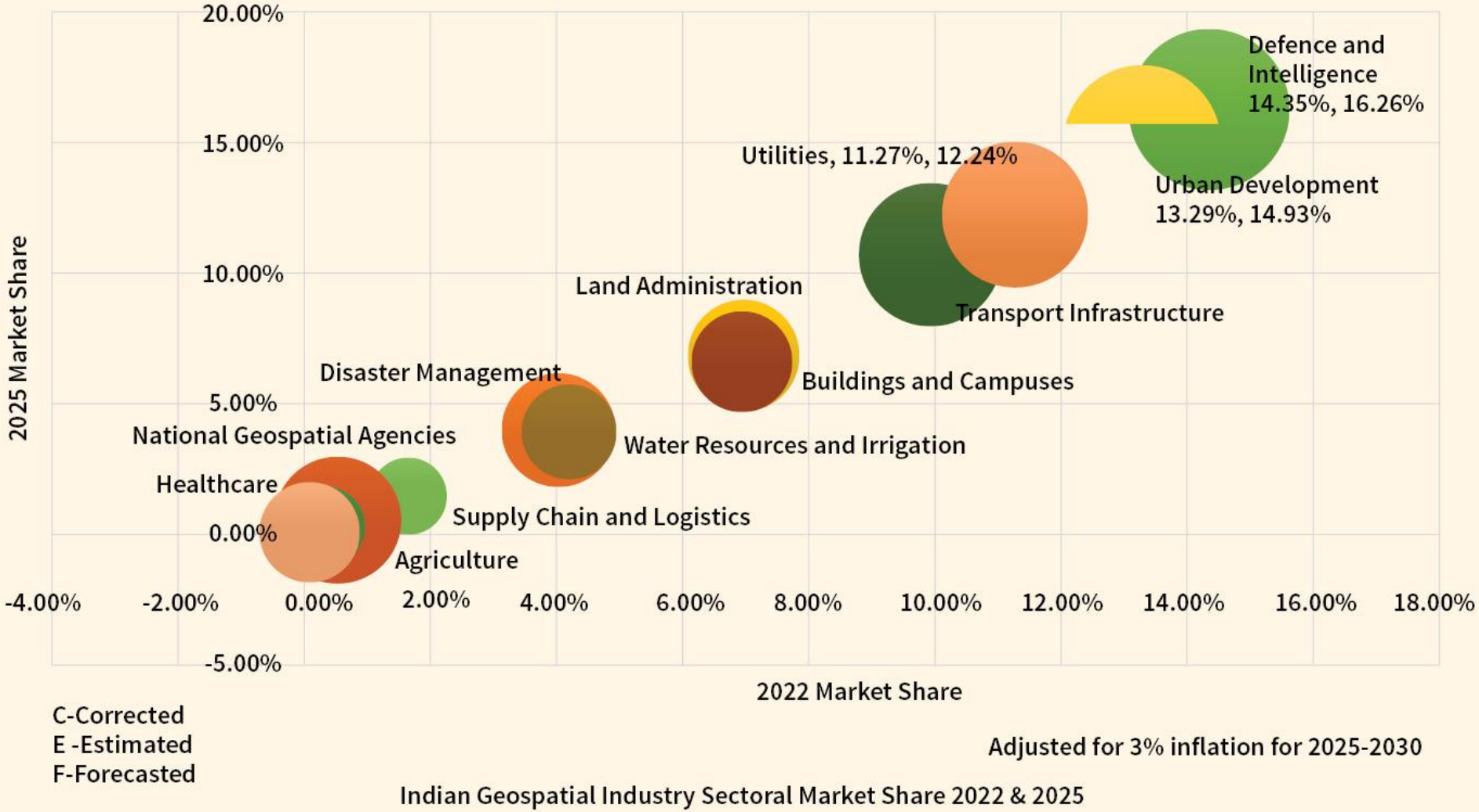
.

