Leaders in LiDAR

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A GMR Group Company

LiDAR Technology and its Applications

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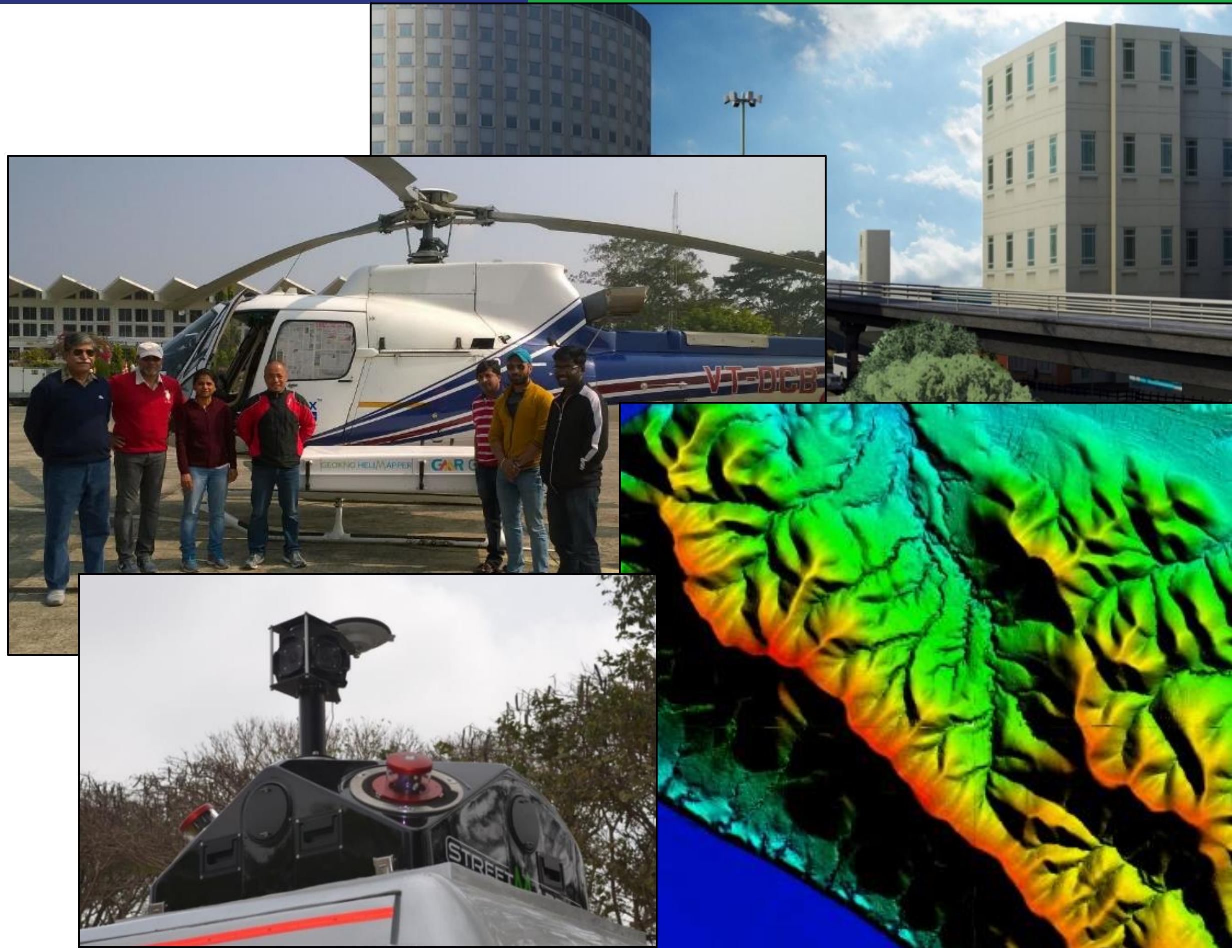

Dr. Bharat Lohani
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&
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Outline

- Specific needs of 3D data for modern/traditional applications
- Principle of LiDAR technology
- Advantages of LiDAR data
- Comparison with other competing technologies
- Latest LiDAR data projects by Geokno
- Latest R&D on LiDAR data at IIT Kanpur

Applications of Topographic Data

- Cadastral Survey/Re-Survey
  - Not only horizontal data but Vertical data also
- Disaster Management
  - Flood Modelling and Forecast
  - Cyclone Impact Analysis and Mitigation
  - Landslide Hazard Zonation
- Irrigation Projects
  - Command Area Survey
  - Lift Irrigation Planning /Design
  - Minor Irrigation Planning / Design

All these can be answered if we have accurate, precise, dense, reliable Topographic data.

Applications of Topographic Data…Contd

- City Surveys
  - Property Solution
  - Rooftop Solar Potential Mapping
- Forest Survey Requirement
  - Individual Tree Mapping
  - Carbon Stock Estimation
  - Water Resource Planning
  - Soil Erosion Susceptibility Mapping
- Road and Railway DPR generation

All these can be answered if we have accurate, precise, dense, reliable Topographic data.

Some of the modern applications

- Autonomous vehicles see through LiDAR
- UAV traffic management systems
- Smart city – 3D City

3D data requirement

Fast, Accurate, Comprehensive, Reliable, Cost-effective method of 3D data capture required !

Currently there are multiple surveys with lot of redundancy and no synchronization of data. This leads to higher cost.

MULTIPLE SURVEYS VS ONE SURVEY

CITY AS AN EXAMPLE

Traditional methods are not suitable

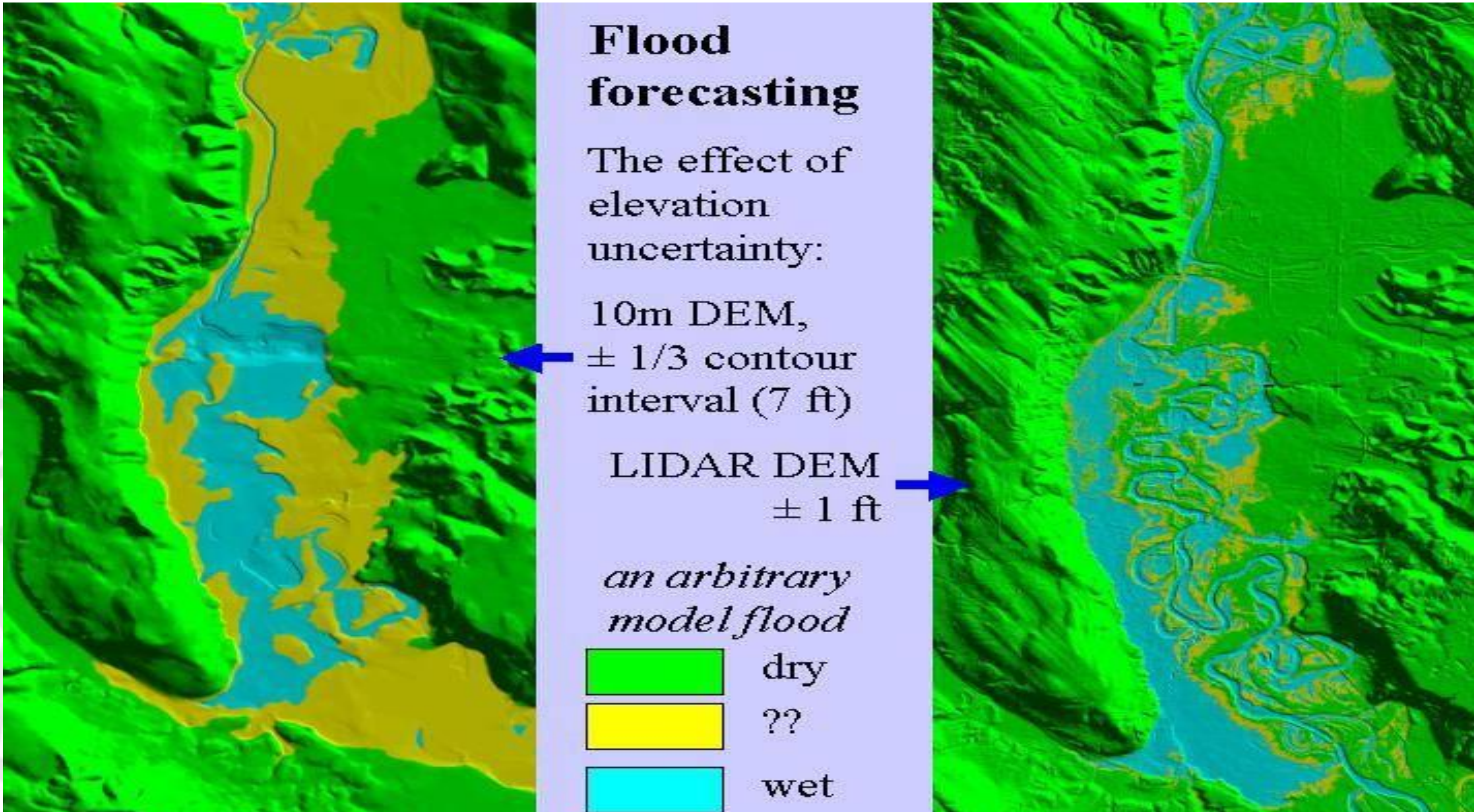
- Traditional methods
  - Total Station
  - GPS/GNSS
  - Satellite Imageries
  - *Drone Photogrammetry –limited area only*
- Not suitable due to
  - Not applicable in inaccessible terrains – hilly terrain
  - Not possible in remote areas – a surveyor cannot go there
  - Too much time taking – results in delays thus cost escalation
  - Errors in survey – need to revisit and re-survey and change design as survey is wrong
  - Incomplete data- data not available in forested area and shadow areas

Survey by Drone is only suitable for small and non-vegetated areas where accuracy is not important.

Comparison of Technologies

Parameter for comparison	TS/ GNSS	Drone Photogrammetry	Satellite	LiDAR
Accuracy	Green	Yellow	Red	Green
Speed	Red	Yellow	Yellow	Green
Completeness	Red	Yellow	Yellow	Green
Reliability of data	Red	Yellow	Yellow	Green
Cost effectiveness	Green	Green	Green	Green
Suitability for inaccessible terrain	Red	Green	Green	Green
Suitability for wooded terrain	Red	Red	Red	Green
Automation	Red	Yellow	Yellow	Green
Human dependence	Red	Yellow	Yellow	Green
Need to revisit field	Red	Yellow	Yellow	Green
Disturbance to ongoing operations	Red	Green	Green	Green
Exposure of surveyors	Red	Yellow	Green	Green
Suitability for small area	Green	Green	Green	Yellow
Suitability for large area	Red	Red	Green	Green

Impact of High Accuracy Data-Flood Example

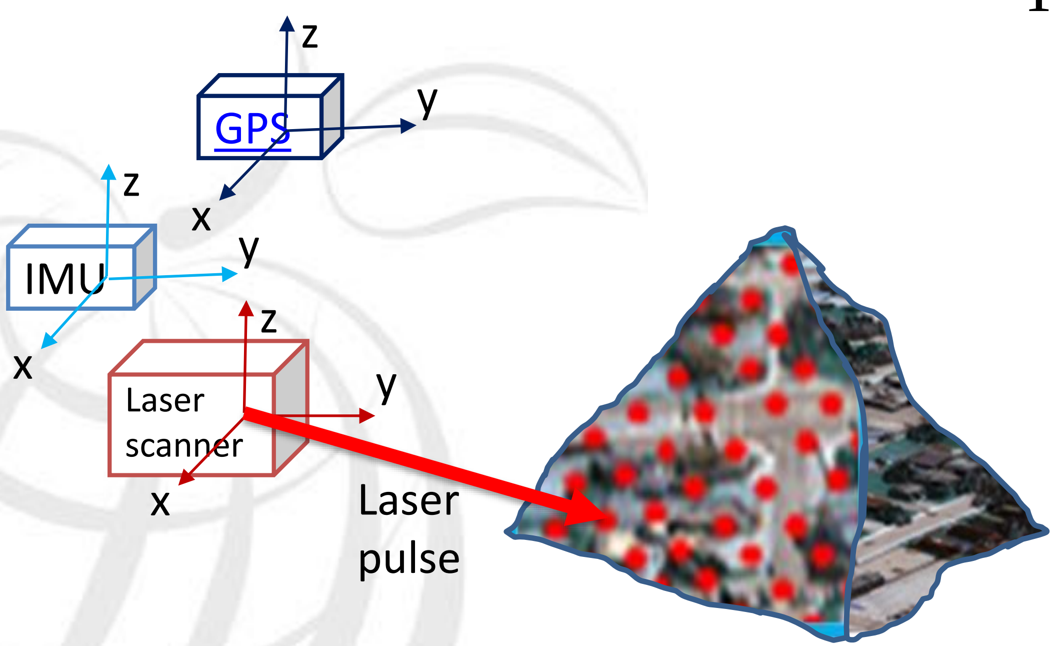


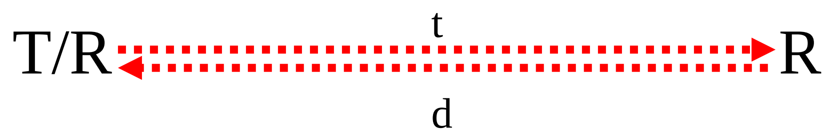
New Technology of Aerial LiDAR

AERIAL LIDAR WITH PHOTOGRAPHS PROVIDE COMPLETE SOLUTION

LiDAR technology

- Initial laser vector is transformed through a series of reference systems to yield object coordinates in a chosen Coordinate System.



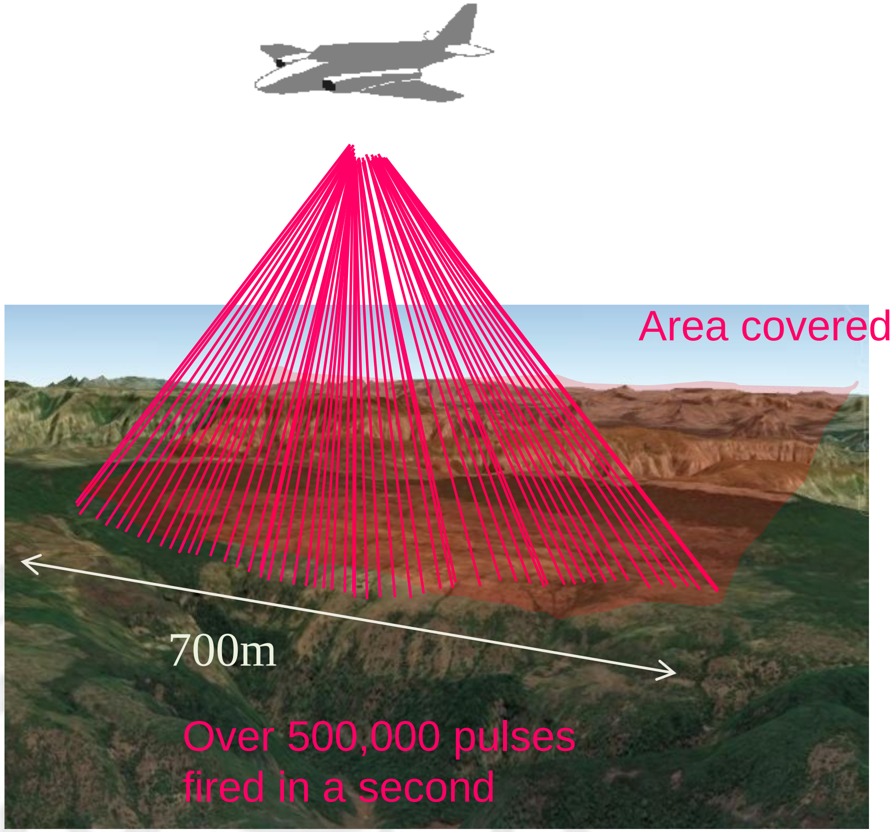


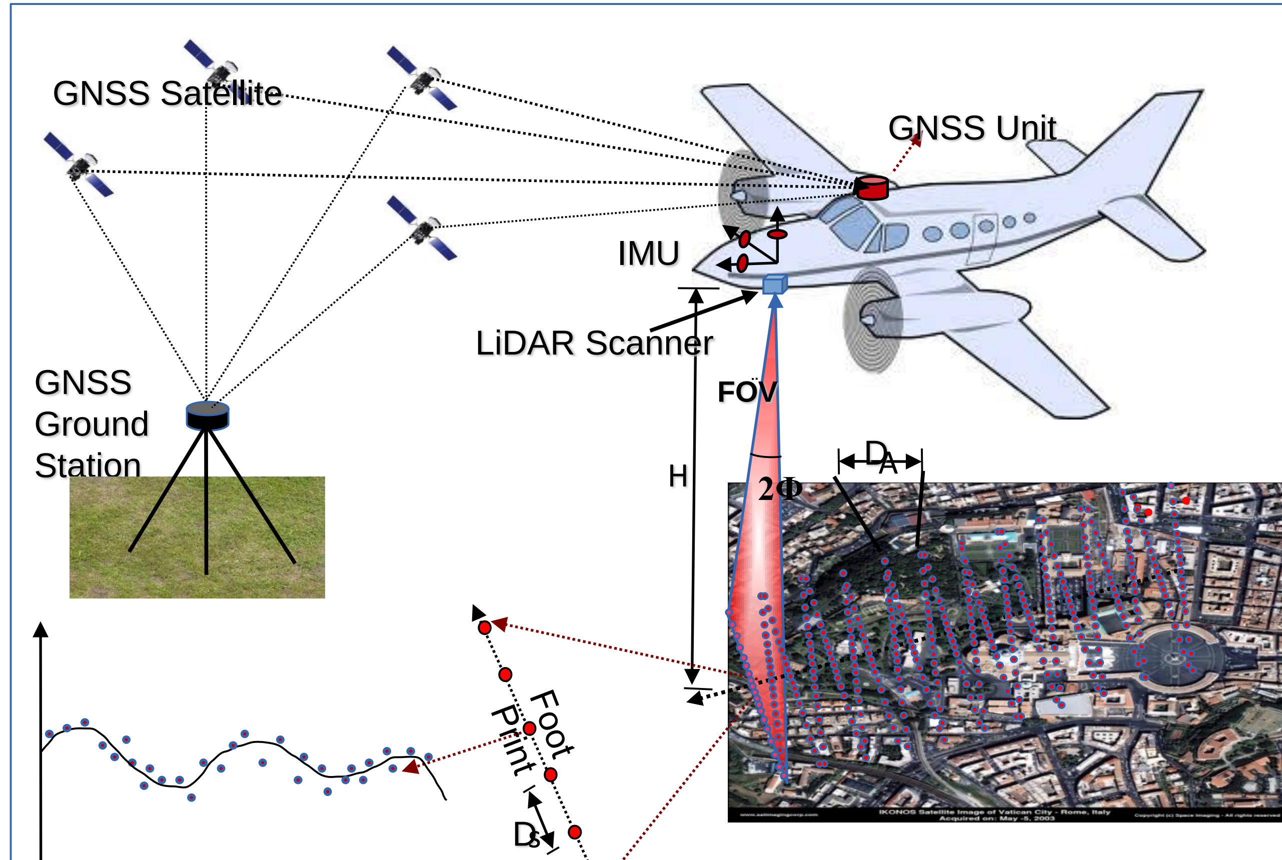
d = c*t/2
c = Velocity of light
t = Time of travel of laser pulse

$$X_A^G = R_L^G X_A^L + X_L^G$$

$$X_A^G = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_A^G \qquad R_L^G = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}_L^G$$

Airborne LiDAR

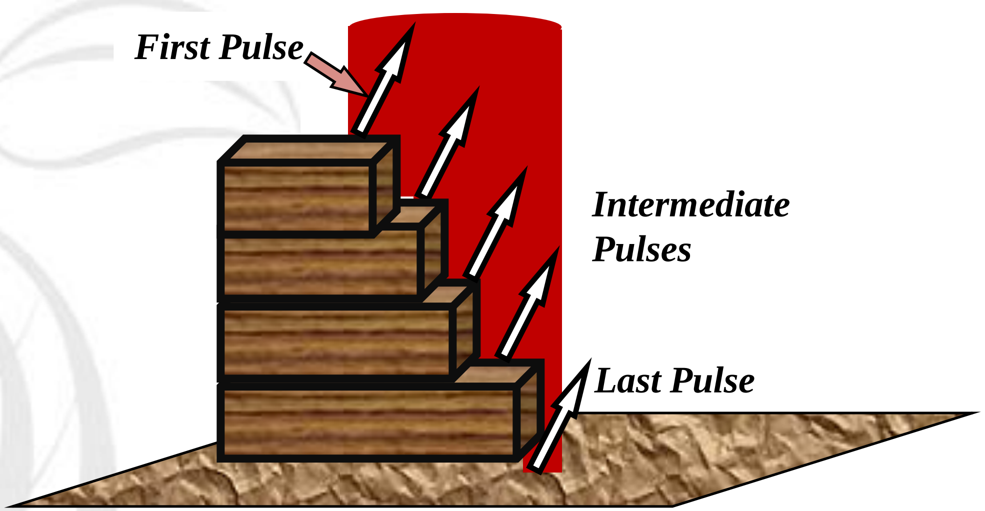




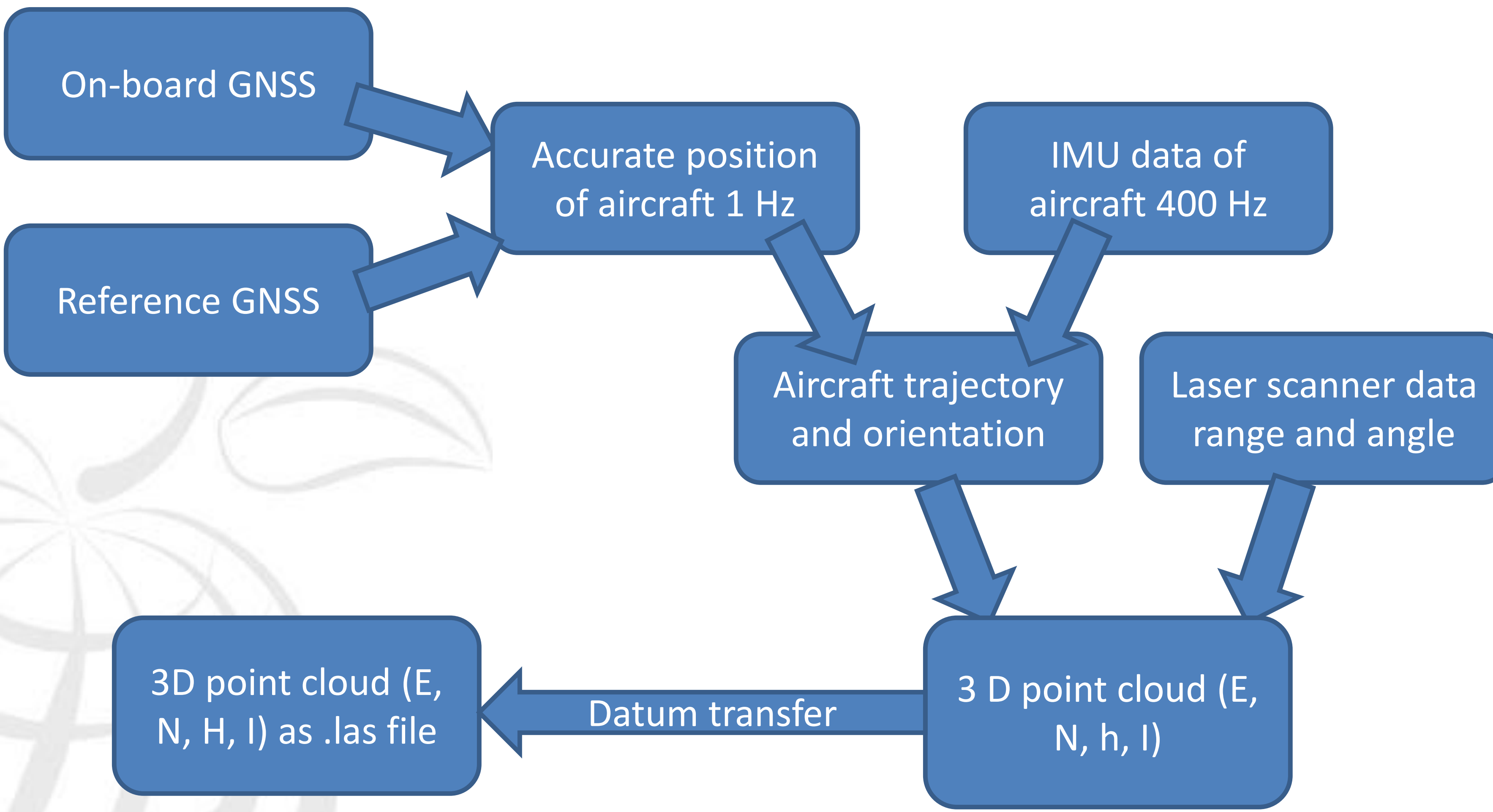
Laser measures range from aircraft to the point hit in ground. This range is converted to the coordinates of the points in ground using on-board GPS and IMU. The final result is large number of points with their known coordinates along with coloured images of entire ground.