Geospatial Analytics market



https://market.us/report/geospatial-analytics-market/

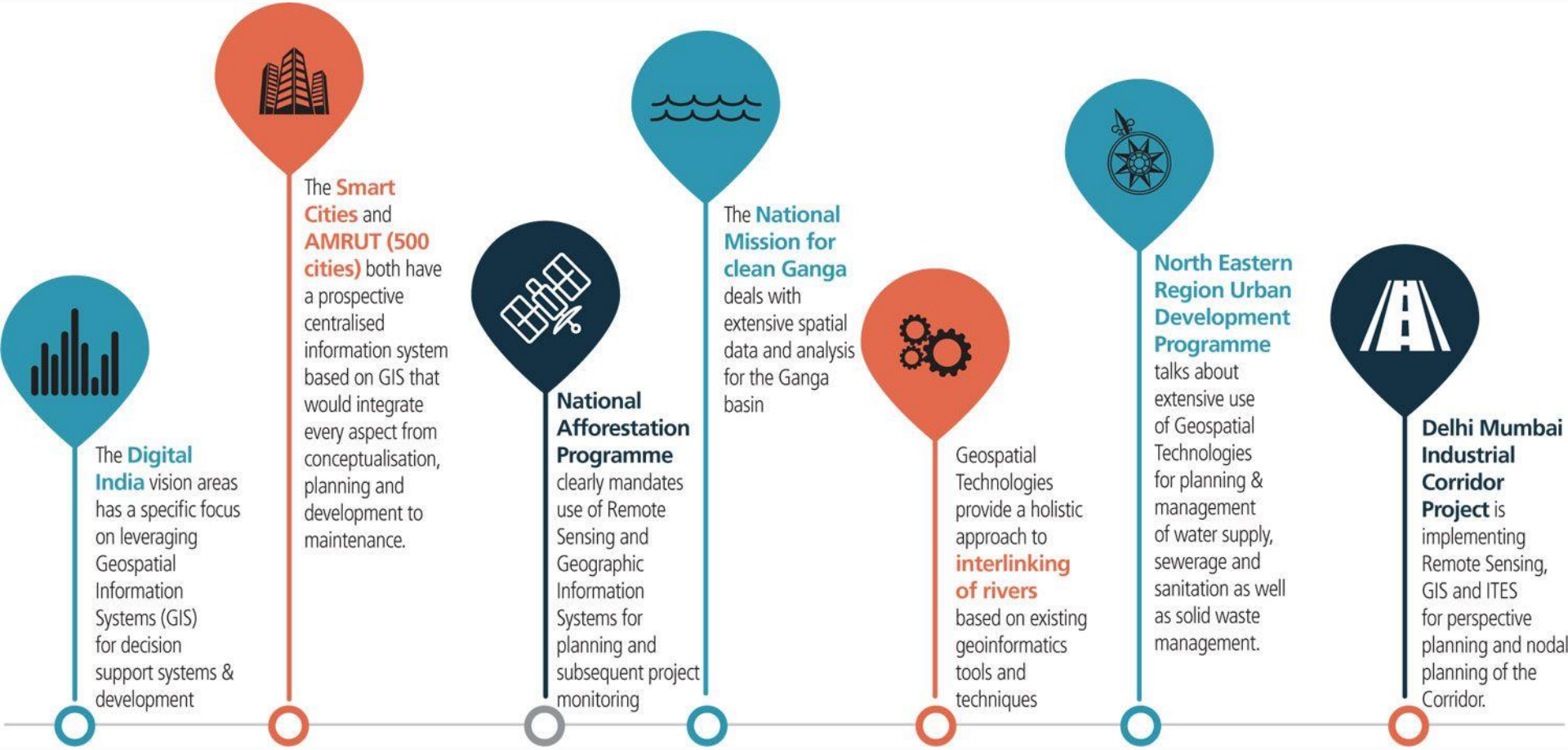
Key Trends and Market Drivers in Indian Geospatial Sector



Indian Geospatial Industry Sectoral Market Share 2022 & 2025

https://www.geospatialworld.net/prime/key-trends-and-market-drivers-in-indian-geospatial-sector/