LiDAR in multiple return mode

- Instrument is timed to pickup signals at certain intervals.
- First pulse to survey the top of objects while the last pulse is used to survey the ground below.
- Intermediate pulses convey information about vertical structure of object.



Initial data processing



Format for LiDAR data

- ASPRS format LAS
- Versions 1.0, 1.1, 1.2, 1.3, 1.4
- http://asprs.org/Committee-General/LASer-LAS-File-Format-Exchange-Activities.html

- LASUtility to download from
- http://home.iitk.ac.in/~blohani/download.htm

Header information

Header Information

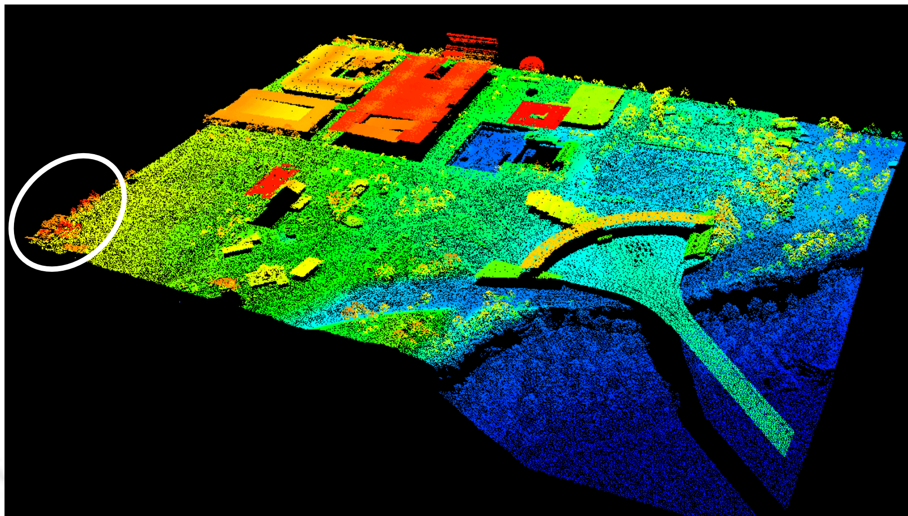
Property	Value
File Signature:	LASF
Version:	1.2
Generating software:	TerraScan
No. of points:	474343
Header size:	227
Point data record lengt...	34
No. of variable length ...	0
Offset to data:	229
Point data format ID:	3
Maximum-X, Minimum...	657871.127 m ,657277.961 m
Maximum-Y, Minimum...	4772643.062 m ,4772187.988 ...
Maximum-Z, Minimum...	176.610 m ,61.692 m
X-Scale,Y-Scale,Z-Sca...	0.001 ,0.001 ,0.001
X-Offset,Y-Offset,Z-Off...	500000.000 ,4500000.000 ,-0....
No. of return 1:	474343
No. of return 2:	0
No. of return 3:	0
No. of return 4:	0

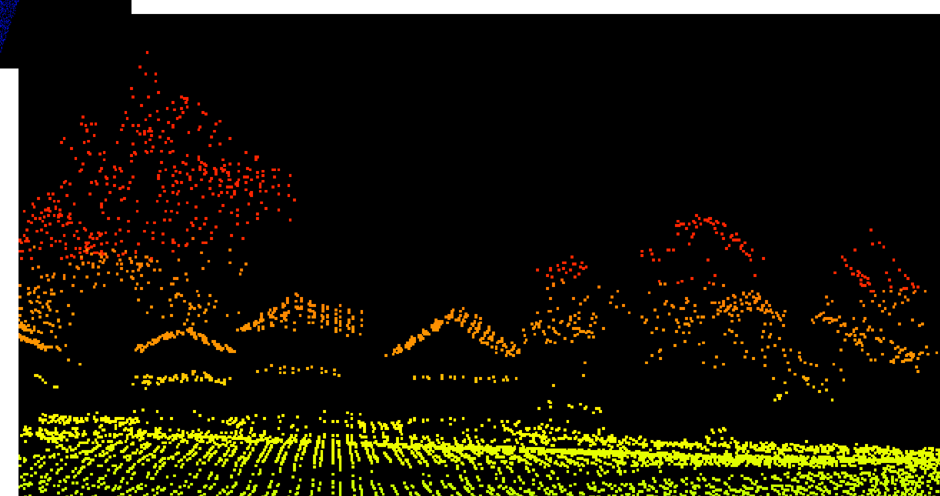
LAS File point data records

Point Data Record

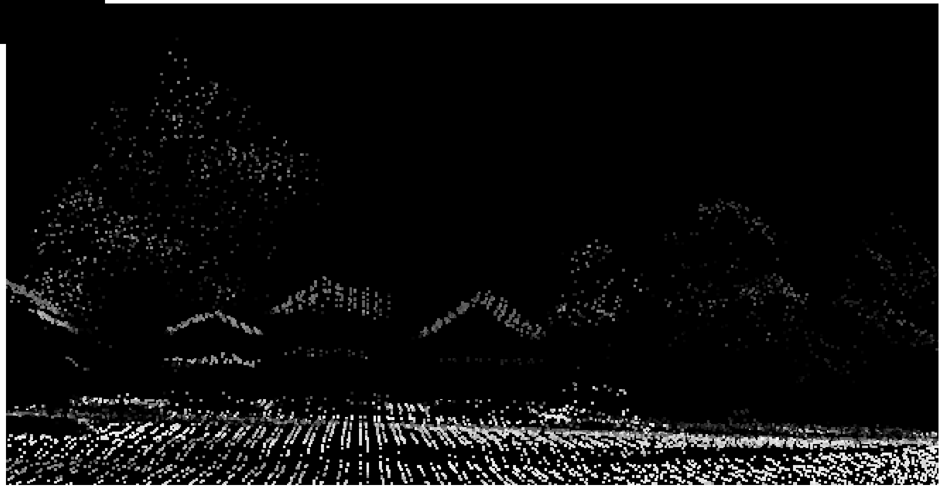
Pt.No.	X	Y	Z	Inten...	Retu...	No. ...	Scan...	Edg...	Clas...	Scan...	User...	Sour...	GPS Time	Red	Green	Blue
1	657285.313	4772547....	62.696	1	0	6	0	0	2	0	0	5	405614.960	54	87	112
2	657284.375	4772542....	62.630	1	0	6	0	0	2	0	0	5	405615.041	63	91	108
3	657282.563	4772539....	62.347	2	0	6	0	0	2	0	0	5	405615.102	54	94	105
4	657284.313	4772486....	62.196	1	0	6	0	0	2	0	0	5	405615.960	84	99	113
5	657283.625	4772485....	62.134	1	0	6	0	0	2	0	0	5	405615.979	65	84	102
6	657285.438	4772483....	62.259	2	0	6	0	0	2	0	0	5	405616.021	135	137	148
7	657284.500	4772483....	62.300	1	0	6	0	0	2	0	0	5	405616.021	105	111	128
8	657284.125	4772482....	61.913	3	0	6	0	0	2	0	0	5	405616.040	99	111	130
9	657282.938	4772482....	61.862	1	0	6	0	0	2	0	0	5	405616.041	86	96	114
10	657279.813	4772476....	62.143	1	0	6	0	0	2	0	0	5	405616.142	94	82	97
11	657282.875	4772474....	64.509	5	0	6	0	0	2	0	0	5	405616.163	146	104	114

LiDAR data example-Elevation

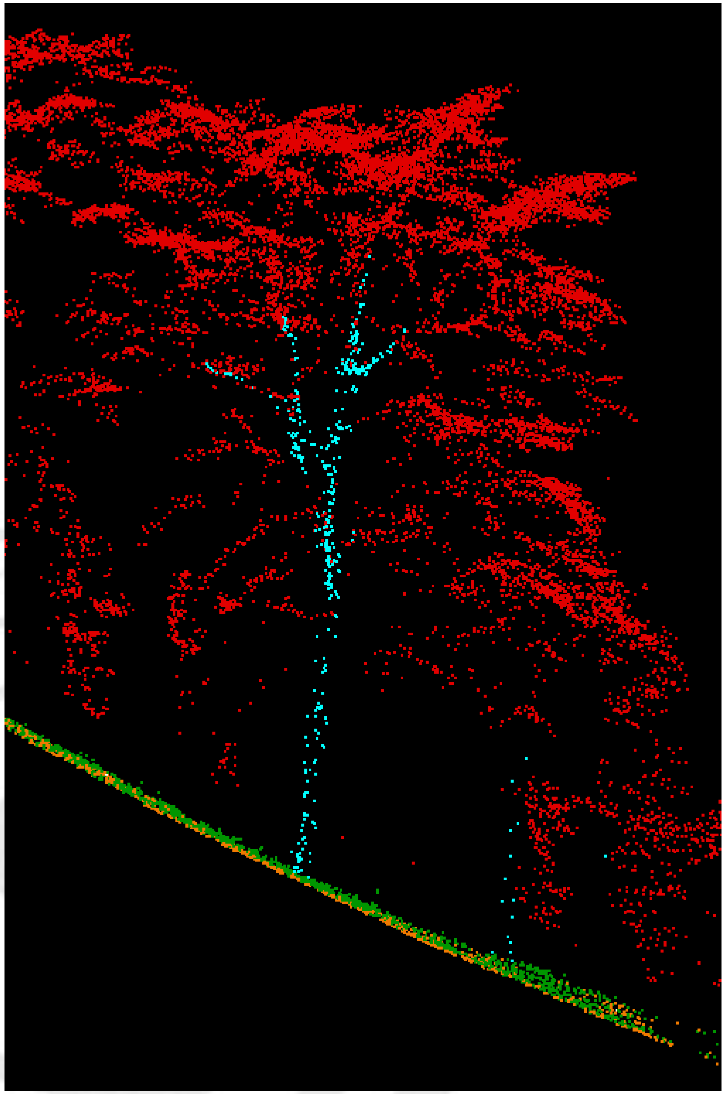


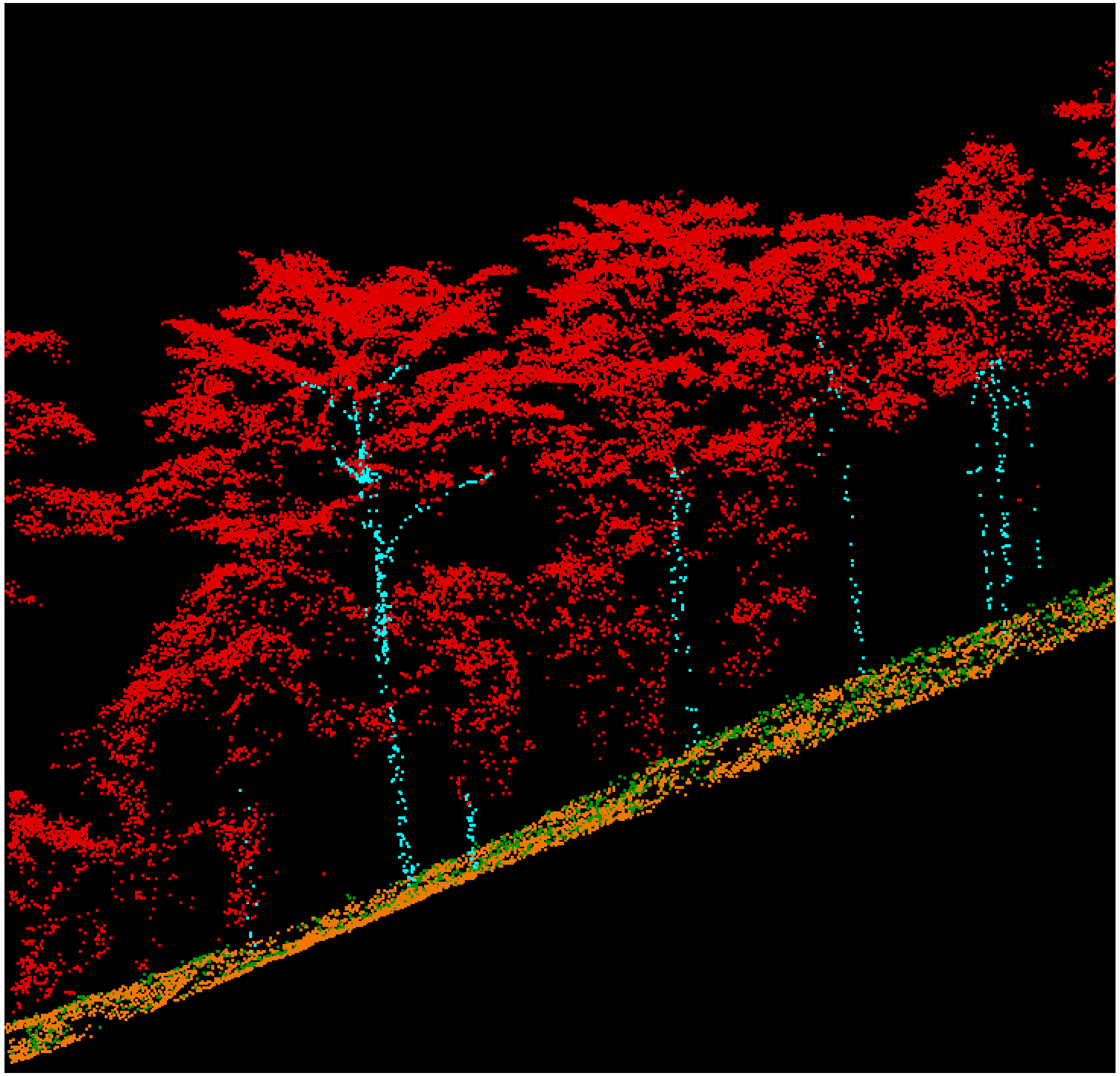


LiDAR data example- Intensity



Classified tree in LiDAR data.

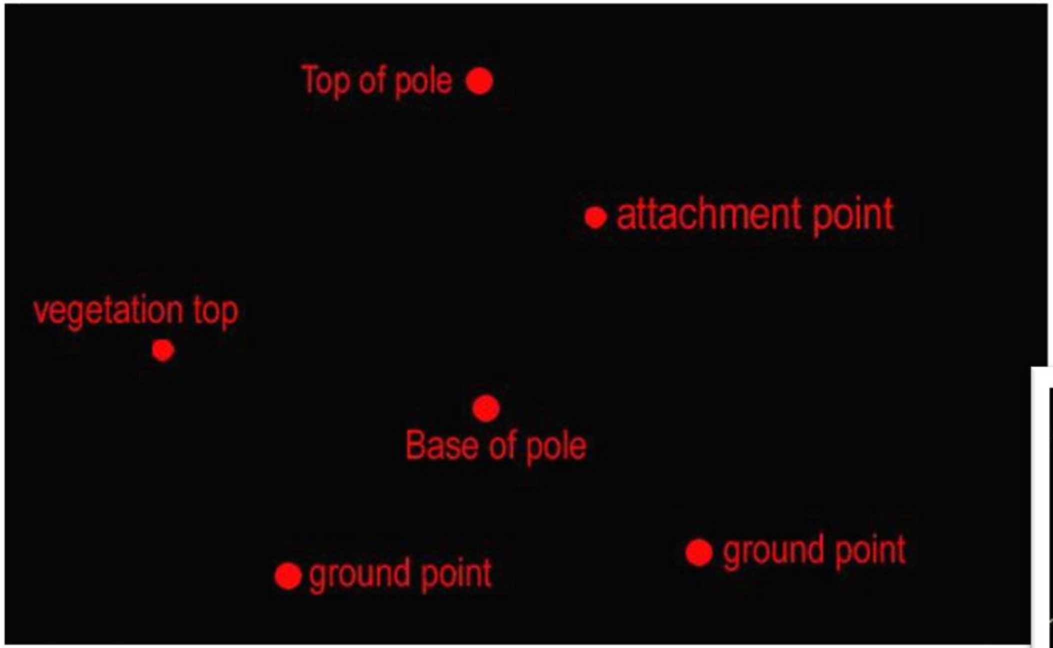




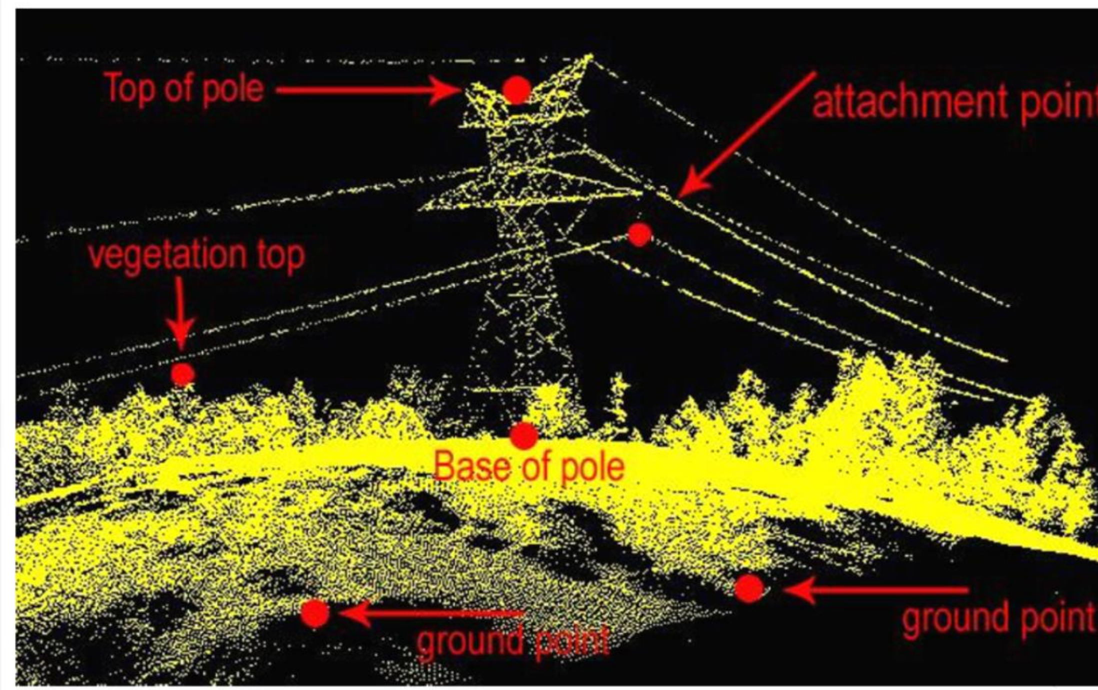
LiDAR is rated as best technology for Topographic Data

ADVANTAGES OF LIDAR

LiDAR Vs Traditional Survey



Traditional survey of a section of transmission ROW.



ROW

Unlike traditional survey LiDAR captures everything—nothing is missing.

LiDAR technology is much better than traditional technology

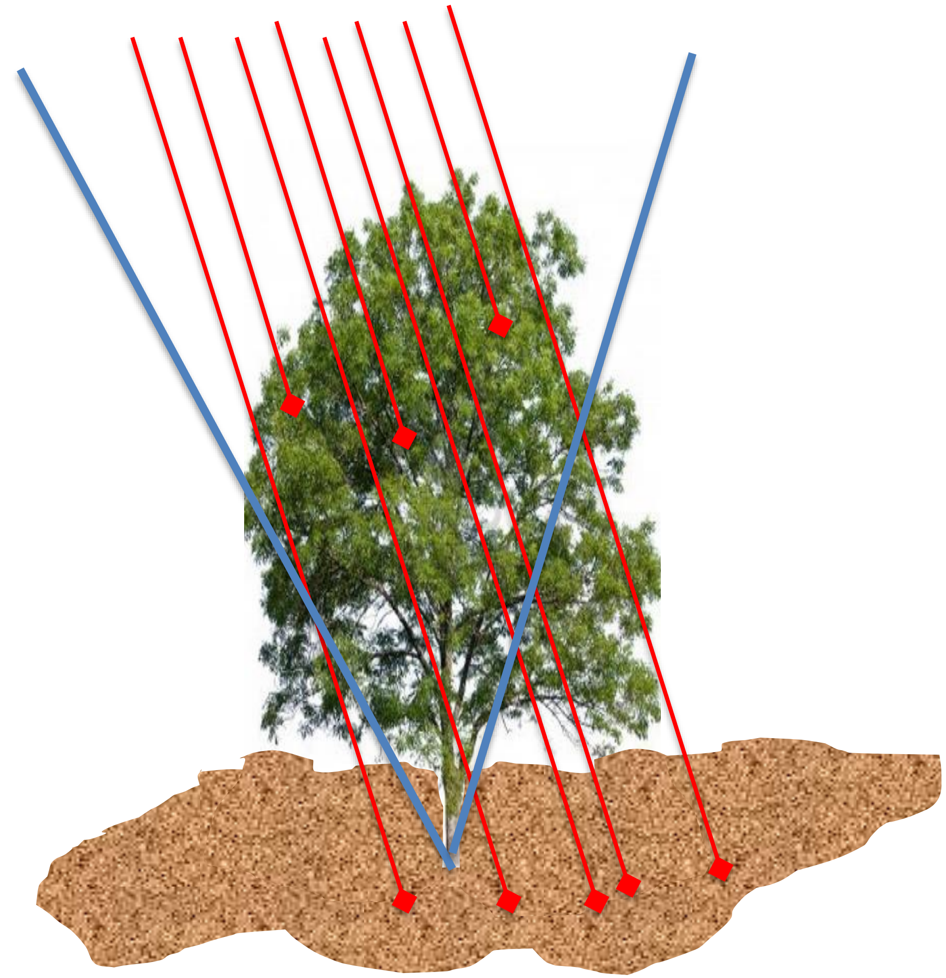
LiDAR

- Very fast: Over 300 sq km of data captured in a day
- Exhaustive: Everything captured
- Fully Automated
- Highly Accurate with verifiable data
- Data can be used for multiple applications

Traditional Survey

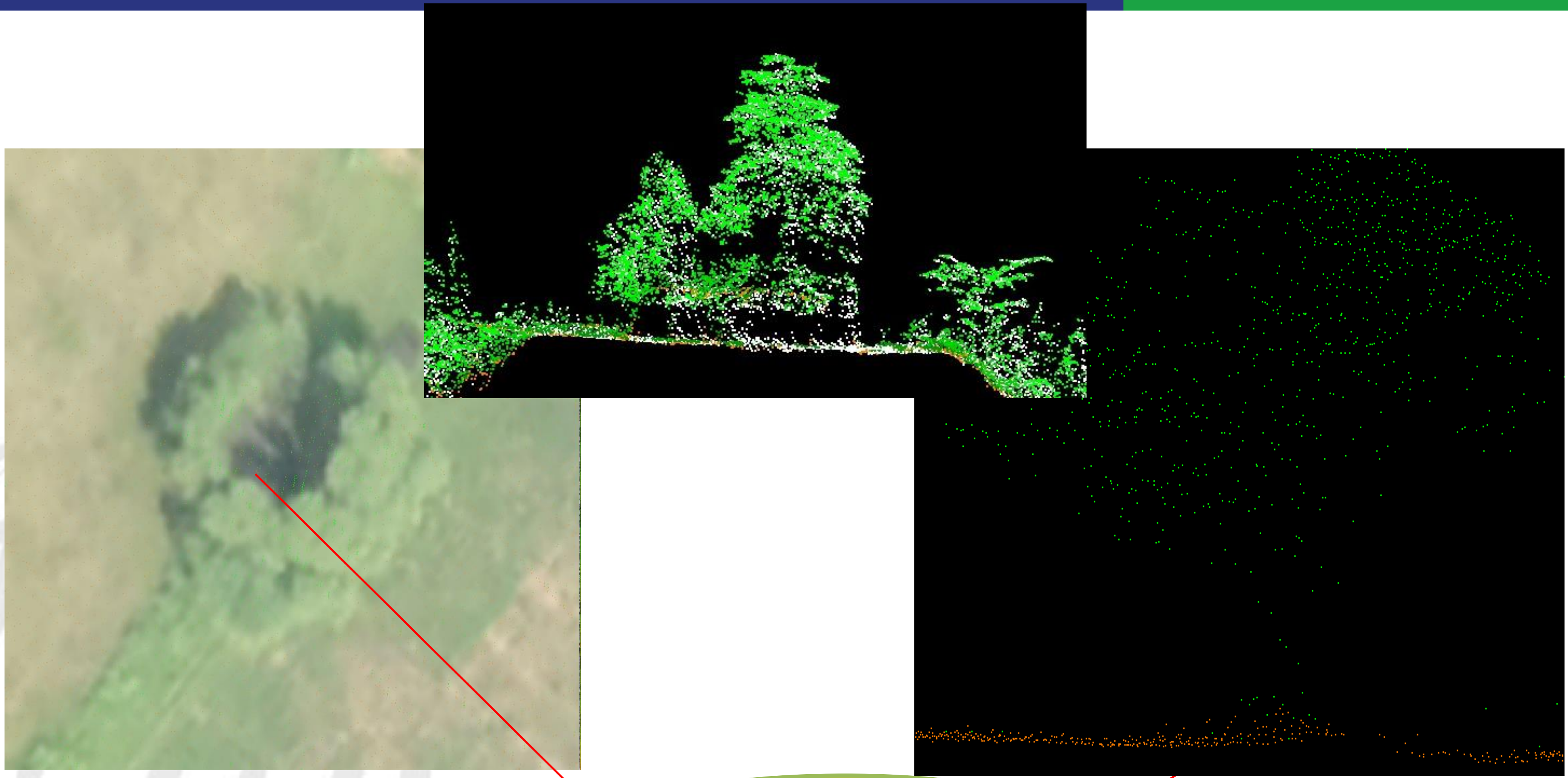
- Slow: Only 1 or 2 sq km captured in a day
- Very little detail is captured
- Totally person dependent
- Inaccurate and no verifiable data
- Data cannot be used for any other purpose

LiDAR Maps Under Forest/Crop Unlike Drone, Total Station/GNSS, Satellite



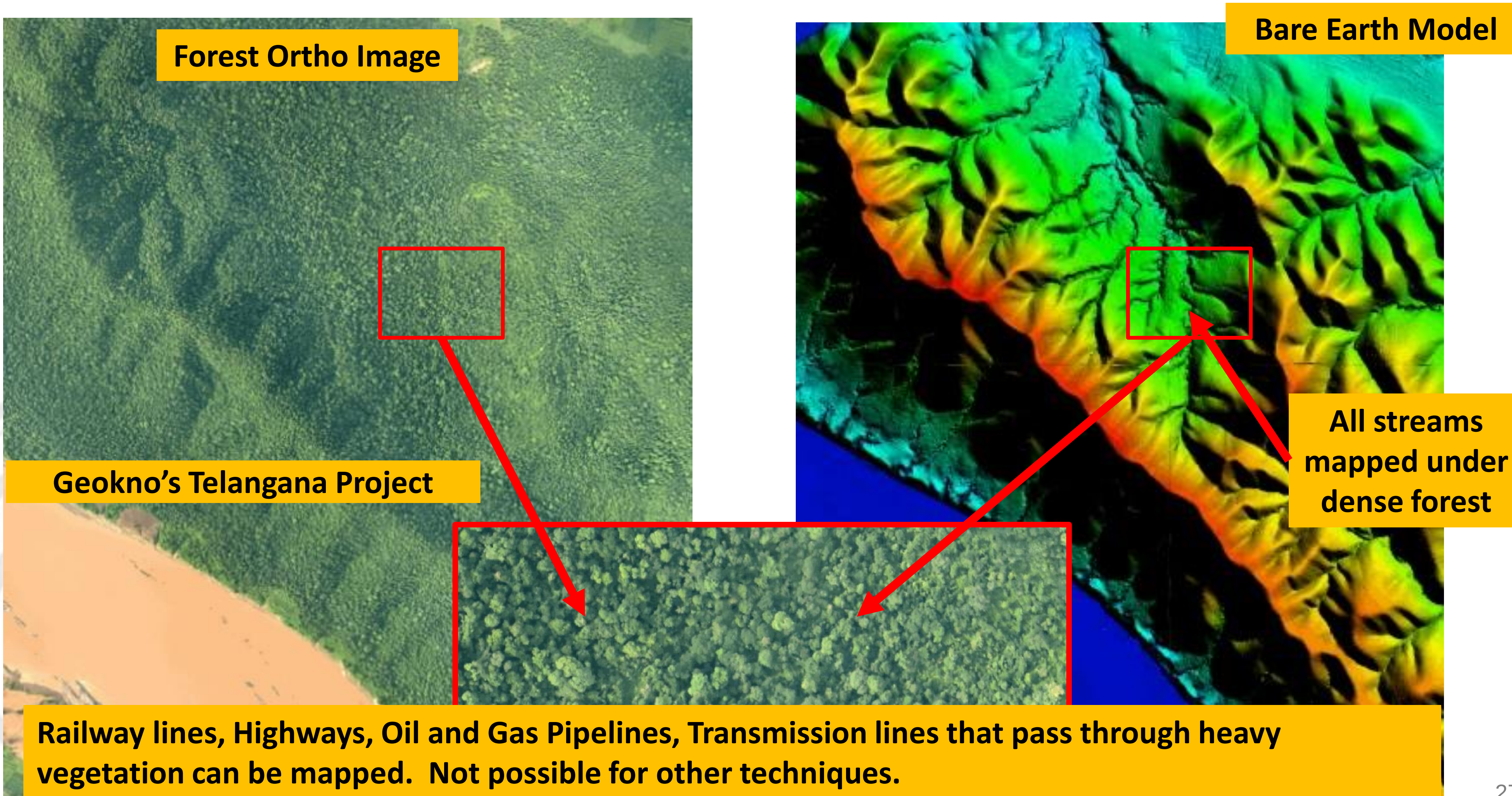
Laser travels from holes in trees and measures points under trees also. Not possible in other methods.

LiDAR can See Under Tree/Forest



LiDAR measures
points under canopy

Forest Sample LiDAR Data and Ortho Image – Areas under thick forest can be mapped easily with LiDAR



Railway lines, Highways, Oil and Gas Pipelines, Transmission lines that pass through heavy vegetation can be mapped. Not possible for other techniques.

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NEWS

Sprawling Maya network discovered under Guatemala jungle

2 February 2018

Share

The Maya city of Tikal was found to be just a fraction of an immense hidden metropolis

Researchers have found more than 60,000 hidden Maya ruins in Guatemala in a major archaeological breakthrough.

Laser technology was used to survey digitally beneath the forest canopy, revealing houses, palaces, elevated highways, and defensive fortifications.

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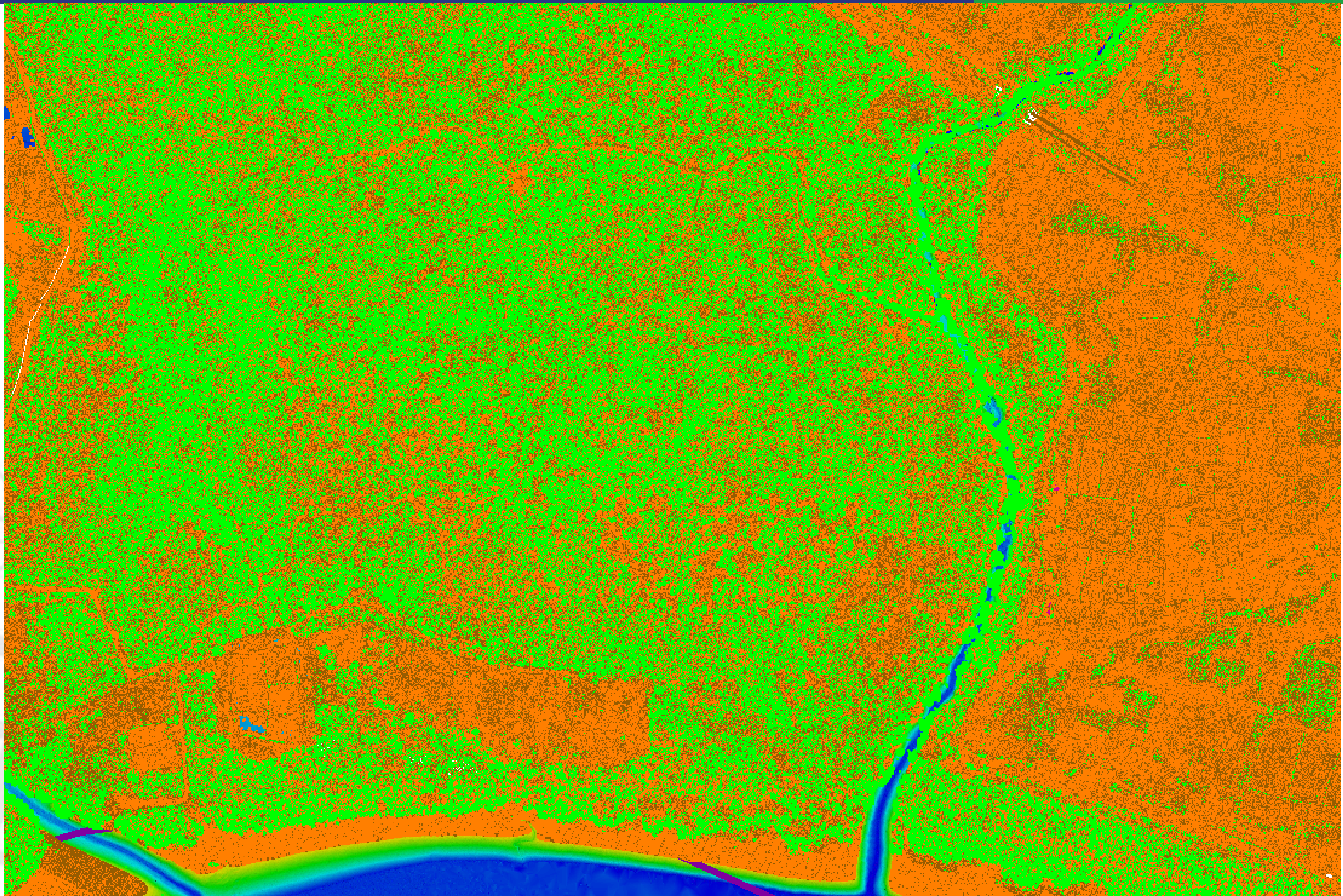
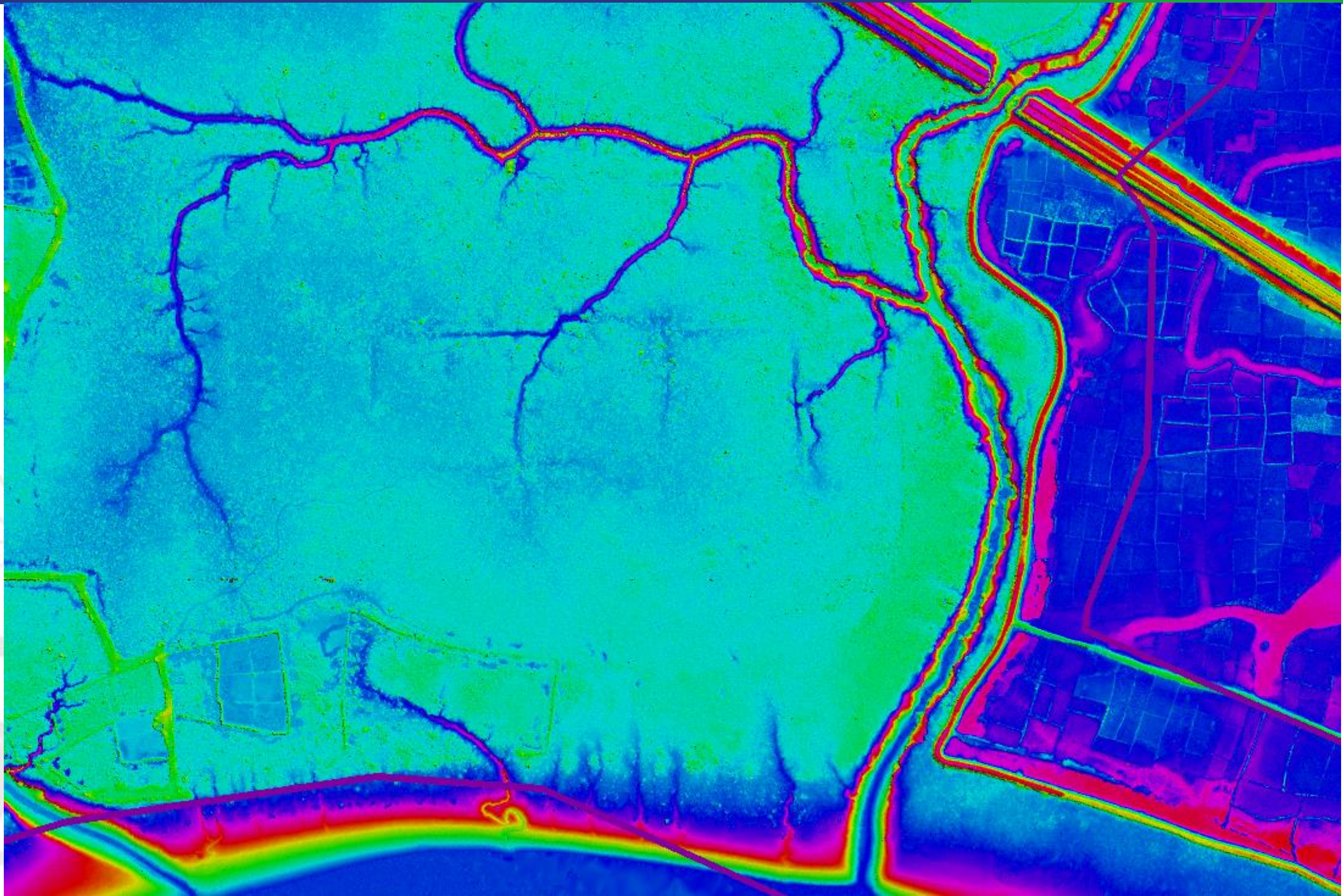
Satellite image

Aerial image

LiDAR point cloud

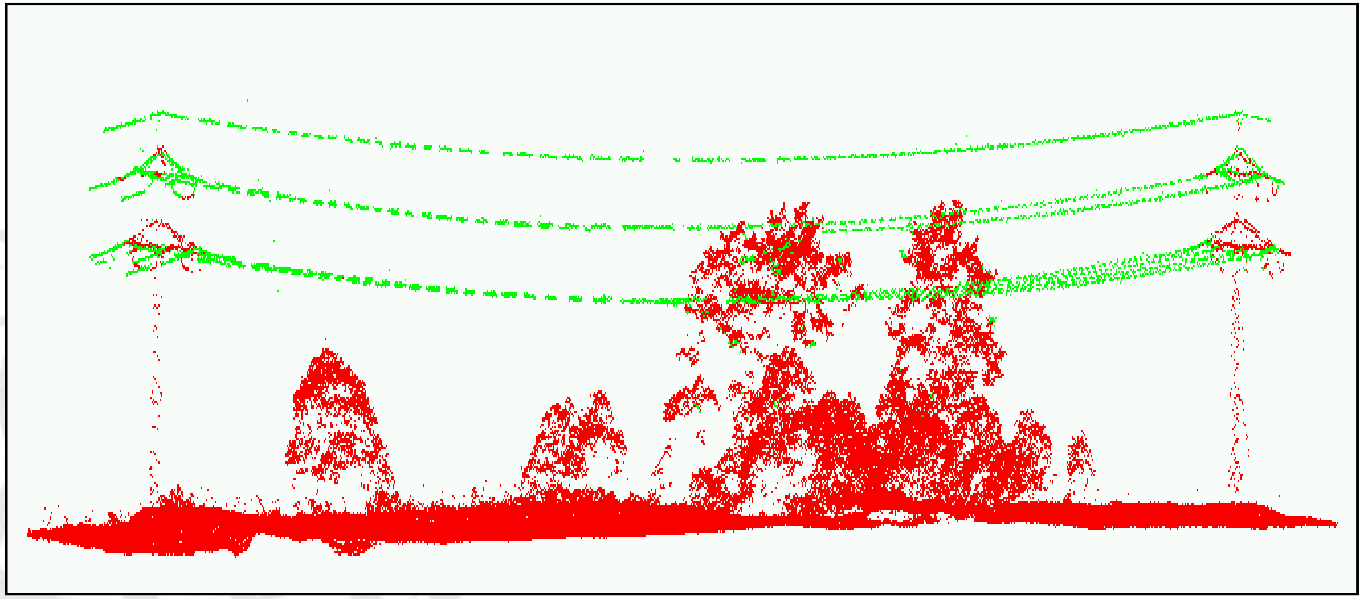


Channels extracted under forest cover

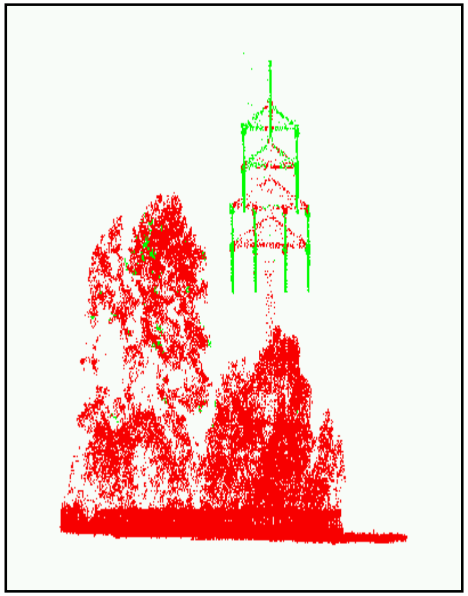


LiDAR Maps Un-mapable

Longitudinal section



Cross section

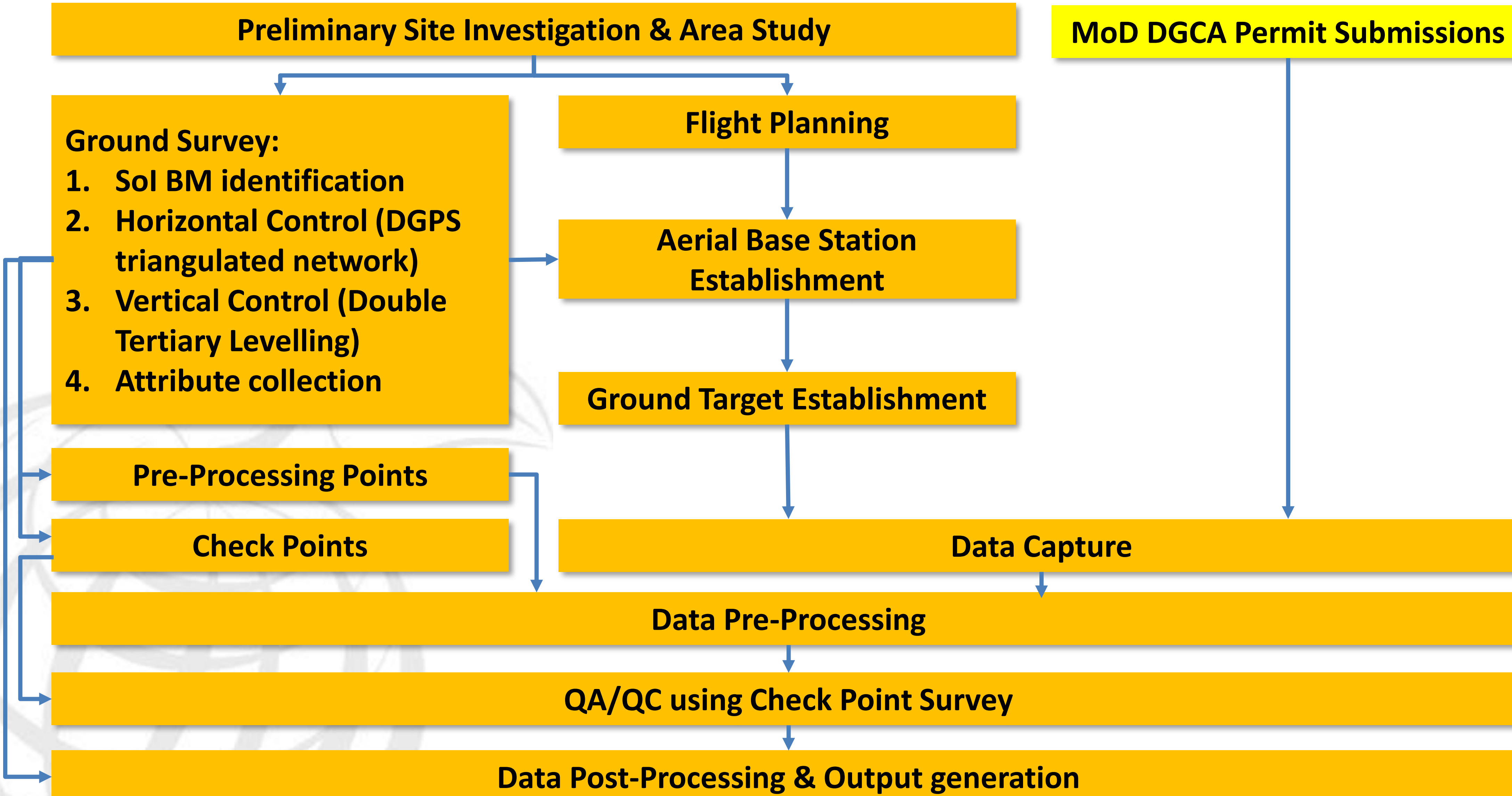


LiDAR also maps objects as thin and inaccessible as transmission lines. Important in monitoring transmission lines especially through thick jungles.