Application in government projects



Jobs@Geospatial Engineering

Sr. Applied Scientist/ASM, Geospatial Science
Amazon
Bengaluru, Karnataka, India

GIS Data Engineer II
HERE Technologies
Navi Mumbai, Maharashtra, India

Data Analyst
Tech Mahindra
Bengaluru, Karnataka, India (On-site)

Flood Risk Modeller
Buro Happold
Bengaluru, Karnataka, India (On-site)

Remote Sensing Analyst
UNDP Careers
New Delhi, Delhi, India (Remote)

Senior GIS Specialist
Burns & McDonnell India
Mumbai, Maharashtra, India

GIS Developer
S&P Global
Hyderabad, Telangana, India (On-site)

Lead / Staff Navigation Designer
Jio Platforms Limited (JPL)
Mumbai, Maharashtra, India (On-site)

GIS Lead
Infosys
Bengaluru East, Karnataka, India (On-sit

Geospatial Analyst
Escorts Kubota Limited
Faridabad, Haryana, India (On-site)

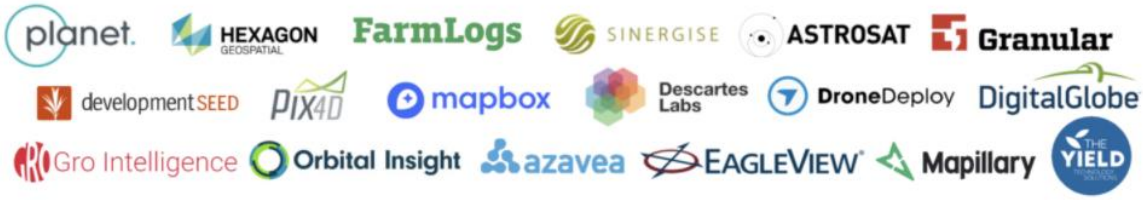
Remote Sensing Technical Specialist
UNDP Careers
New Delhi, Delhi, India (Remote)

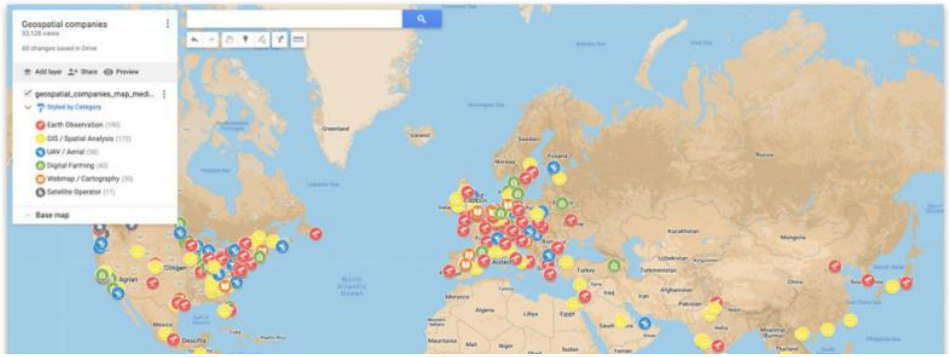
Jobs@Geospatial Engineering

Awesome Geospatial Companies 

List of 500+ geospatial companies & interactive map

🌎 Earth Observation 🌐 GIS / Spatial Analysis ✈️ UAV / Aerial 🌱 Digital Farming 🗺️ Webmap / Cartography 🛰️ Satellite Operator





List of 700+ geospatial companies & interactive map:
https://github.com/chrieke/awesome-geospatial-companies

Benefits of using Geospatial components

1. Better precision and accuracy
2. Enhanced data safety, security and control
3. Faster decision making
4. Cost effective, particularly for large areas
5. Higher productivity, and
6. Increased transparency and better planning

Summary

In order to apply Geomatics in various applications, it is important to understand data collection using various Geomatics Tools and subsequent analysis of data.

The Geospatial technologies, like **Digital aerial photographs, LiDAR, Satellite images, GPS, LiDAR, Sensors, UAV/Drone, GIS**, etc., provide real-time information of land surface, and are expected to open new avenues and applications of geomatics for better planning and decision making.