Steps in field to collect LiDAR data

PROJECT EXECUTION

Methodology



DGCA/MoD Permissions – Necessary for all Aerial Survey projects including drone survey

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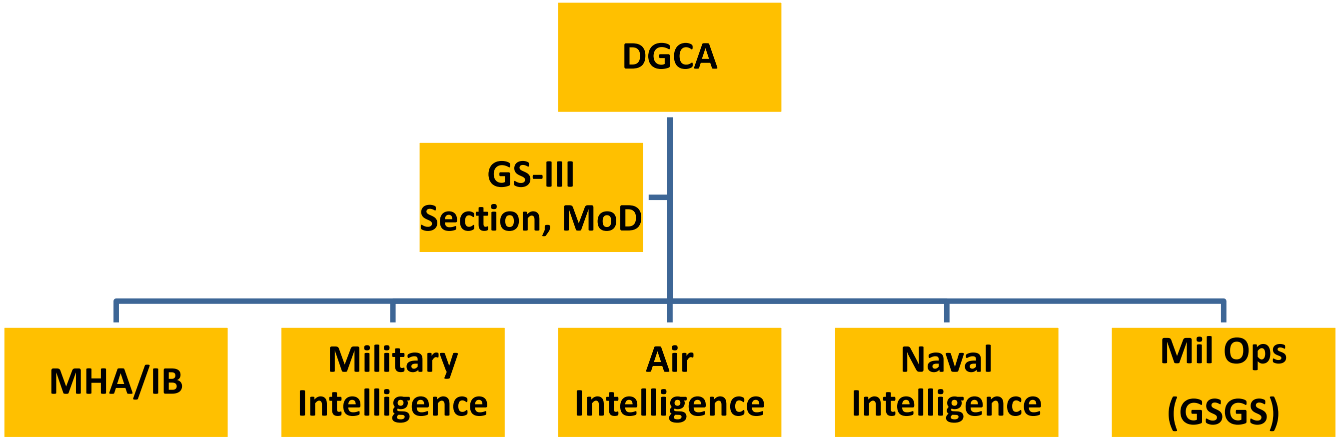
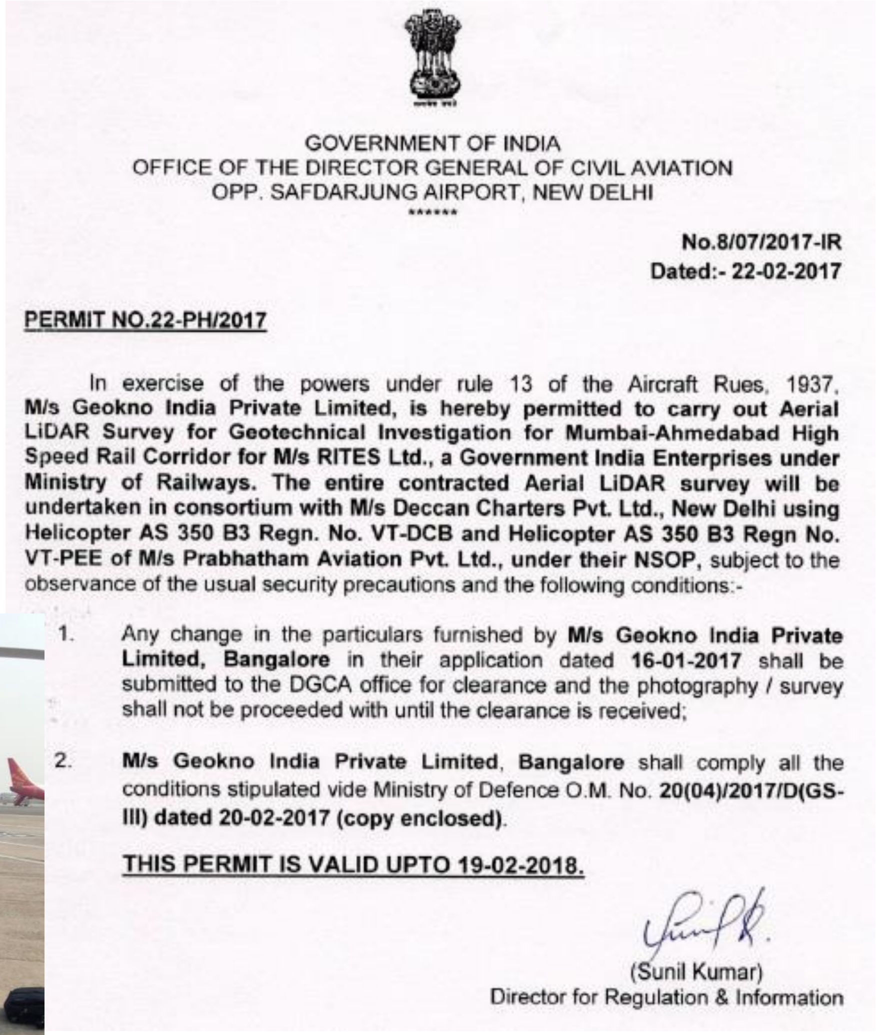




GOVERNMENT OF INDIA
OFFICE OF THE DIRECTOR GENERAL OF CIVIL AVIATION
OPP. SAFDARJUNG AIRPORT, NEW DELHI
******

No.8/07/2017-IR
Dated:- 22-02-2017

PERMIT NO.22-PH/2017

In exercise of the powers under rule 13 of the Aircraft Rues, 1937, **M/s Geokno India Private Limited, is hereby permitted to carry out Aerial LiDAR Survey for Geotechnical Investigation for Mumbai-Ahmedabad High Speed Rail Corridor for M/s RITES Ltd., a Government India Enterprises under Ministry of Railways. The entire contracted Aerial LiDAR survey will be undertaken in consortium with M/s Deccan Charters Pvt. Ltd., New Delhi using Helicopter AS 350 B3 Regn. No. VT-DCB and Helicopter AS 350 B3 Regn No. VT-PEE of M/s Prabhatham Aviation Pvt. Ltd., under their NSOP**, subject to the observance of the usual security precautions and the following conditions:-

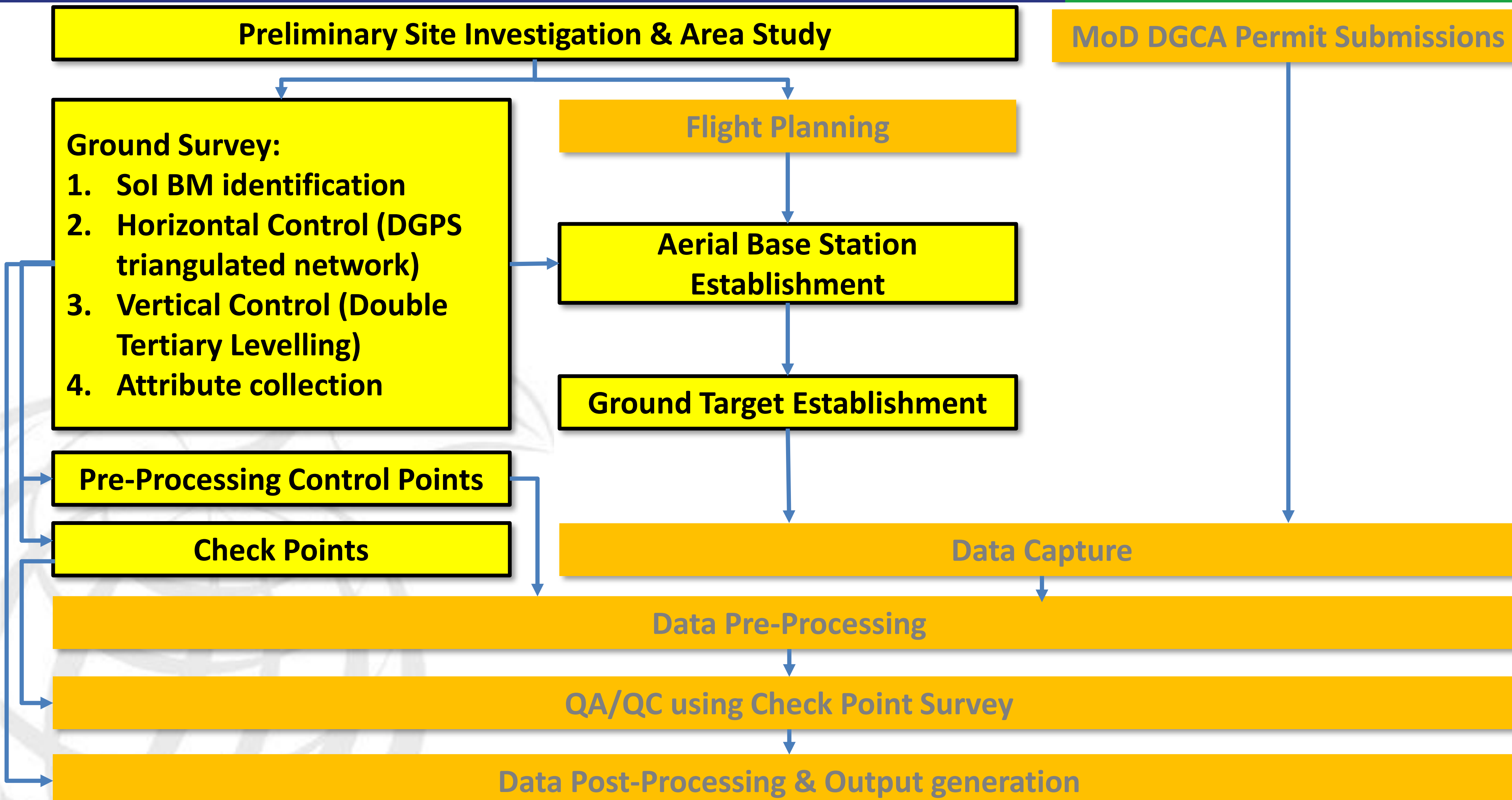
1. Any change in the particulars furnished by **M/s Geokno India Private Limited, Bangalore** in their application dated **16-01-2017** shall be submitted to the DGCA office for clearance and the photography / survey shall not be proceeded with until the clearance is received;

2. **M/s Geokno India Private Limited, Bangalore** shall comply all the conditions stipulated vide Ministry of Defence O.M. No. **20(04)/2017/D(GS-III) dated 20-02-2017 (copy enclosed)**.

THIS PERMIT IS VALID UPTO 19-02-2018.

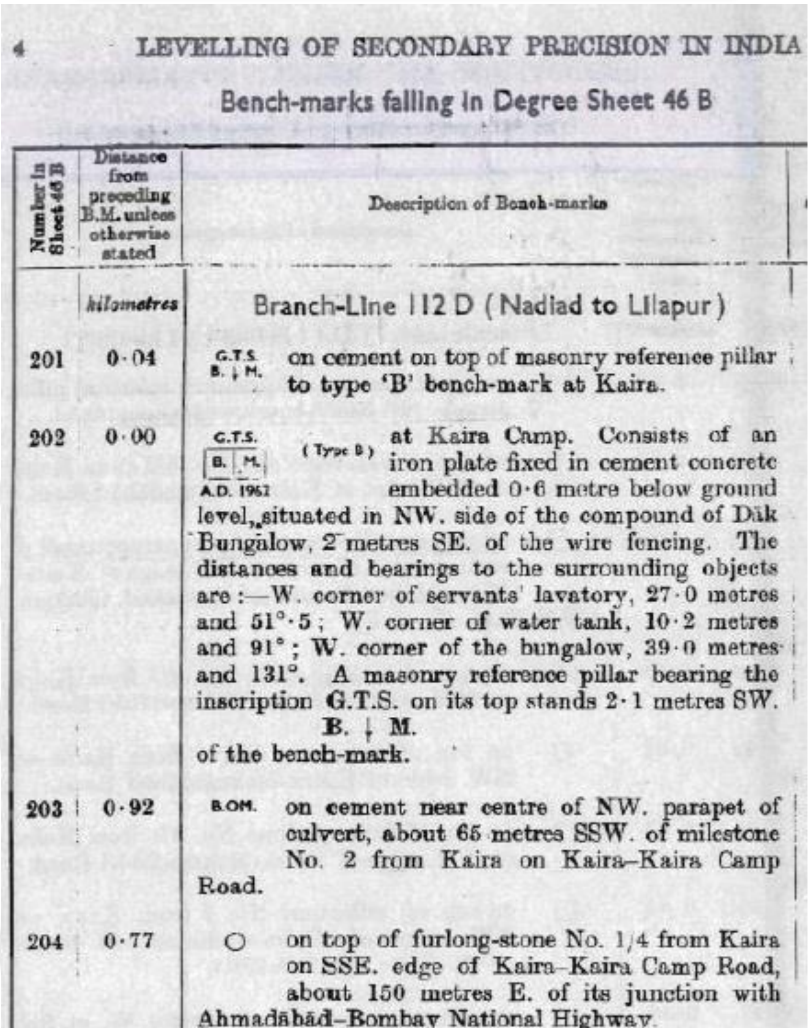
(Sunil Kumar)
Director for Regulation & Information

Activities – Ground Survey



SoI Bench Mark need to be identified

Sample BM Description



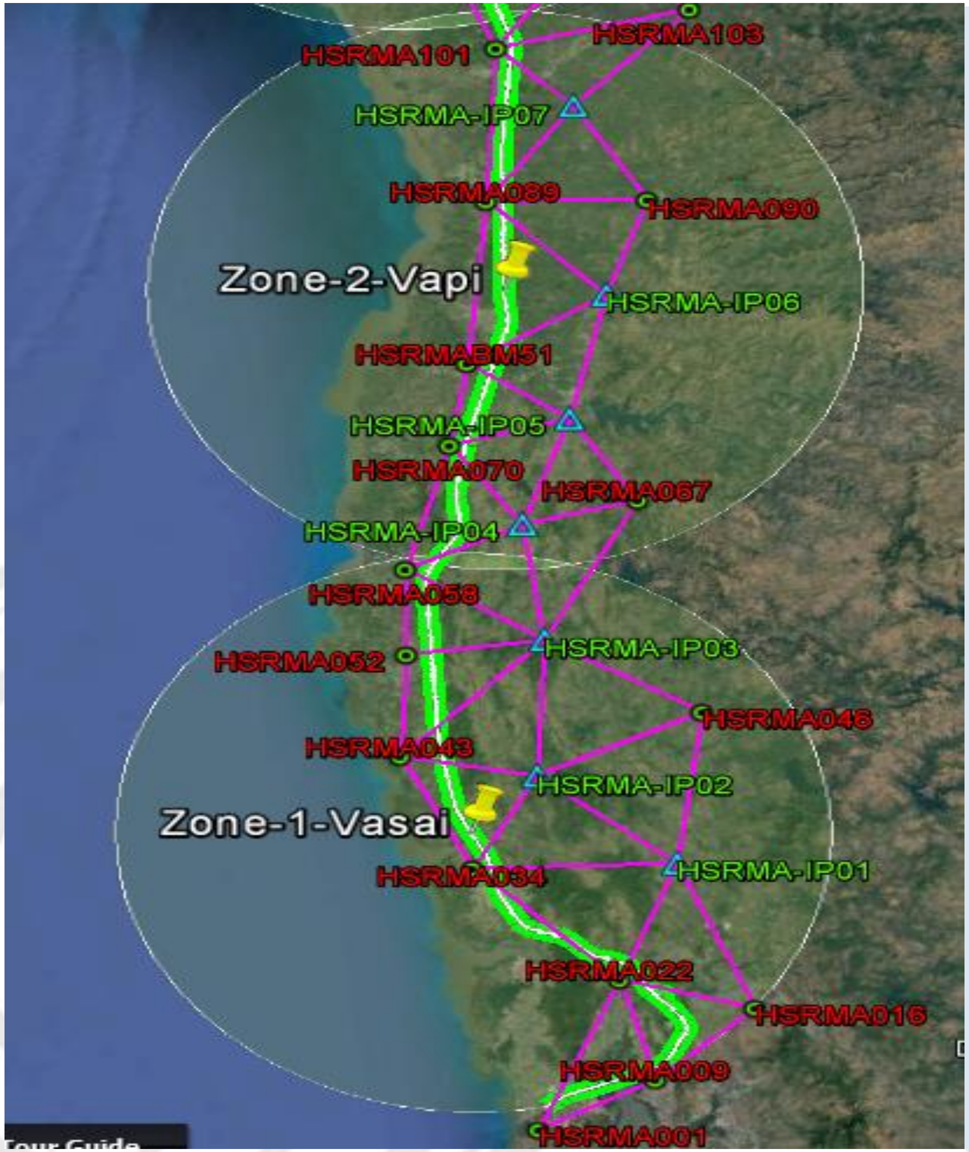
4 LEVELLING OF SECONDARY PRECISION IN INDIA

Bench-marks falling in Degree Sheet 46 B

Number in Sheet 46 B	Distance from preceding B.M. unless otherwise stated	Description of Bench-marks
	kilometres	Branch-Line 112 D (Nadiad to Lilapur)
201	0·04	G.T.S. B. ↓ M. on cement on top of masonry reference pillar to type 'B' bench-mark at Kaira.
202	0·00	G.T.S. B. M. A.D. 1962 (Type B) at Kaira Camp. Consists of an iron plate fixed in cement concrete embedded 0·6 metre below ground level, situated in NW. side of the compound of Dāk Bungalow, 2 metres SE. of the wire fencing. The distances and bearings to the surrounding objects are :—W. corner of servants' lavatory, 27·0 metres and 51°·5; W. corner of water tank, 10·2 metres and 91°; W. corner of the bungalow, 39·0 metres and 131°. A masonry reference pillar bearing the inscription G.T.S. on its top stands 2·1 metres SW. B. ↓ M. of the bench-mark.
203	0·92	B.OM. on cement near centre of NW. parapet of culvert, about 65 metres SSW. of milestone No. 2 from Kaira on Kaira–Kaira Camp Road.
204	0·77	○ on top of furlong-stone No. 1/4 from Kaira on SSE. edge of Kaira–Kaira Camp Road, about 150 metres E. of its junction with Ahmadābād–Bombay National Highway.

GTS BM located by team in Bharuch GTS BMV397 (112)

Ground Control Network- Master Control



- Control network needs to be established starting from SoI GCPs
- Important to check the stability and suitability of SoI BMs
- Levelling network to be established connecting SoI BMs to project controls

Aerial LiDAR Survey Base Station identification

- GNSS base stations need to be established
- Such that the aircraft is never beyond 30 km distance from base station

Activities – Flight Planning

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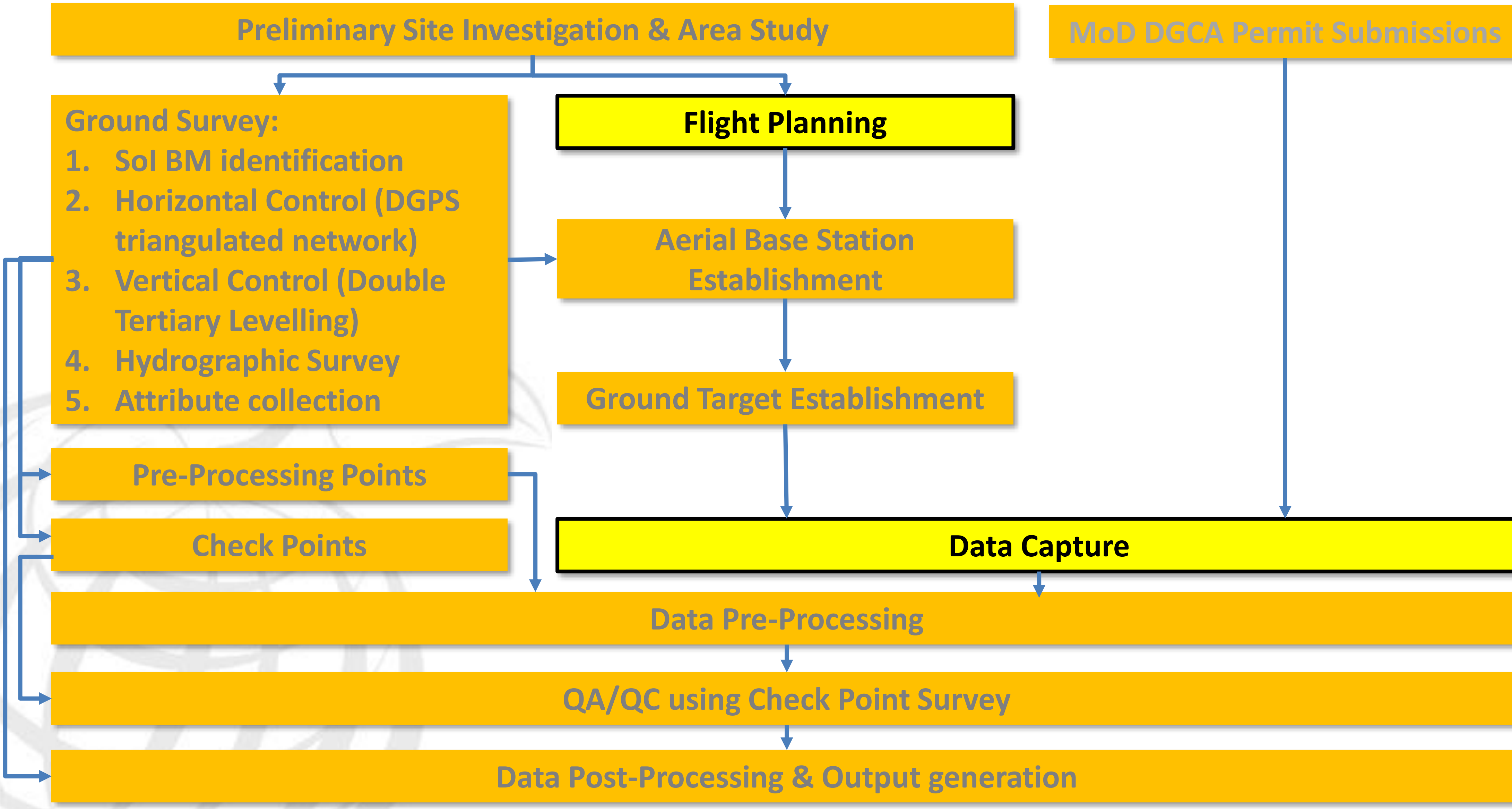
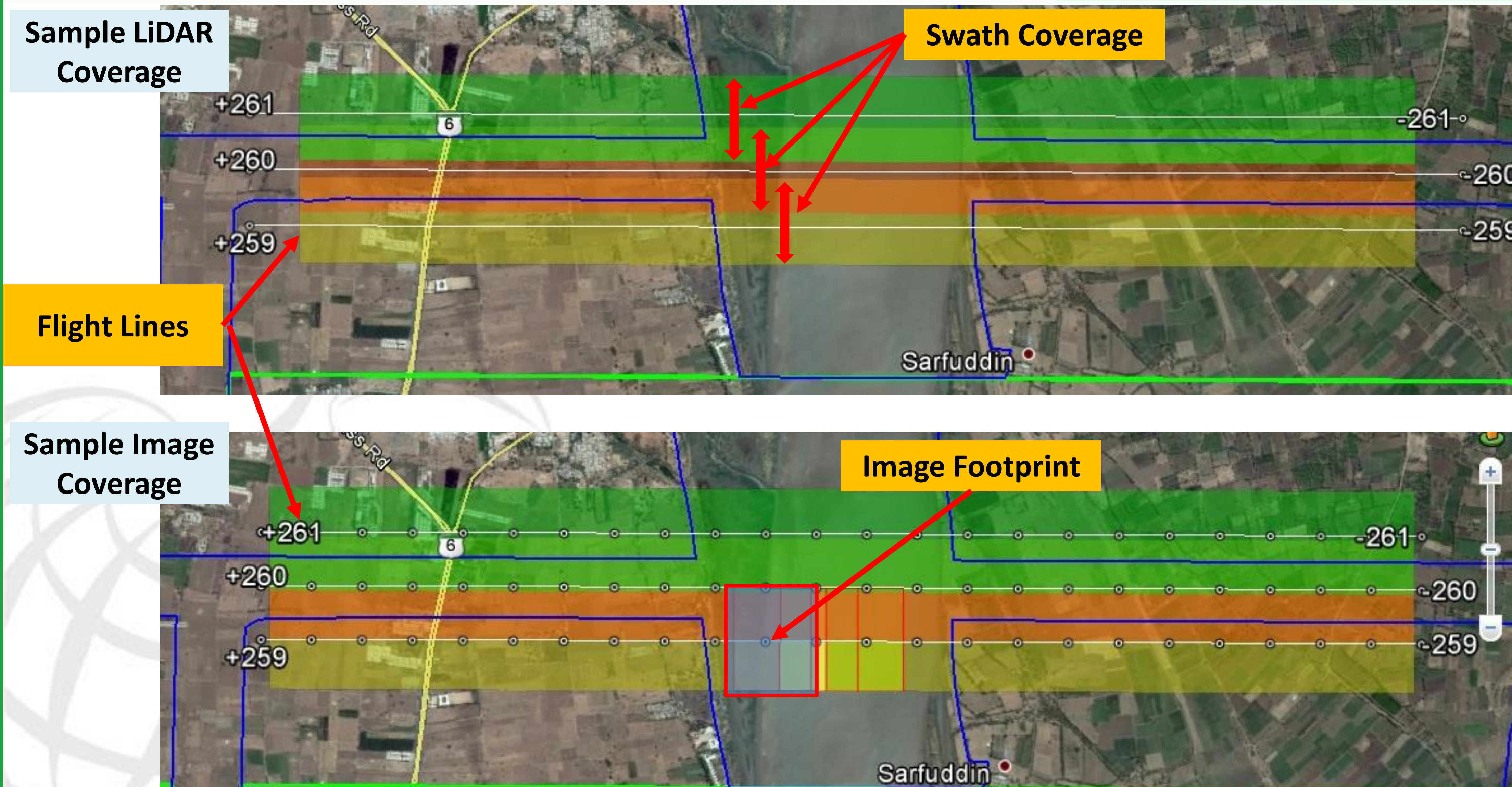
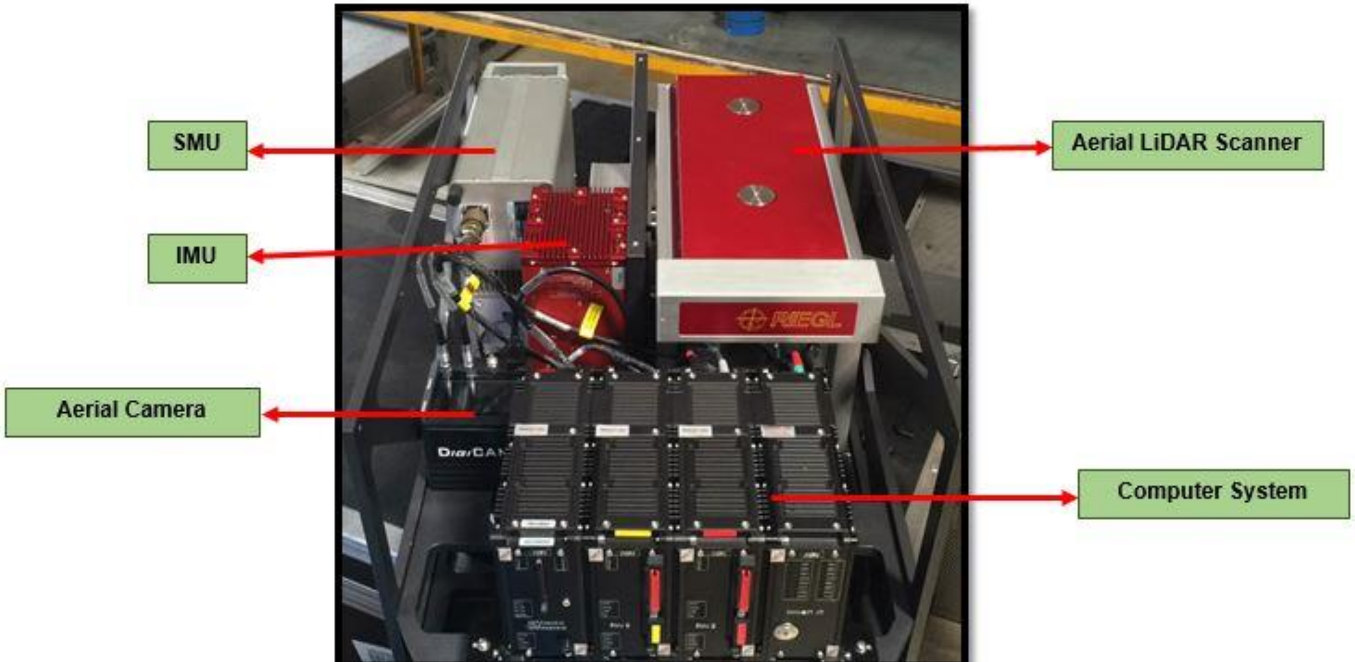


Flight Path planning – Sample Flight Plan



Aerial Survey System



Flight Plans depends on Aerial LiDAR Platform – Riegl LMS Q780 LiDAR with 100 MP Phase One Industrial Camera

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LiDAR Sensor

Riegl LMS Q780

Minimum Range [11]	50 m
Accuracy [12] [13]	20 mm
Precision [12] [14]	20 mm
Laser Pulse Repetition Rate	up to 400 kHz
Effective Measurement Rate	up to 266 kHz @ 60° scan angle
Laser Wavelength	near infrared
Laser Beam Divergence [15]	≤ 0.25 mrad
Number of Targets per Pulse	digitized waveform processing: unlimited [16] monitoring data output: first pulse
Scanner Performance	
Scanning Mechanism	rotating polygon mirror
Scan Pattern	parallel scan lines
Scan Angle Range	± 30° = 60° total
Scan Speed	14 - 200 lines/sec[17] @ laser power level ≥ 50% 10 - 200 lines/sec[18] @ laser power level < 50%
Angular Step Width Δϑ [19]	Δϑ ≥ 0.012° @ laser power level ≥ 50% Δϑ ≥ 0.006° @ laser power level < 50%
Angle Measurement Resolution	0.001°
Scan Sync	Option for synchronizing scan lines to external timing signal
Intensity Measurement	For each echo signal, high-resolution 16-bit intensity information is provided which can be used for target discrimination and/or identification/classification.

Camera 100 MP

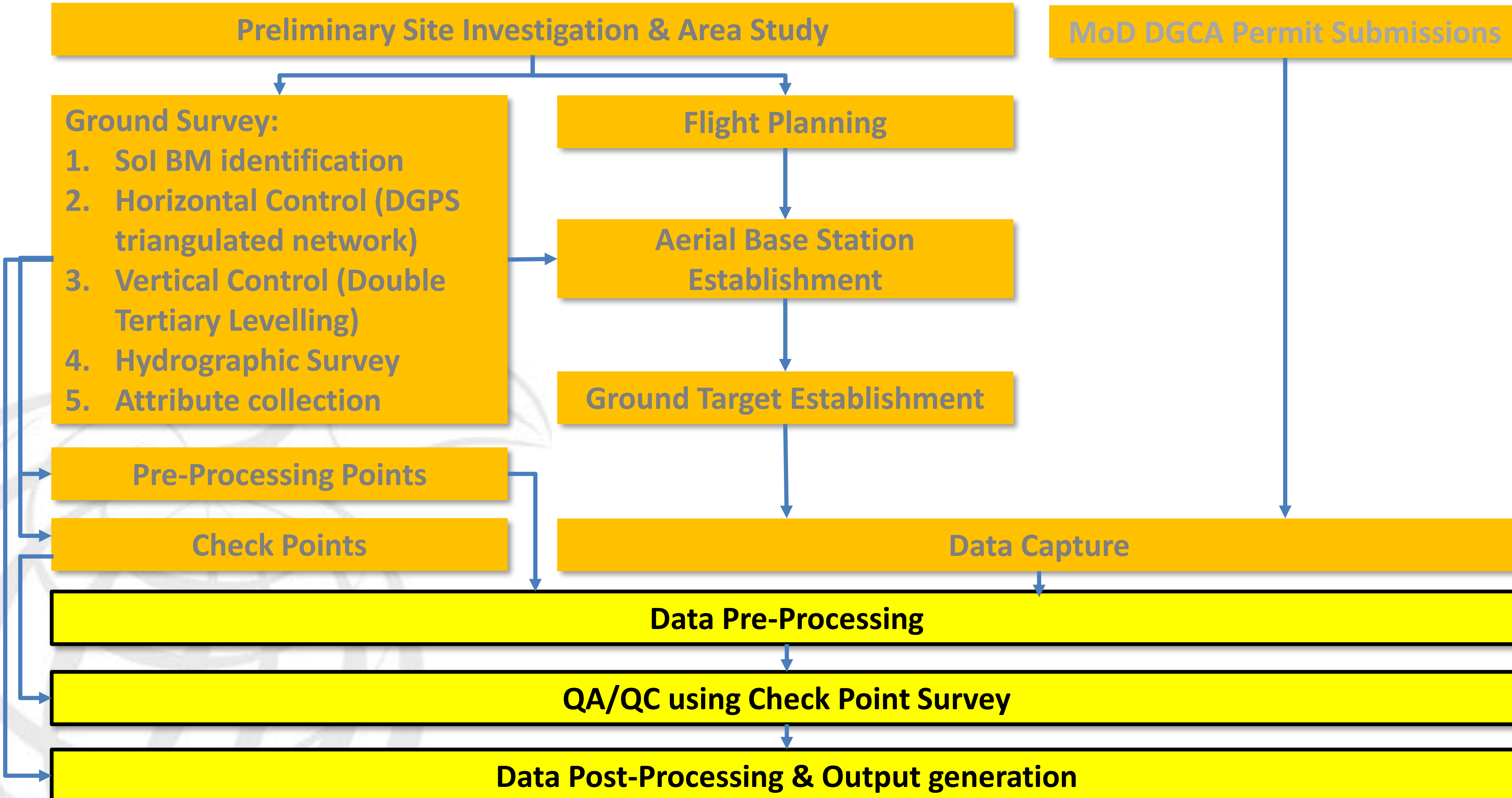
Phase One Industrial

Resolution	100 MP 11608 x 8708
Dynamic range	>84 db
Aspect ratio	4:3
Pixel size	4.6 micron
Sensor size effective	53.4 x 40.0 mm
Lens factor	1.0
Light sensitivity (ISO)	50-6400

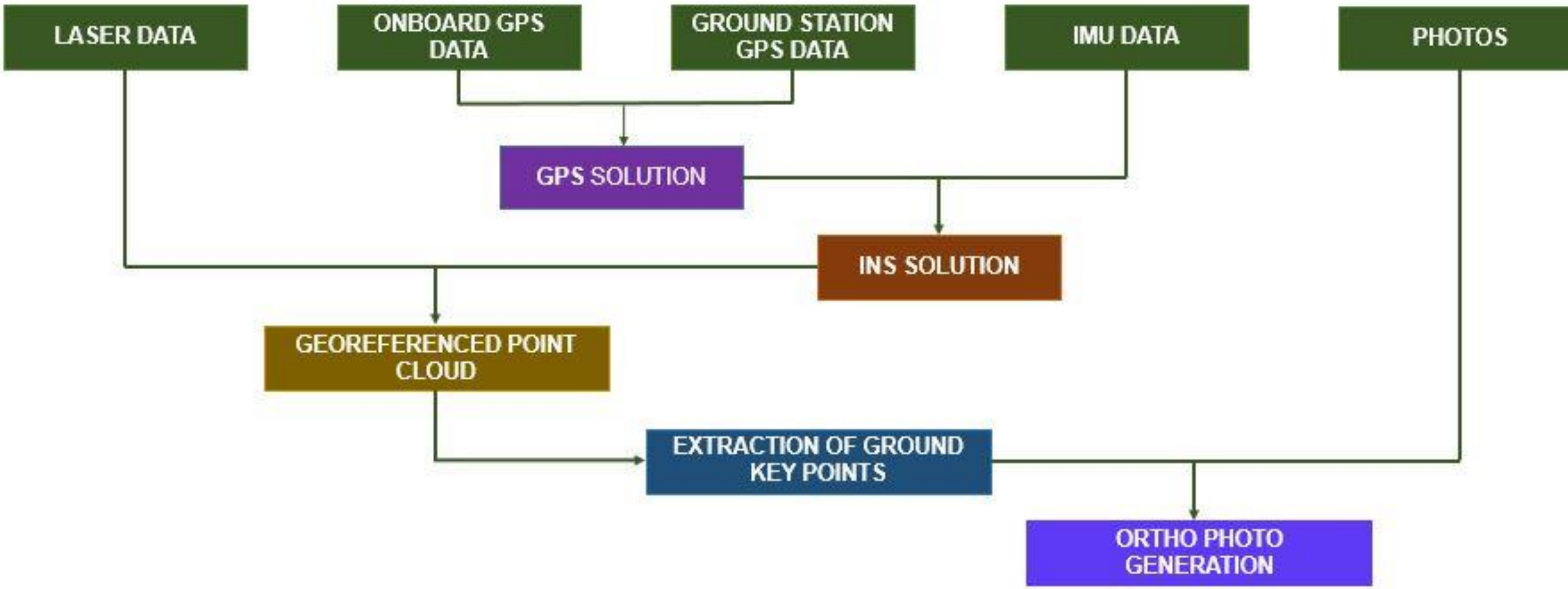
Positional System

IGI AeroControl

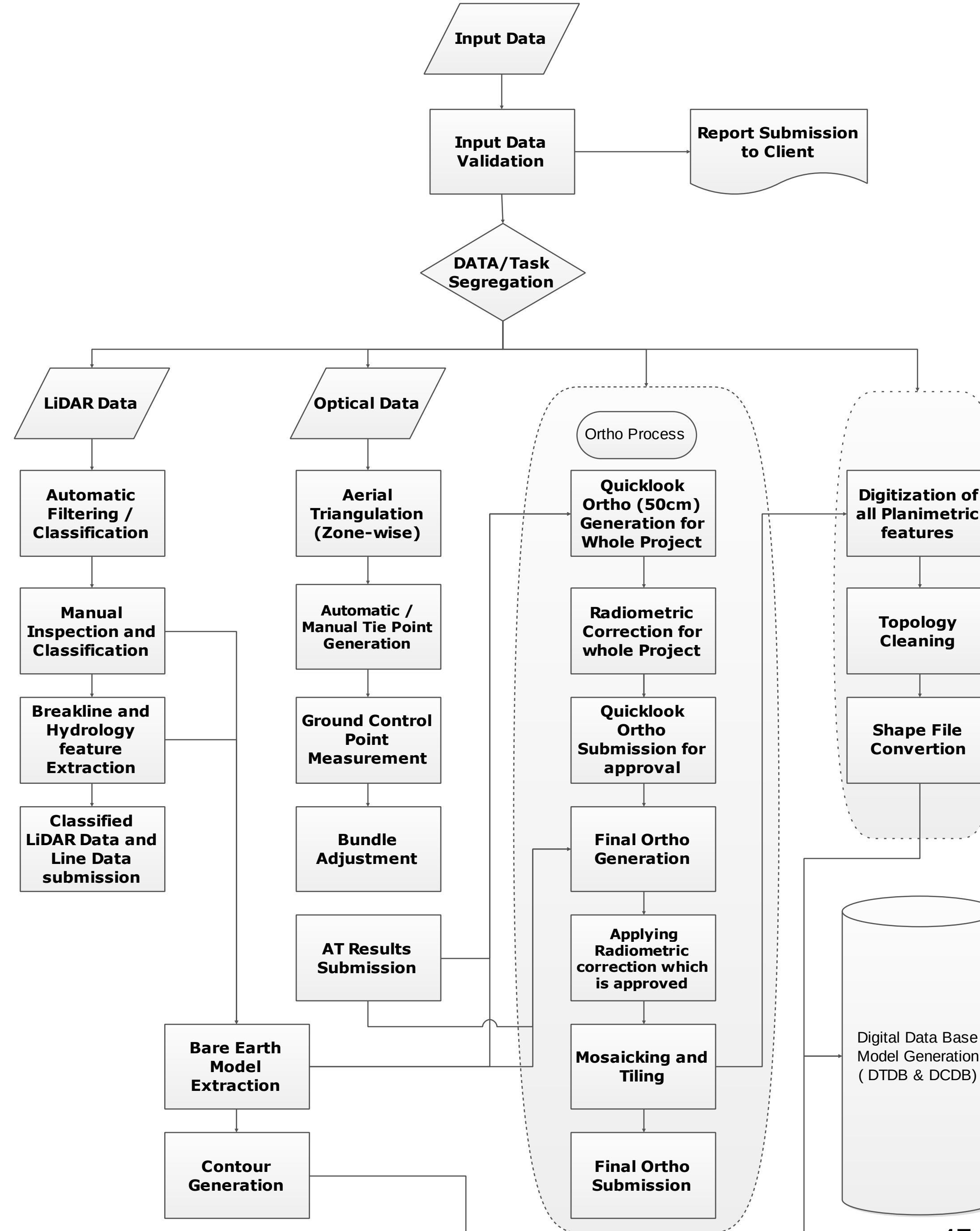
Activities – Output Generation



Data Pre-Processing



Data Post-Processing



Example of LiDAR Data-Accuracy < 10 cm

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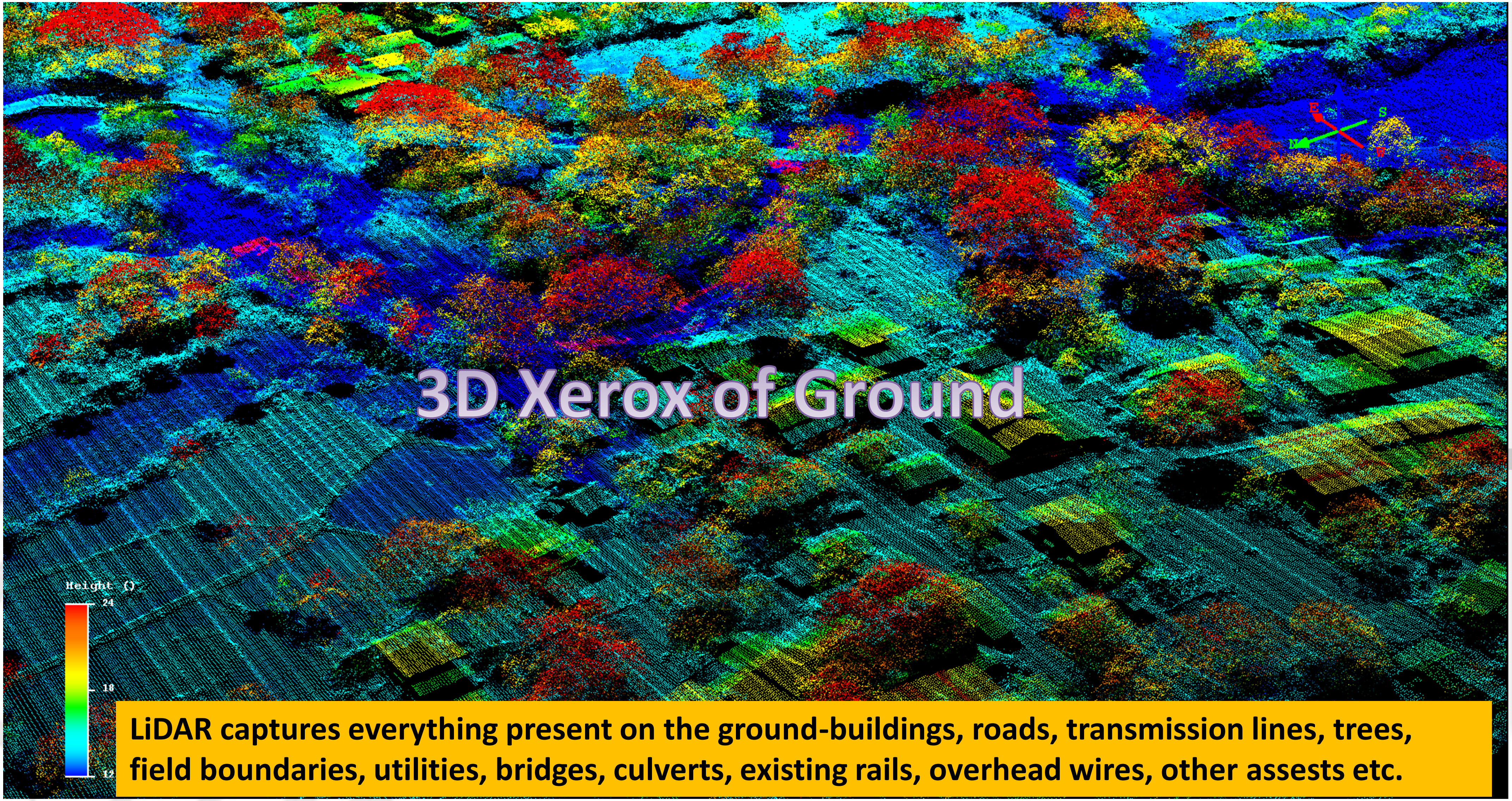
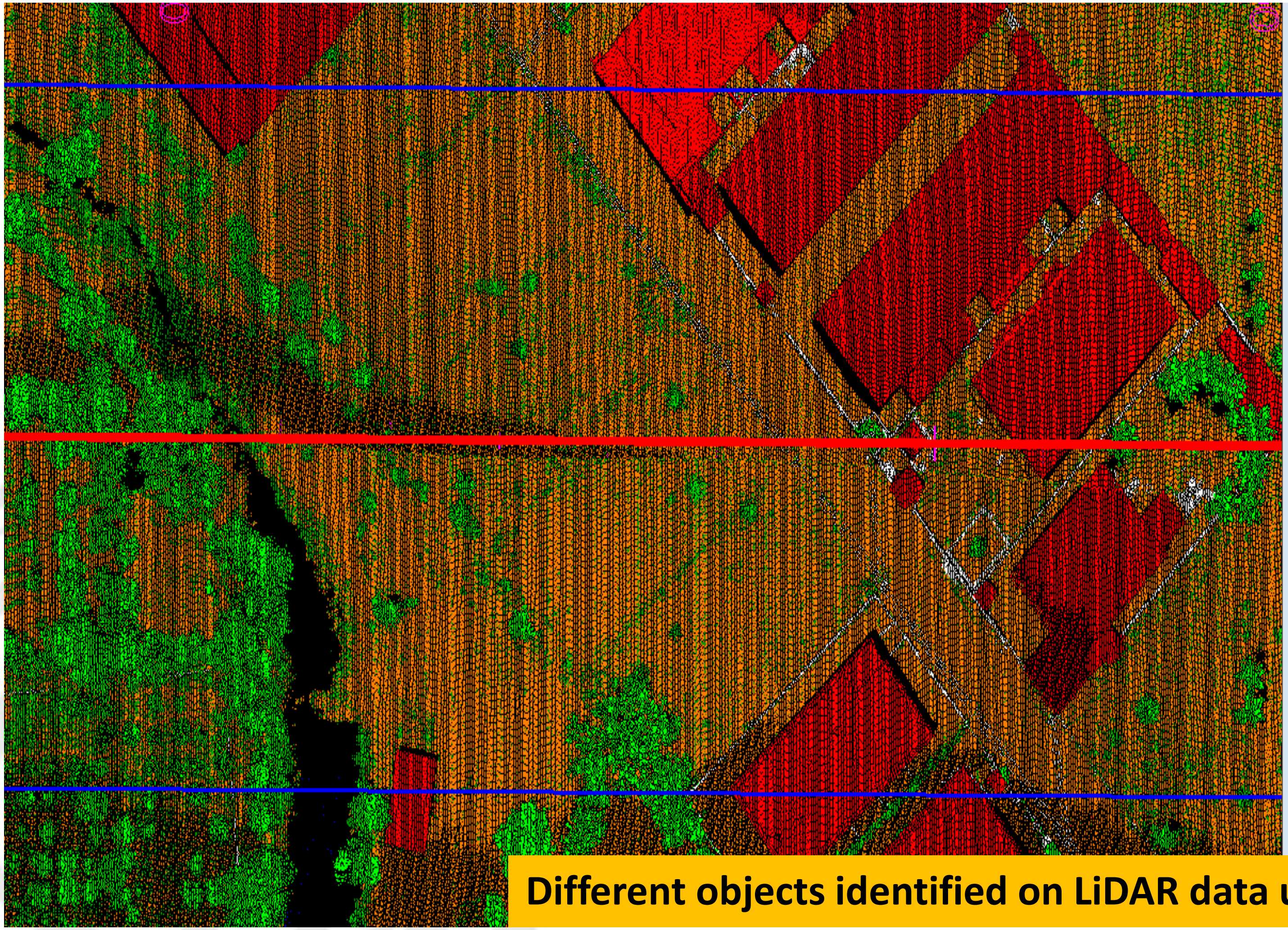


LiDAR captures everything present on the ground-buildings, roads, transmission lines, trees, field boundaries, utilities, bridges, culverts, existing rails, overhead wires, other assests etc.

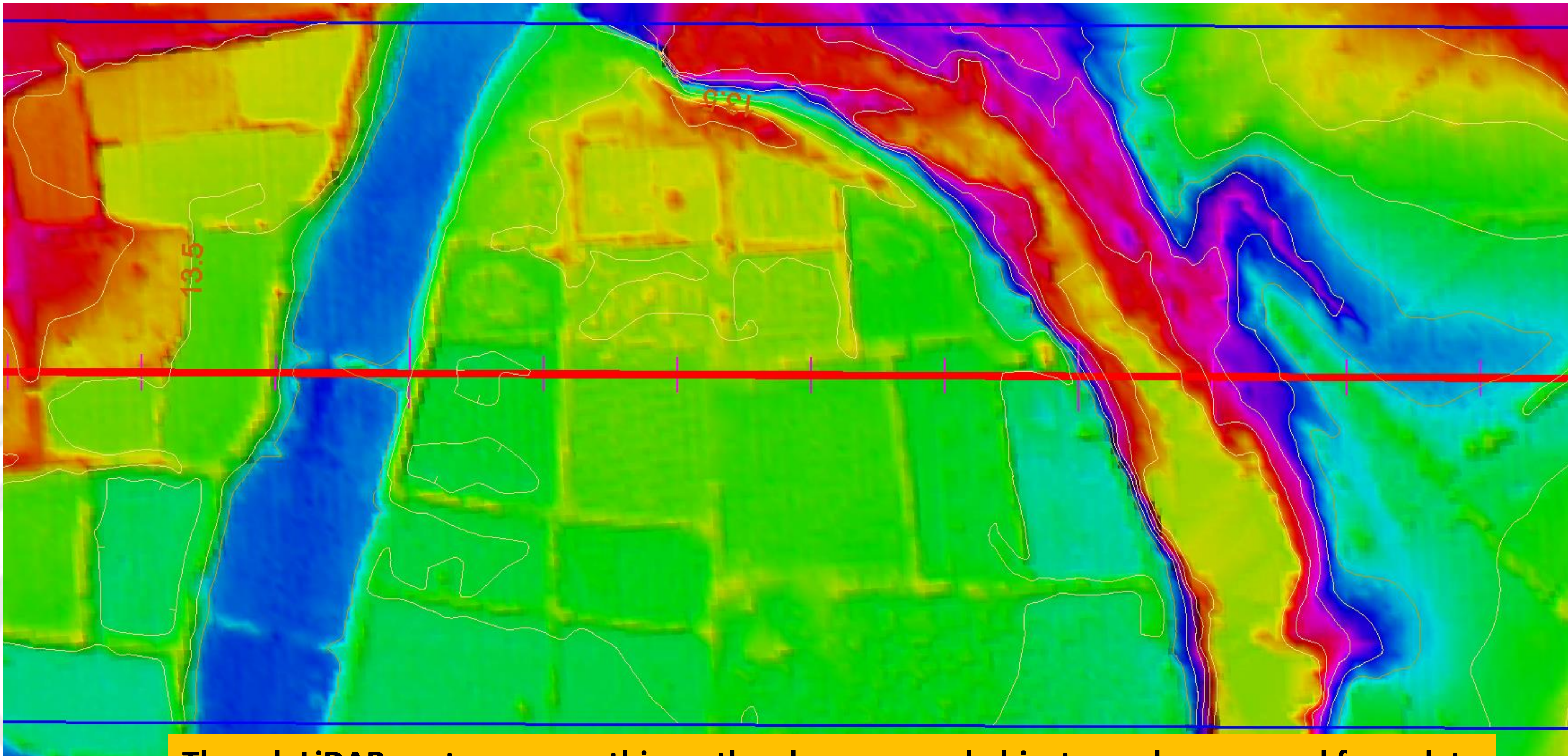
Example of Simultaneously Captured Aerial Image 10 cm GSD

LiDAR Point Cloud - Classified



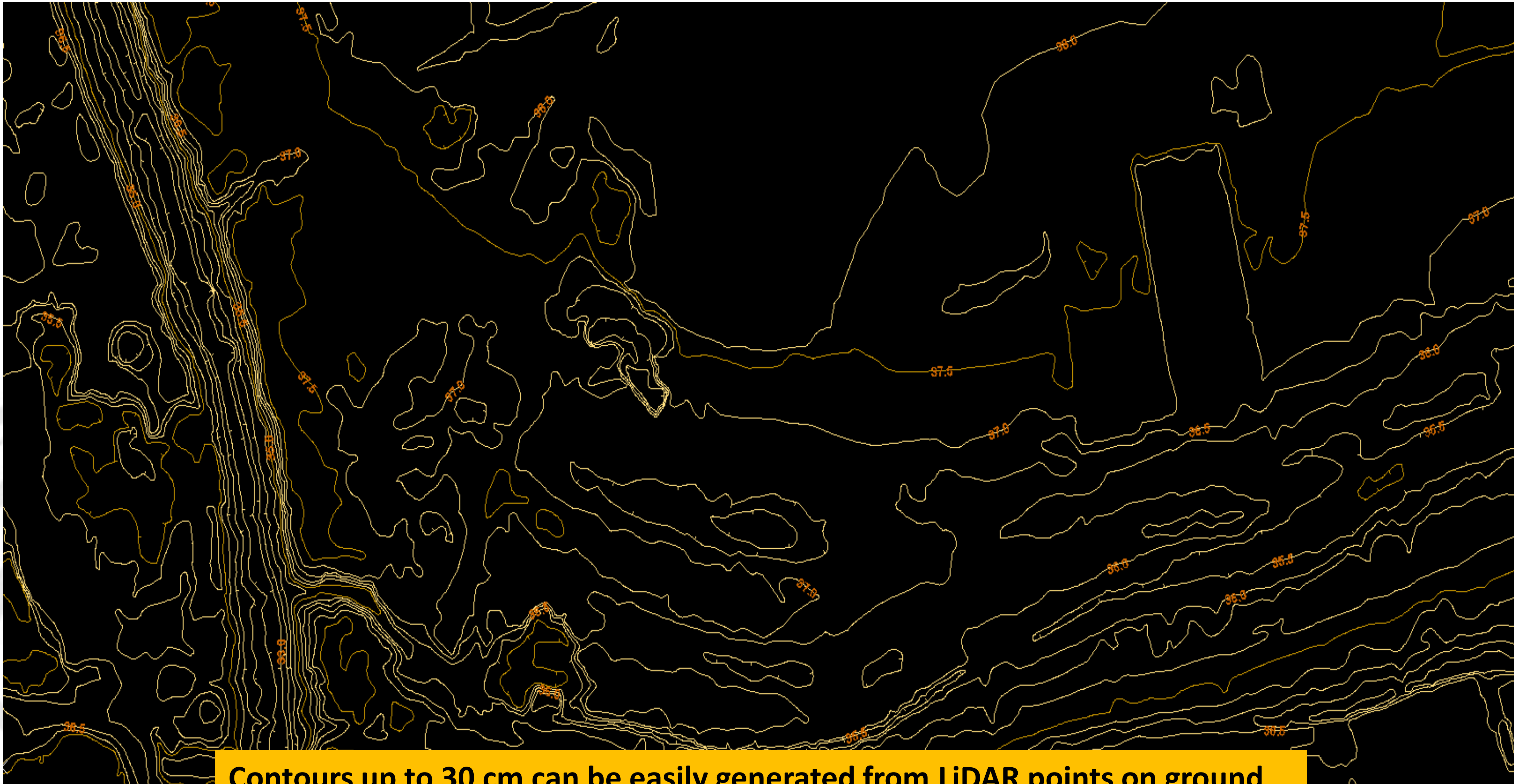
Different objects identified on LiDAR data using algorithms

Digital Elevation Model



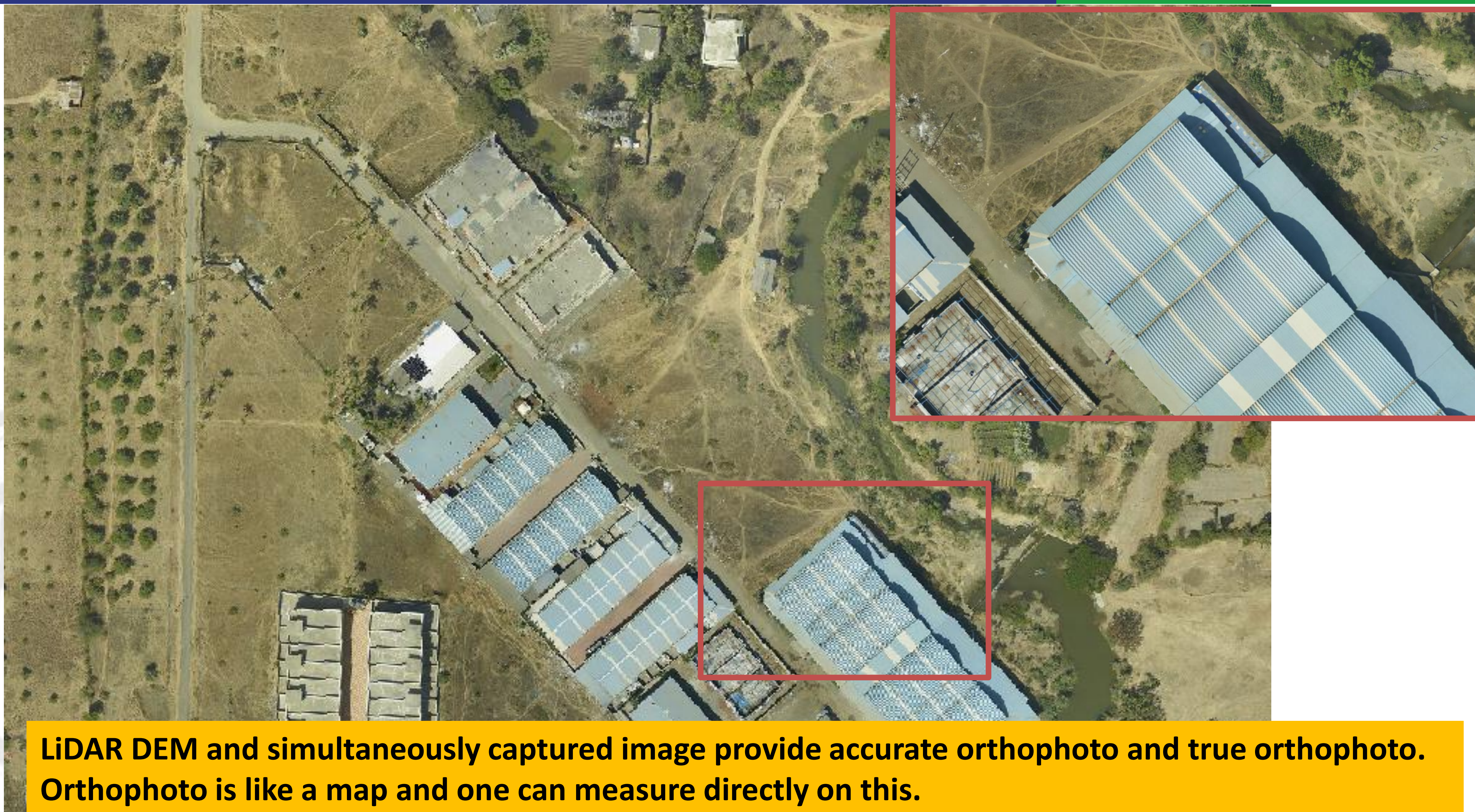
Though LiDAR captures everything—the above ground objects can be removed from data thus giving only the ground data, i.e., bare earth DEM

Contour Map up to 30 cm CI



Contours up to 30 cm can be easily generated from LiDAR points on ground

Ortho-Photograph up to 10 cm GSD



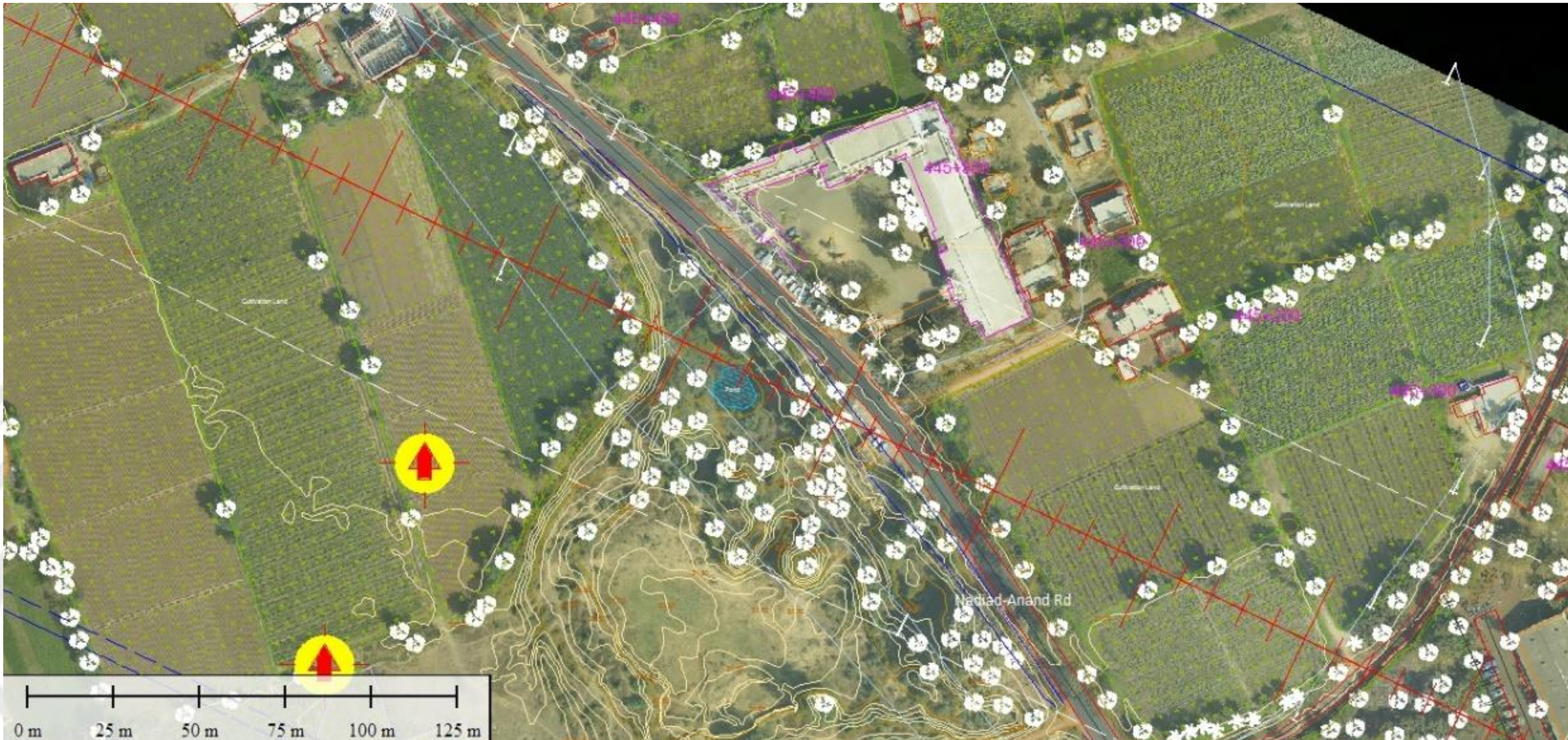
LiDAR DEM and simultaneously captured image provide accurate orthophoto and true orthophoto. Orthophoto is like a map and one can measure directly on this.

GIS Layers/Topographic Map up to 1:1000

Example from Bullet Train Corridor project

From classified LiDAR data and orthophotos, the GIS layers are extracted—buildings, poles, trees, bridges, land plot boundaries, water channels, transmission lines, utilities etc.

Data example from Bullet Train project



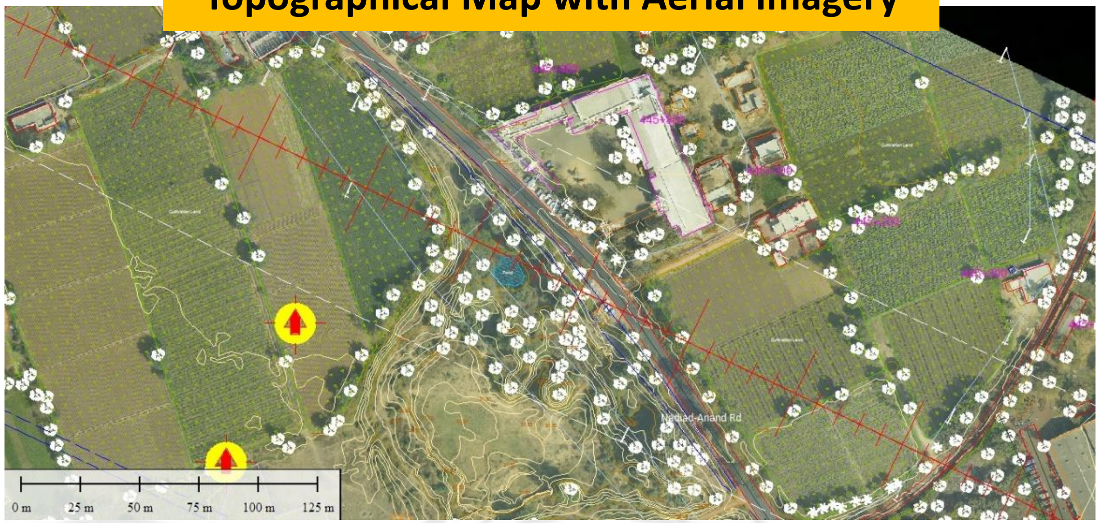
A large number of LiDAR flights have already been completed in India. 4,000,000 ha area captured by Geokno. A few listed here.

SUCCESSFUL PROJECTS BY GEOKNO IN INDIA

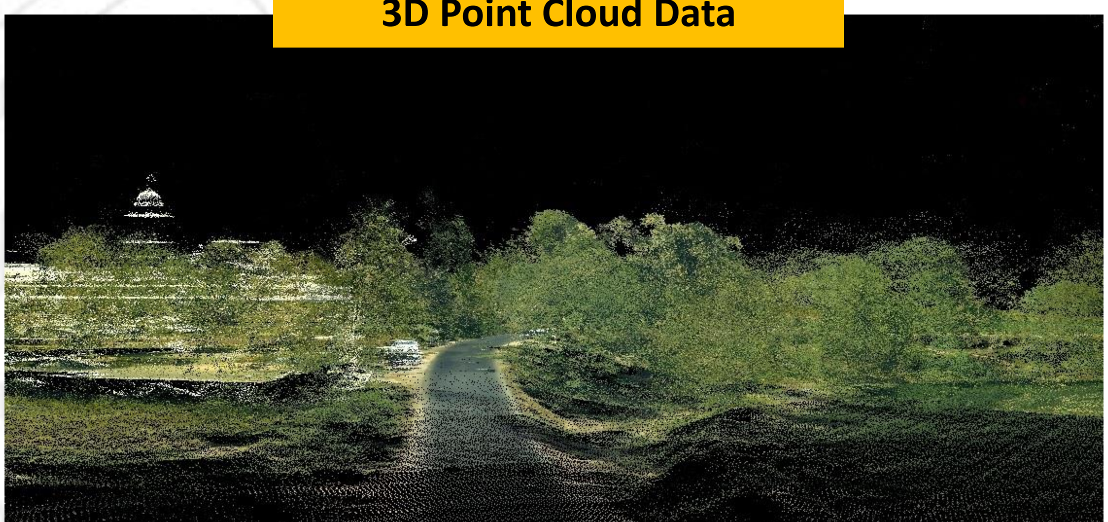
Case Study: Bullet Train, Railways – Geokno saved over 6 months for the prestigious Ahmedabad-Mumbai High Speed Rail Corridor

Geokno
Leaders in LiDAR

Topographical Map with Aerial Imagery



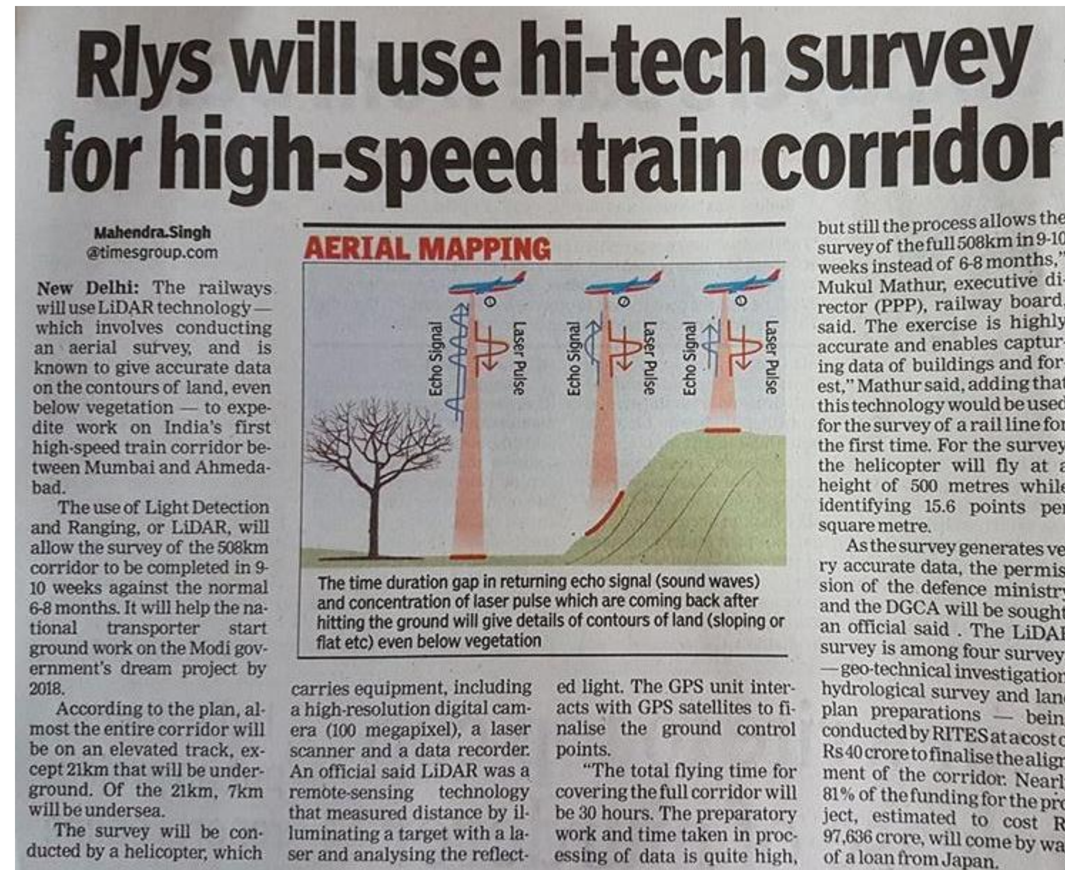
3D Point Cloud Data



RITES
THE INFRASTRUCTURE PEOPLE
A Government of India Enterprise

NHSRCL
National High Speed Rail Corporation Ltd.

JICA



Rlys will use hi-tech survey for high-speed train corridor

Mahendra.Singh
@timesgroup.com

New Delhi: The railways will use LiDAR technology — which involves conducting an aerial survey, and is known to give accurate data on the contours of land, even below vegetation — to expedite work on India's first high-speed train corridor between Mumbai and Ahmedabad.

The use of Light Detection and Ranging, or LiDAR, will allow the survey of the 508km corridor to be completed in 9-10 weeks against the normal 6-8 months. It will help the national transporter start ground work on the Modi government's dream project by 2018.

According to the plan, almost the entire corridor will be on an elevated track, except 21km that will be underground. Of the 21km, 7km will be undersea.

The survey will be conducted by a helicopter, which carries equipment, including a high-resolution digital camera (100 megapixel), a laser scanner and a data recorder. An official said LiDAR was a remote-sensing technology that measured distance by illuminating a target with a laser and analysing the reflected light. The GPS unit interacts with GPS satellites to finalise the ground control points.

"The total flying time for covering the full corridor will be 30 hours. The preparatory work and time taken in processing of data is quite high, but still the process allows the survey of the full 508km in 9-10 weeks instead of 6-8 months," Mukul Mathur, executive director (PPP), railway board, said. The exercise is highly accurate and enables capturing data of buildings and forest," Mathur said, adding that this technology would be used for the survey of a rail line for the first time. For the survey, the helicopter will fly at a height of 500 metres while identifying 15.6 points per square metre.

As the survey generates very accurate data, the permission of the defence ministry and the DGCA will be sought, an official said . The LiDAR survey is among four surveys — geo-technical investigation, hydrological survey and land plan preparations — being conducted by RITES at a cost of Rs 40 crore to finalise the alignment of the corridor. Nearly 81% of the funding for the project, estimated to cost Rs 97,636 crore, will come by way of a loan from Japan.

AERIAL MAPPING

The time duration gap in returning echo signal (sound waves) and concentration of laser pulse which are coming back after hitting the ground will give details of contours of land (sloping or flat etc) even below vegetation

Project Statistics

Leaders in LiDAR

Project Statistics

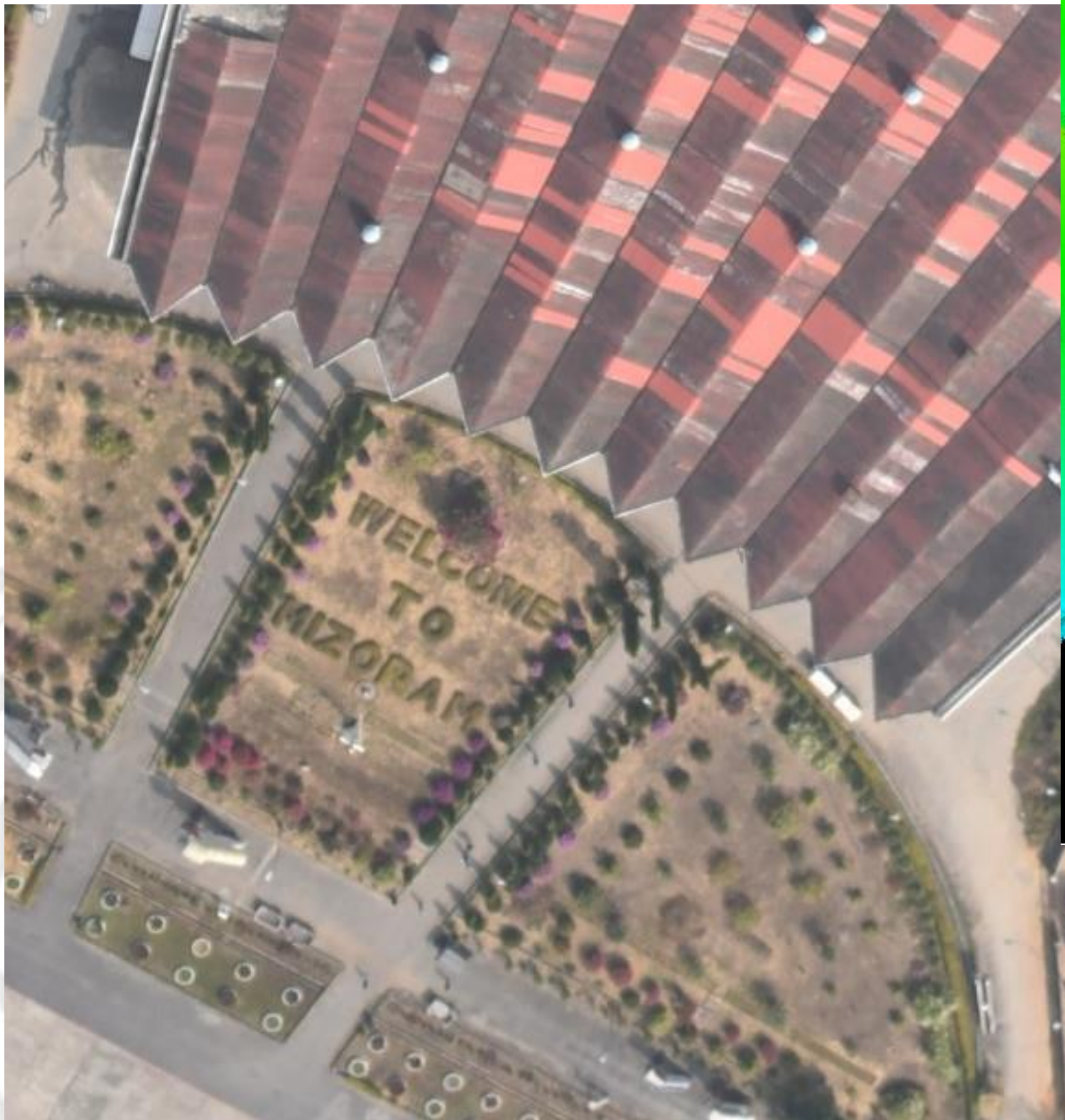
Project Length Surveyed	875 kms
Hydrological Survey	283 rivers/streams
Master GCP Points	81 Nos
Secondary GCP Points	233 Nos
LiDAR Target Points	103 Nos
Levelling survey	1200 Kms (DT)
No of Features mapped	4,31,908 Nos
Elevation accuracy achieved	4 cm (9 cm) (RFP specified accuracy is 10 cm)
Positional accuracy achieved	9 cm (11 cm) (RFP specified accuracy is 15 cm)
Topographical map Scale delivered	1:1000 (RFP specified scale is 1:2500)
Orthophoto GSD	10 cm
DEM,DSM and Contour Interval delivered	50 cm

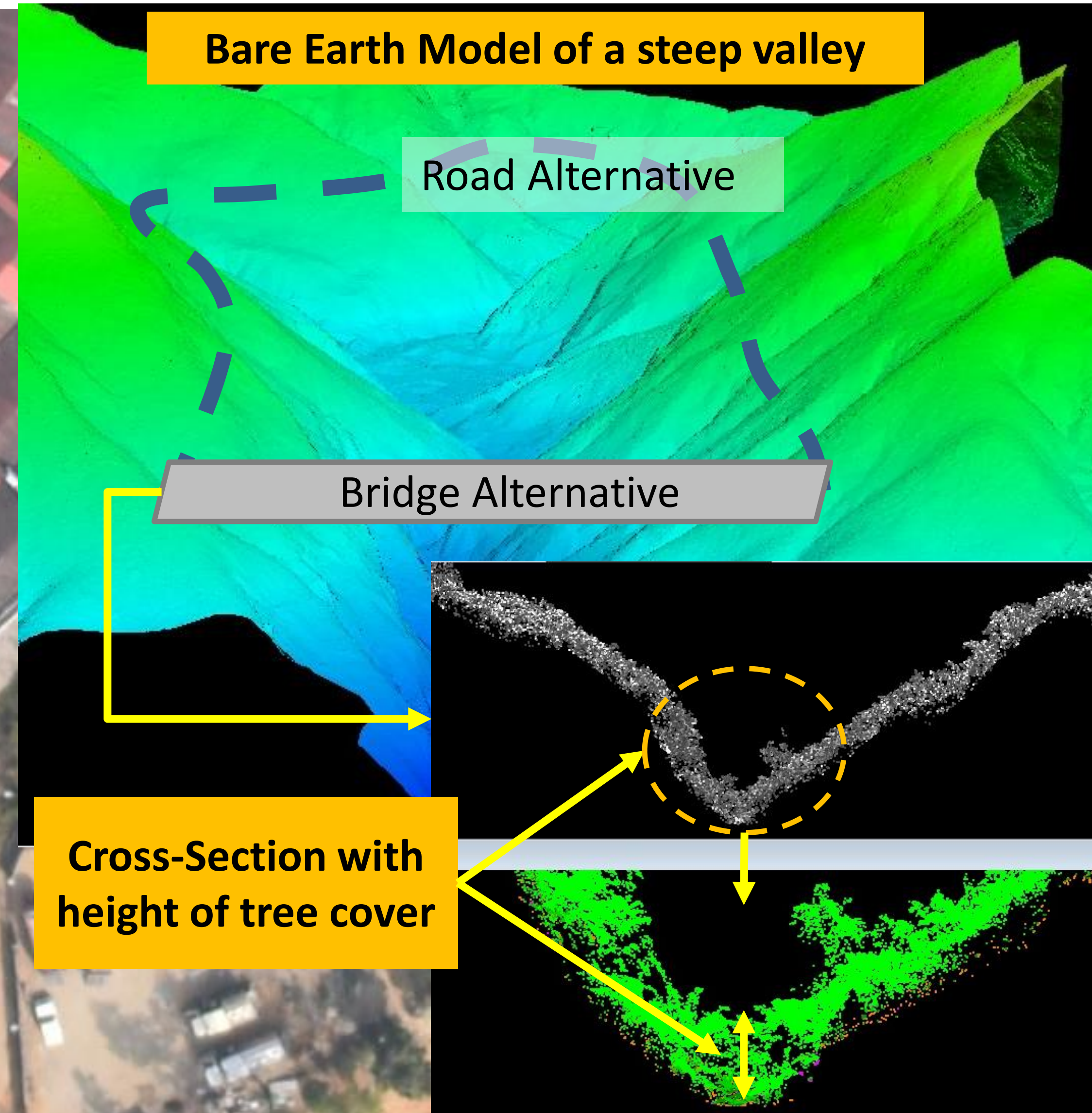
Aerial Survey Statistics

Aircraft type	Eurocopter AS 350 B3
Flying altitude	1300 ft / 400 m
Aircraft Speed	80 knots
Flying duration	03/Mar/17 to 18/Mar/17
Flying length	1000 km
Flying Hours	40 hrs
Resultant Point density	15 PPSM (RFP specified is 10 PPSM)
Raw data collected	4 TB
No of Images captured	11500 Nos
No of Base-stations	13 Nos
Airport/heliport locations	Ahmedabad Vadodhara Surat Valsad Mumbai

Case Study: Himalayan Greenfield Roads, Mizoram: Geokno completed Aerial LiDAR Survey for thickly forested & remote highway corridor

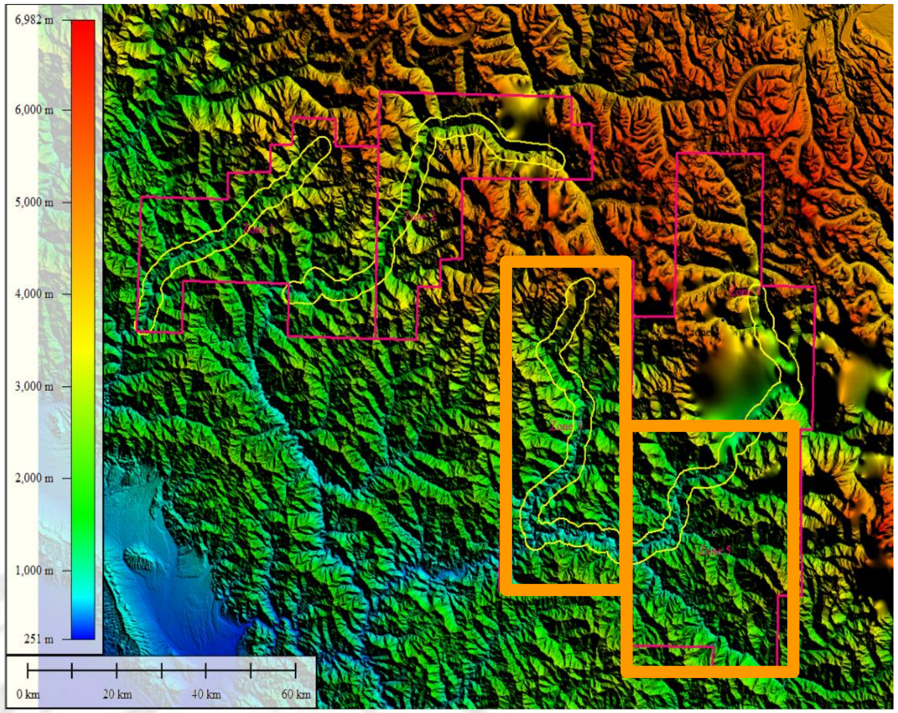
Geokno
Leaders in LiDAR





Case Study: Disaster/Floods – Geokno completed flood disaster management project in Himalayas, Uttrakhand

Geokno
Leaders in LiDAR



First Airborne LiDAR Project for Major Disaster Assessment in India executed by Geokno for Survey of India

- Terrain: The project area is characterized by its remote location, very high altitude, extreme terrain variations, frequent high winds and variable ground cover (snow, rock, vegetation)
- Summary: The project specifications call for a exceptionally high data standards, across an exceptionally difficult site

Specification	Value
LiDAR Data	▪ 8 points per sq m except on slopes
Orthophotos	▪ 20 cm
Accuracy	▪ Vertical accuracy better than 20 cm
Contours	▪ 50 cm Contour Interval
DEM	▪ 50 cm grid DEM (Bare Earth)
Topographic Map	▪ 1:10,000 scale with 50 cm contour interval in digital form
DTDB & DCDB	▪ As per feature based Data Model of SoI

Case Study: Irrigation, Telangana – Geokno helped Govt. of Telangana ink pact on Godavari water projects with Maharashtra

Geokno
Leaders in LiDAR

Geokno team presenting project outcomes to Hon'ble Chief Minister along with WAPCOS

THE HINDU

Telangana, Maharashtra CMs ink pact on Godavari water projects

Mr. Chandrasekhar Rao explained how they had been working for over an year including conducting a LiDAR (Light Detection and Ranging) survey for identifying locations to tap water of Godavari and its tributaries to minimise submergence in Maharashtra so that disputes could be avoided.

THE NEW INDIAN EXPRESS

Hope Springs as Telangana, Maharashtra Set to Script Water-sharing Treaty

"The actual negotiation process for Medigadda and Tummadi Hatti barrages started three months back. After TS government conducted Lidar survey, the Maharashtra officials too conducted a ground survey. They were convinced and accepted our viewpoint," top sources in irrigation department told Express.

Case Study: River-Interlinking, Andhra Pradesh – Geokno completed River Interlinking project using Aerial LiDAR

Geokno
Leaders in LiDAR

Geokno CEO presenting benefits of LiDAR technology to Hon'ble Chief Minister

THE HINDU

VIJAYAWADA

'Linking Godavari and Penna high on agenda'

With the linking of the three rivers - Krishna, Godavari, and Penna, Mr. Naidu would create a new history.

Irrigation Minister Devineni Umamaheswara Rao on Tuesday said that Chief Minister N. Chandrababu Naidu's main aim was to complete the linking of the Godavari-Penna rivers as early as possible.

Speaking to the media here, the Minister said that with the linking of the three rivers - Krishna, Godavari, and Penna, Mr. Naidu would create a new history.

Project Title	Aerial LiDAR survey for linking River Godavari & River Penna
Project Details	▪ Awarded 1,800 sq km ▪ Complete project to be referenced to Survey of India benchmarks ▪ LiDAR scanner: Riegl LMSQ780 ▪ Camera: Phase One 100 MP
Data specifications	▪ LiDAR: 10 points per sq m ▪ Images: 10 cm GSD Orthophotos
Significant project achievements	▪ 3rd Indian state after Telangana & Rajasthan to use LiDAR technology for River Basin projects ▪ To use completely Indian team and Geokno owned equipment
Project Learning	▪ Success of our projects in Telangana & Rajasthan shows the strength of LiDAR technology and Geokno's delivery for Aerial LiDAR projects in India

Case Study: River-Interlinking, Rajasthan – Geokno completed the Eastern Rajasthan Canal Project using Aerial LiDAR

दौसा में चल रहा नदियों को जोड़ने का सर्वे

वेबकॉस कम्पनी कर रही हेलिकॉप्टर से सर्वे

पत्रिका न्यूज़ नेटवर्क
rajasthanpatrika.com

दौसा. राज्य सरकार राजस्थान की नदियों को जोड़ने, नदियों में पानी की मात्रा, गुणवत्ता व उपयोगिता को लेकर इन दिनों अनुबंधित कम्पनी वेबकॉस की ओर से सर्वे कार्य करा रही है। इन दिनों सर्वे के आधार पर दौसा जिले की बाणगंगा, गंभीरी, बनास, मोरेल, ढूण्ढ सहित अन्य नदियों को परस्पर जोड़ने को लेकर हेलिकॉप्टर से सर्वे कार्य चल रहा है। सर्वे टीम में सिंचाई विभाग के कार्यकारी अभियंता राकेश गुप्ता सहित तकनीकी विशेषज्ञ डीपीआर रिपोर्ट बनाकर सरकार को पेश करेंगे। कार्यकारी अभियंता गुप्ता ने बताया कि नदियों को जोड़ने, उनमें पानी की मात्रा, गुणवत्ता कैसी है। पानी पेयजल के योग्य कितना है, सिंचाई के लिए कितना व कहां उपयोग किया जा सकता है।नदियों के जल संतुलन को लेकर रिपोर्ट बनाकर सरकार को पेश किया जाएगा। दौसा जिले में अभी दो दिन और सर्वे किया जाएगा।

दौसा सर्किट हाउस के समीप सर्वे के लिए आया हेलिकॉप्टर।

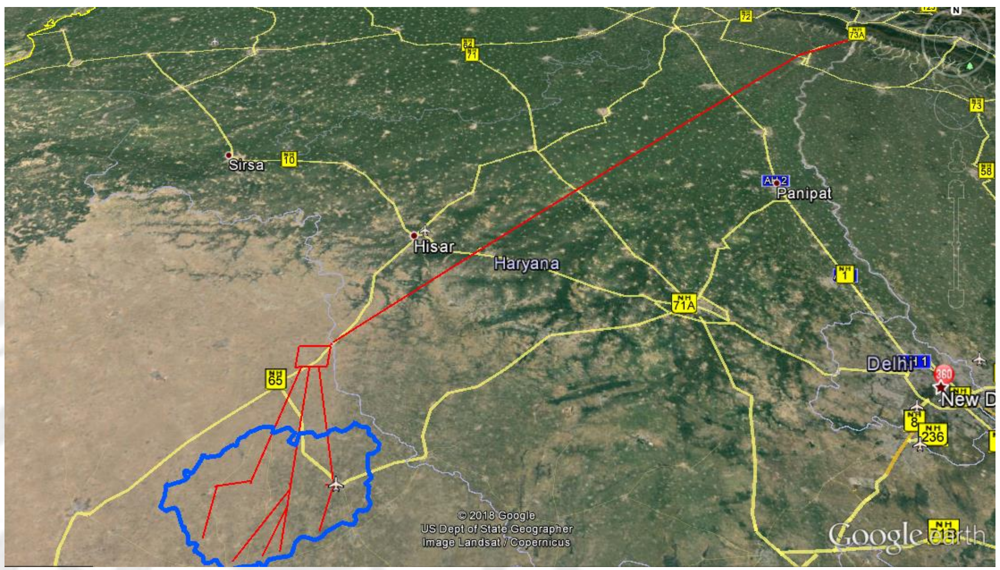
तकनीकी सर्वे एक्सपर्ट कम्पनी कर रही काम

वेबकॉस ने देश की एकमात्र तकनीकी सर्वे एक्सपर्ट कम्पनी जियोनो को यह काम सौंप रखा है। जियोनो के पास सर्वे की विशेषमशीन हेलिकॉप्टर के आगे के हिस्से में लगी है, जो नदियों से जुड़ी तमाम तकनीकी जानकारी जुटा रही है।

Project Title	Aerial LiDAR survey for Eastern Rajasthan Canal Project to link rivers Chambal, Parbati & Kalisindh
Project Details	▪ Initially awarded 850 sq km ▪ Phase I of the project got extended to 2,200 sq km ▪ Further project extended by another 700 sq km for a **total of 2,900 sq km** ▪ Complete project referenced to Survey of India benchmarks ▪ LiDAR scanner: Riegl LMSQ780 ▪ Camera: Phase One 100 MP
Data specifications	▪ LiDAR: 10 points per sq m ▪ Images: 10 cm GSD Orthophotos
Significant project achievements	▪ Used completely Indian team and Geokno owned equipment ▪ Phase 1 of project data captured within one month of MoD clearances ▪ First major river interlinking project completed using LiDAR technology
Current project status	▪ Security vetting scheduled for Phase I ▪ Phase II data capture to start soon
Project Learning	▪ Completely Indian resourced solutions can achieve faster project completions

Aerial LiDAR Survey for Yamuna Water Transfer
from Tejawala, Haryana to Jhunjhunu, Rajasthan

Leaders in LiDAR



Project Title	Aerial LiDAR Survey for Water Link between Tejawala and Jhunjhunu
Project Details	▪ Project Area – 1300 sq km ▪ Haryana and Rajasthan ▪ LiDAR scanner: Riegl LMSQ780 ▪ Camera: Phase One 100 MP
Data specifications	▪ LiDAR: 10 points per sq m ▪ Images: 10 cm GSD Orthophotos
Client	▪ PDCORE, Rajasthan ▪ Water Resource Department, Rajasthan
Status	▪ Permission obtained – in 1 month ▪ Data collection completed – in 1 week ▪ Data processing – Started ▪ Delivery – 15 days from now ▪ Complete project duration – 2 months

Aerial LiDAR Survey for Kalisindh and Parwati Micro Lift Irrigation Scheme - Indira Sagar Project

Project Title	Aerial LiDAR Survey for Kalisindh and Parwati Micro Lift Irrigation Scheme - Indira Sagar Project
Project Details	▪ Study Area – 9040 sq km ▪ Madhya Pradesh, ▪ LiDAR scanner: Riegl LMSQ780 ▪ Camera: Phase One 100 MP
Data specifications	▪ LiDAR: 10 points per sq m ▪ Images: 10 cm GSD Orthophotos
Client	▪ L&T Construction ▪ Narmada Valley Development Authority
Status	▪ MOD Inspection Completed, Aerial Flying Started

Case Study: Solar Rooftop Mapping – Geokno completed India's first project for Solar Rooftop Mapping potential project

Leaders in LiDAR

- LiDAR is the used world-wide for mapping city management and infrastructure projects including solar rooftop potential
- Geokno has been awarded the India's first project for Solar rooftop potential mapping for Bengaluru

Rooftop solar could provide almost 40 percent of US electricity

This is huge.

To come up with the estimate, scientists from the National Renewable Energy Laboratory (NREL) used light detection and ranging (LiDAR) data to calculate the suitability of rooftops for hosting solar panels – aka rooftop photovoltaic (PV) systems – in 128 cities across the US, then extrapolated from there.

Within the cities examined, the researchers found 83 percent of small buildings have a suitable location for installation of solar panels. But when they analysed each building's capacity to hold a PV system on their roof, only 26 percent passed the grade.

While only about a quarter of most small buildings' roofs could practically be used for solar panels, there are a whole lot of them across the US, which means this type of building could actually provide the greatest combined technical potential compared to other kinds of structures.

Deccan Chronicle

Bengaluru's first 3-D map to harness solar energy

DECCAN CHRONICLE. | B R SRIKANTH
Published Mar 7, 2018, 3:15 am IST Updated Mar 7, 2018, 3:15 am IST

Bengaluru: For the first time in the country, researchers deployed an advanced Light Detection and Ranging (LiDAR) system on a helicopter to draw up a 3D map of Bengaluru city, to assess the potential for harnessing solar energy over each building, and provide civic agencies the data for better planning of all amenities in the state capital.

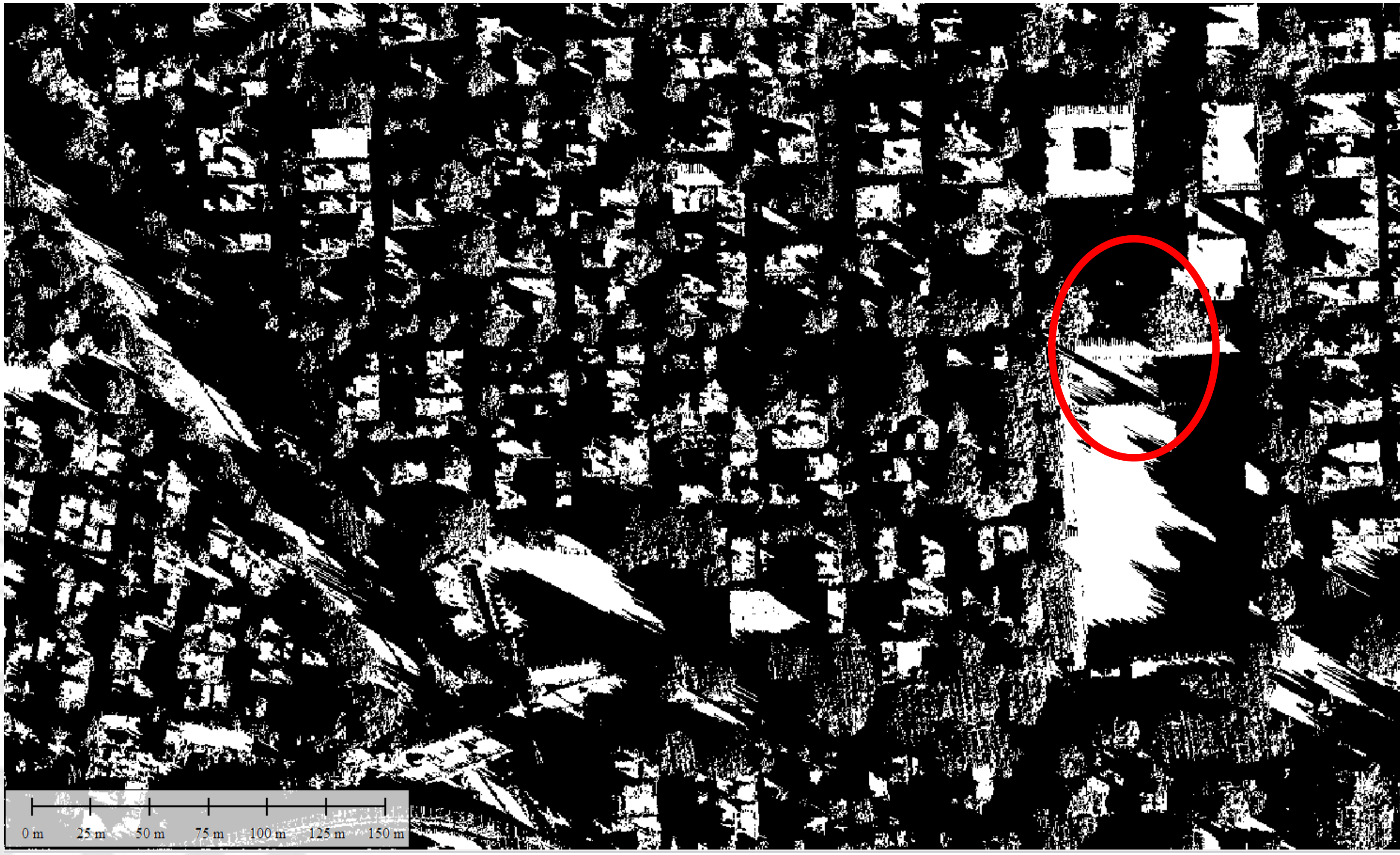
This high-resolution map of the city would help researchers estimate the shadow-free area atop each building, provide the details to owners and help them pick the best spot for installation of rooftop photovoltaic (RTPV) sets, and help BESCOM achieve the target of one Gega watt power from such sets in a couple of years. The aerial survey was carried out in collaboration with Geokno Pvt Ltd, and funded by MacArthur Foundation. CSTEP will be able to figure out all rooftops suitable for RTPV installations in BESCOM area.

A helicopter equipped with Light Detection and Ranging system.

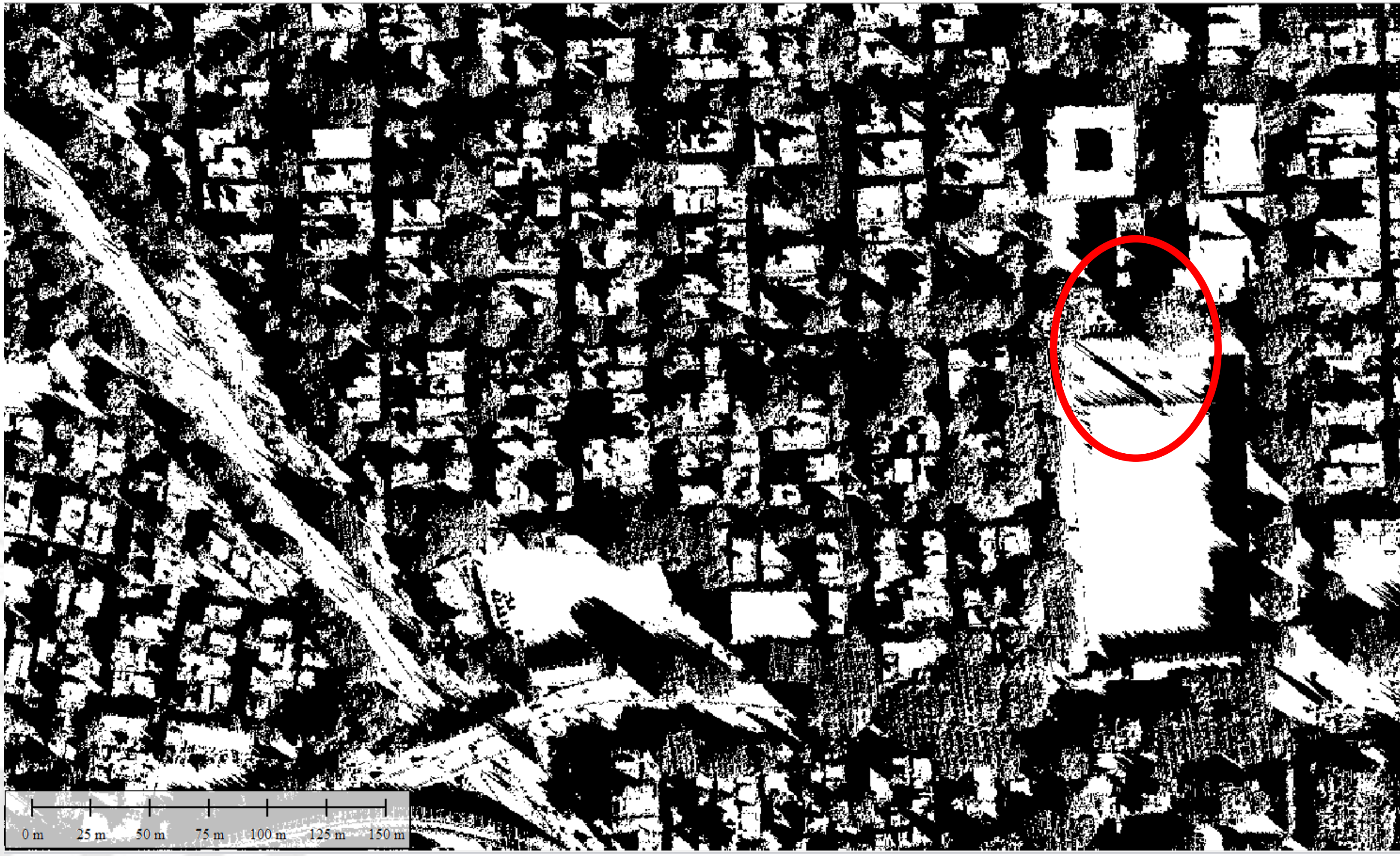
Source: http://www.sciencealert.com/rooftop-solar-could-provide-almost-40-percent-of-us-electricity ; https://www.deccanchronicle.com/nation/current-affairs/070318/bengalurus-first-3-d-map-to-harness-solar-energy.html

Ortho Photo

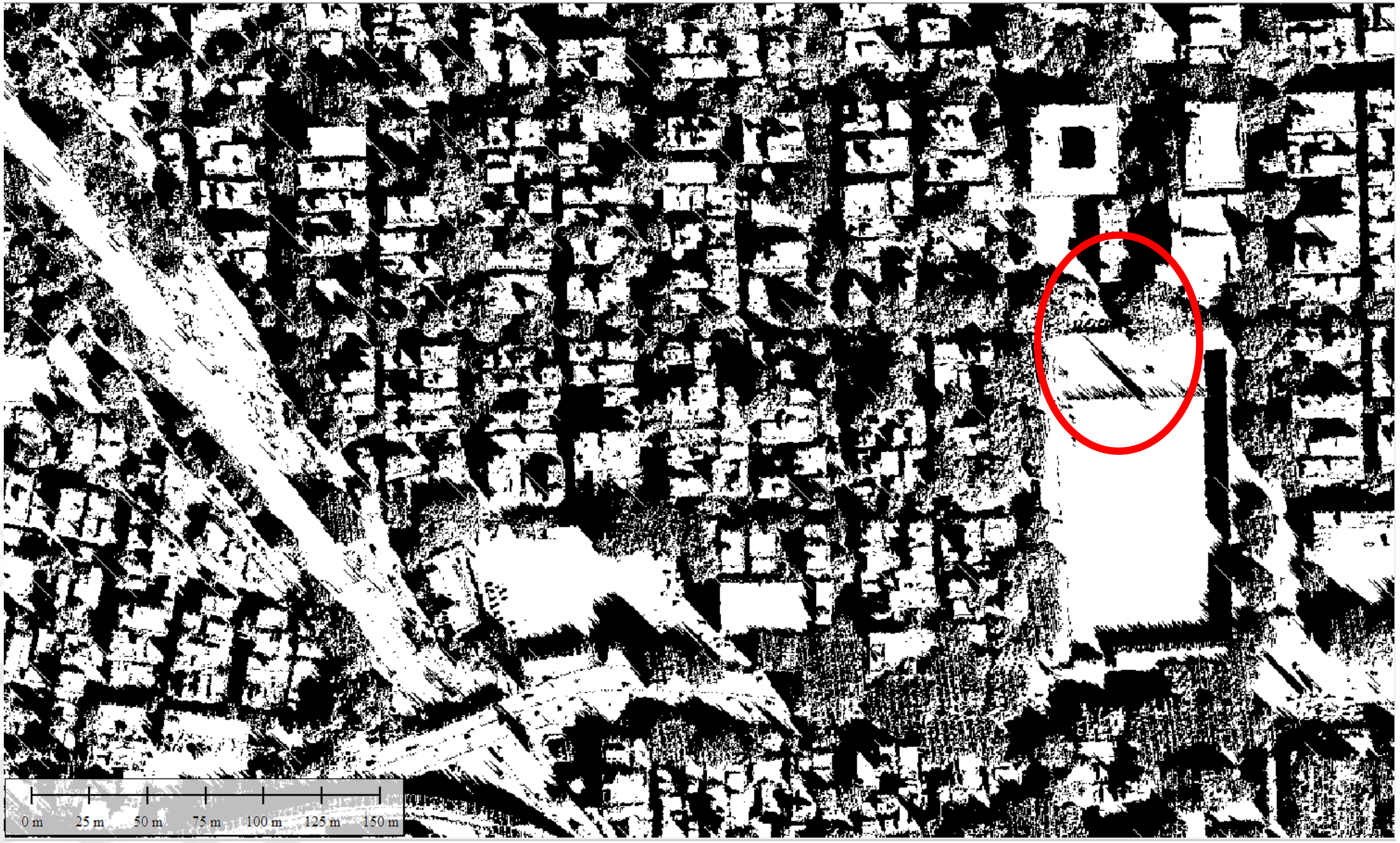
Shadow Map – 01/01/2018 – 08:00



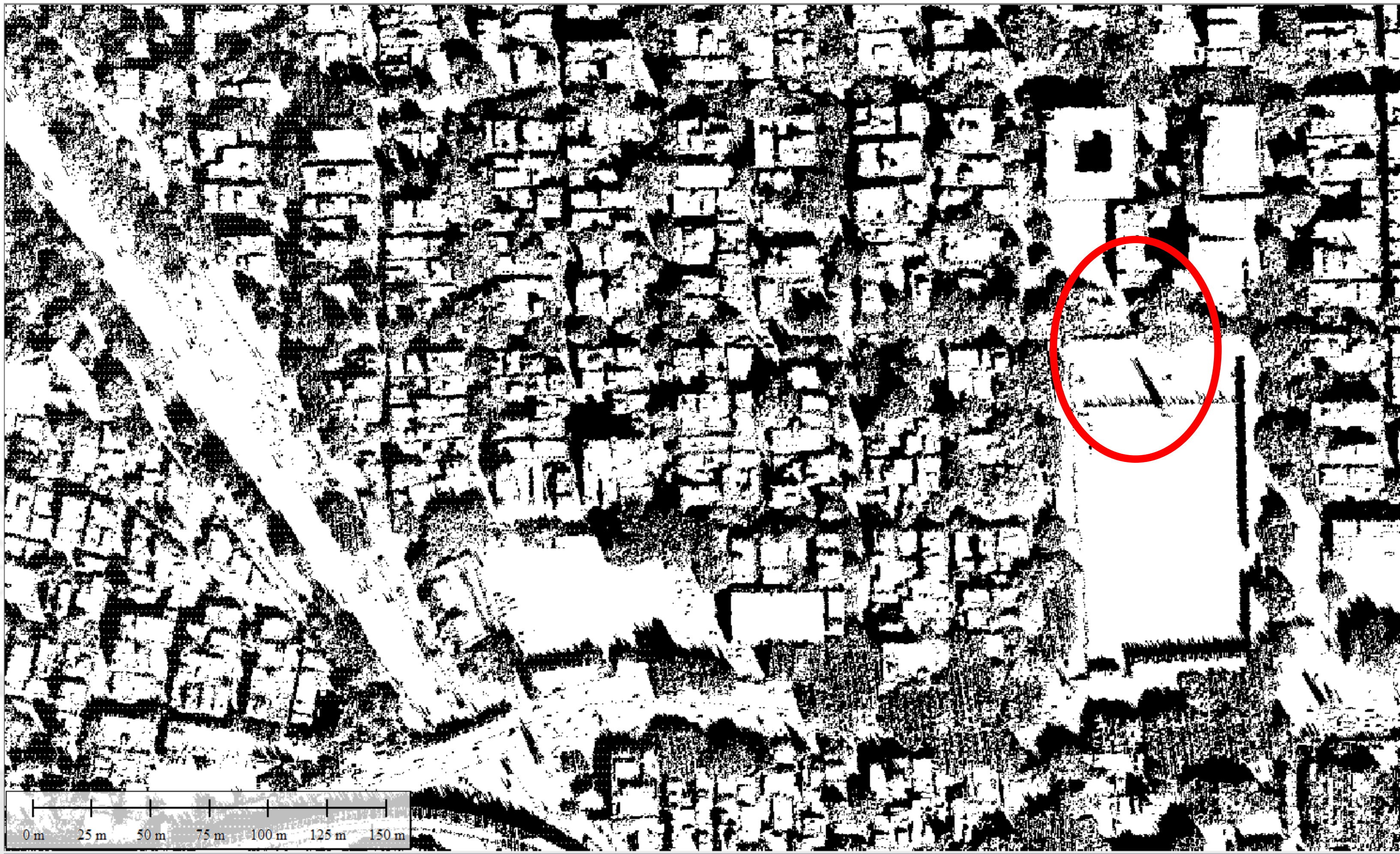
Shadow Map – 01/01/2018 – 09:00



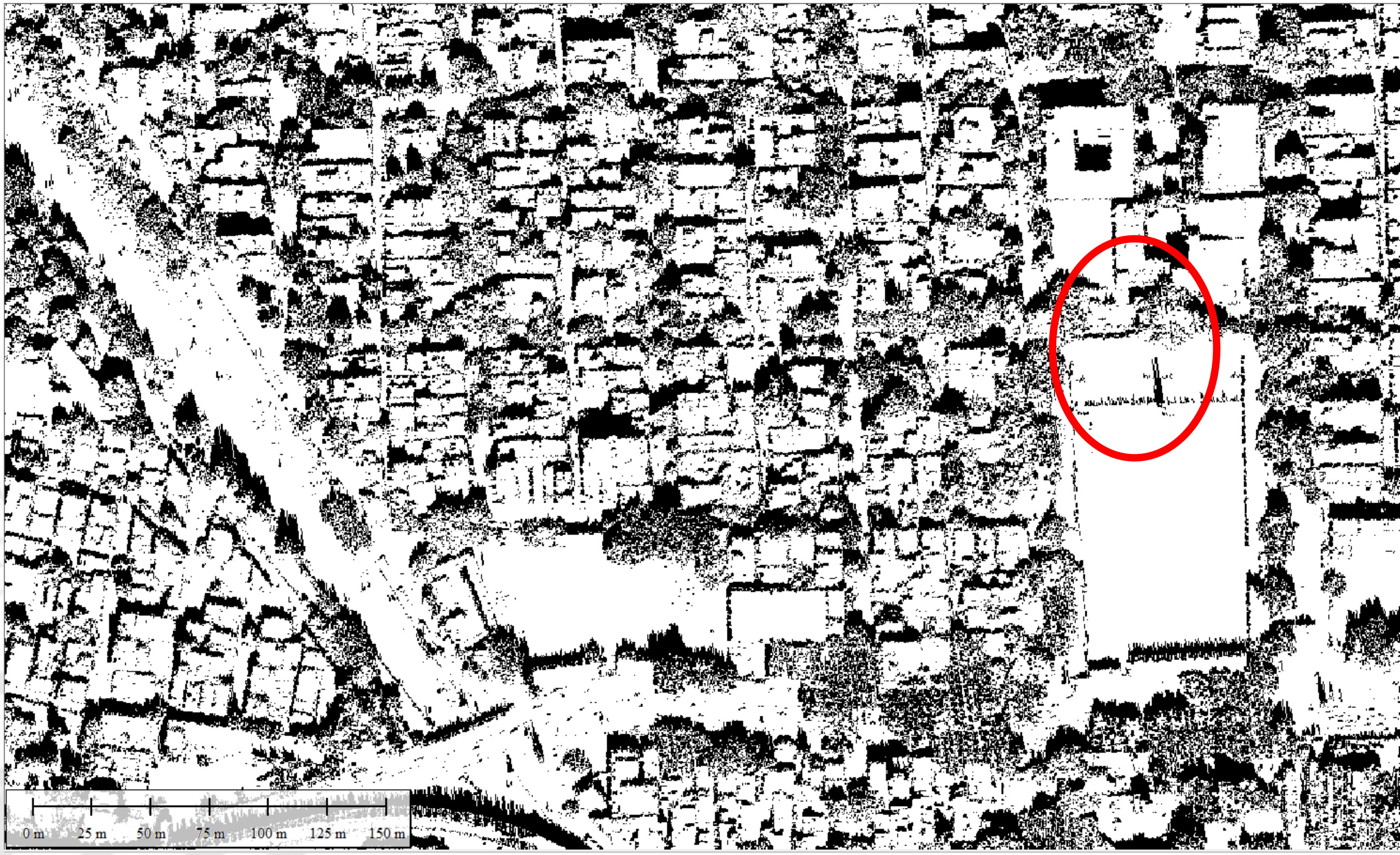
Shadow Map – 01/01/2018 – 10:00



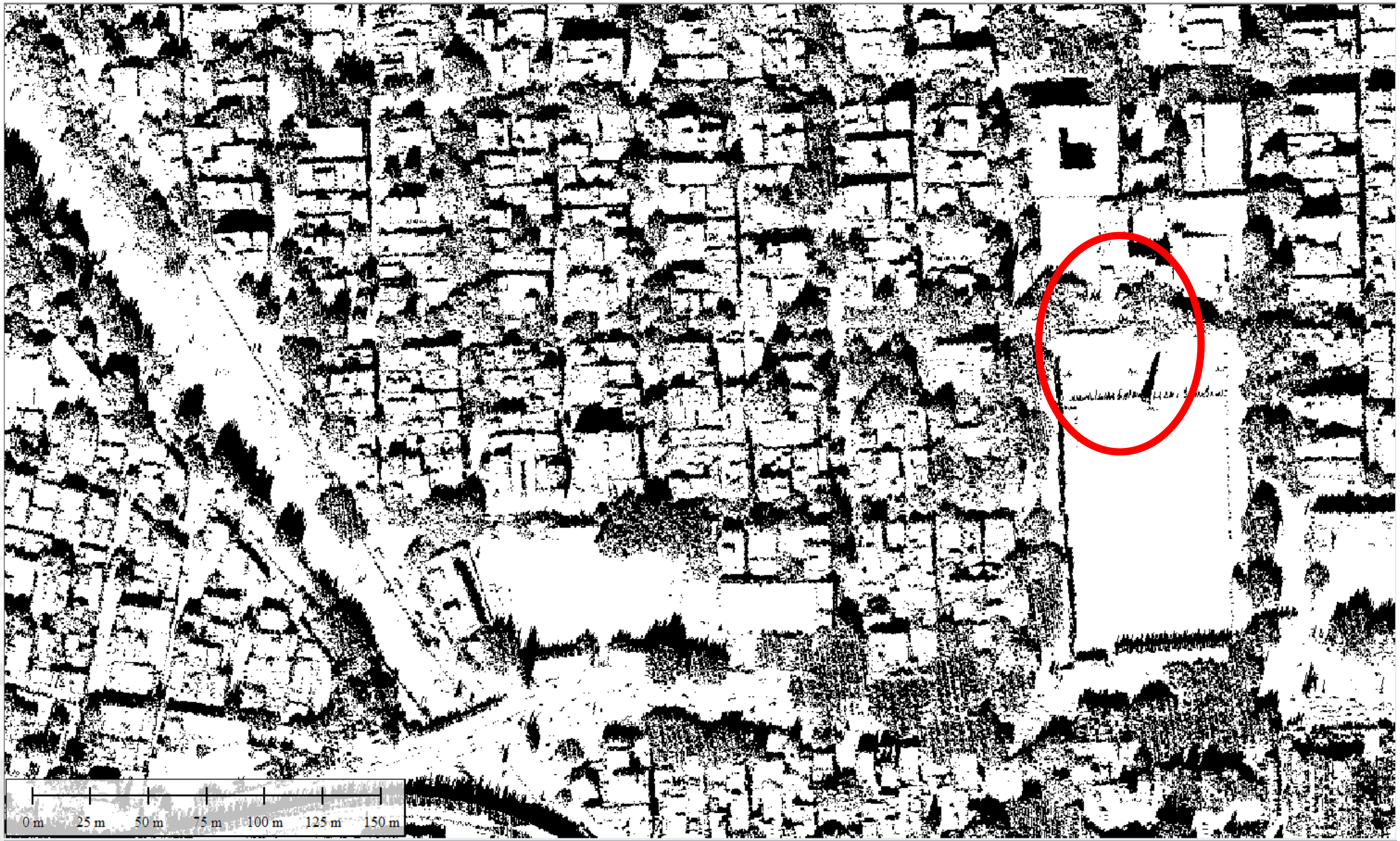
Shadow Map – 01/01/2018 – 11:00



Shadow Map – 01/01/2018 – 12:00



Shadow Map – 01/01/2018 – 13:00



Shadow Map – 01/01/2018 – 14:00

Shadow Map – 01/01/2018 – 15:00

Shadow Map – 01/01/2018 – 16:00

Leaders in LiDAR

Shadow Map – 01/01/2018 – 17:00

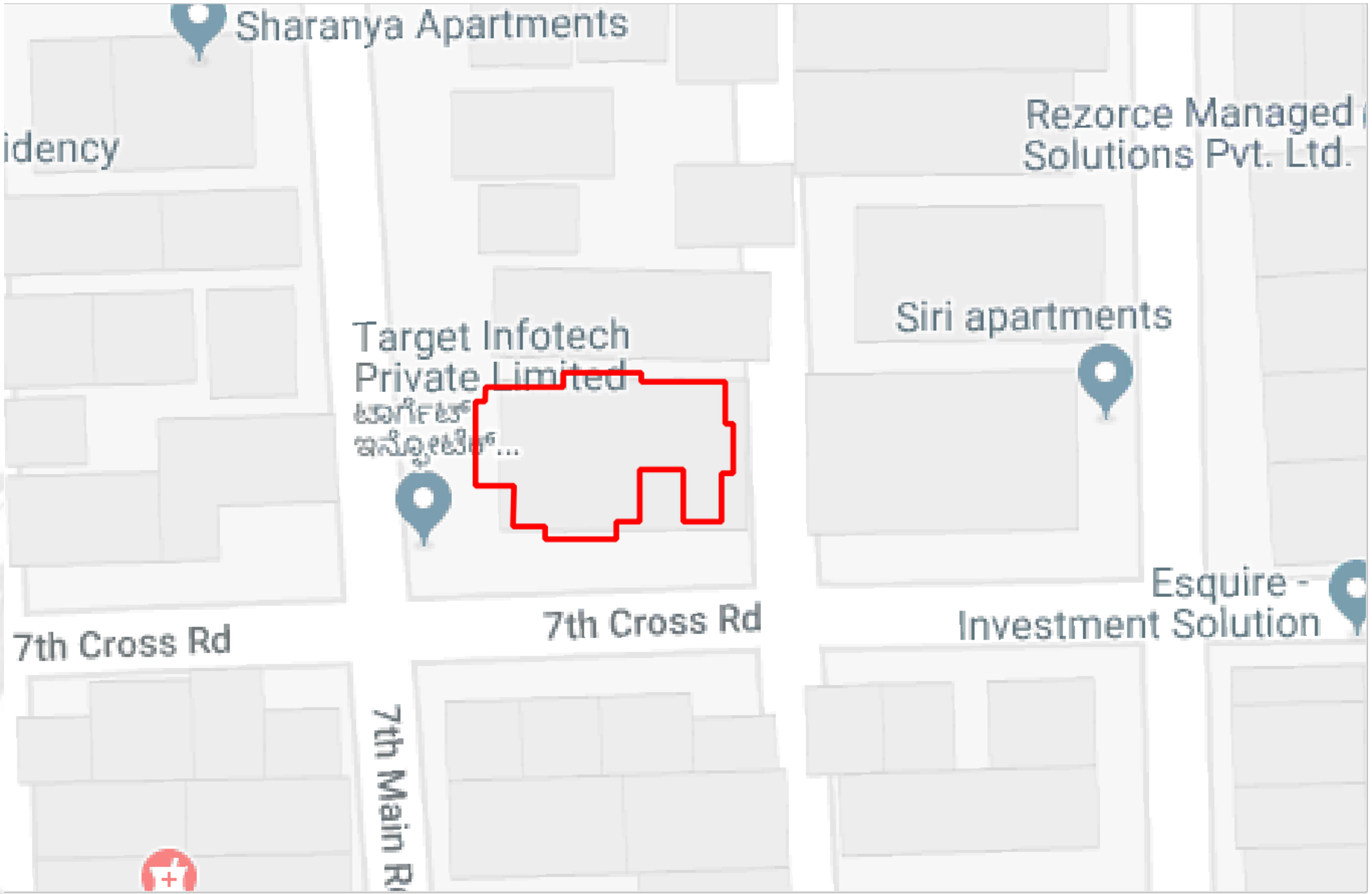
Leaders in LiDAR

Annual Global Horizontal Irradiance

Leaders in LiDAR

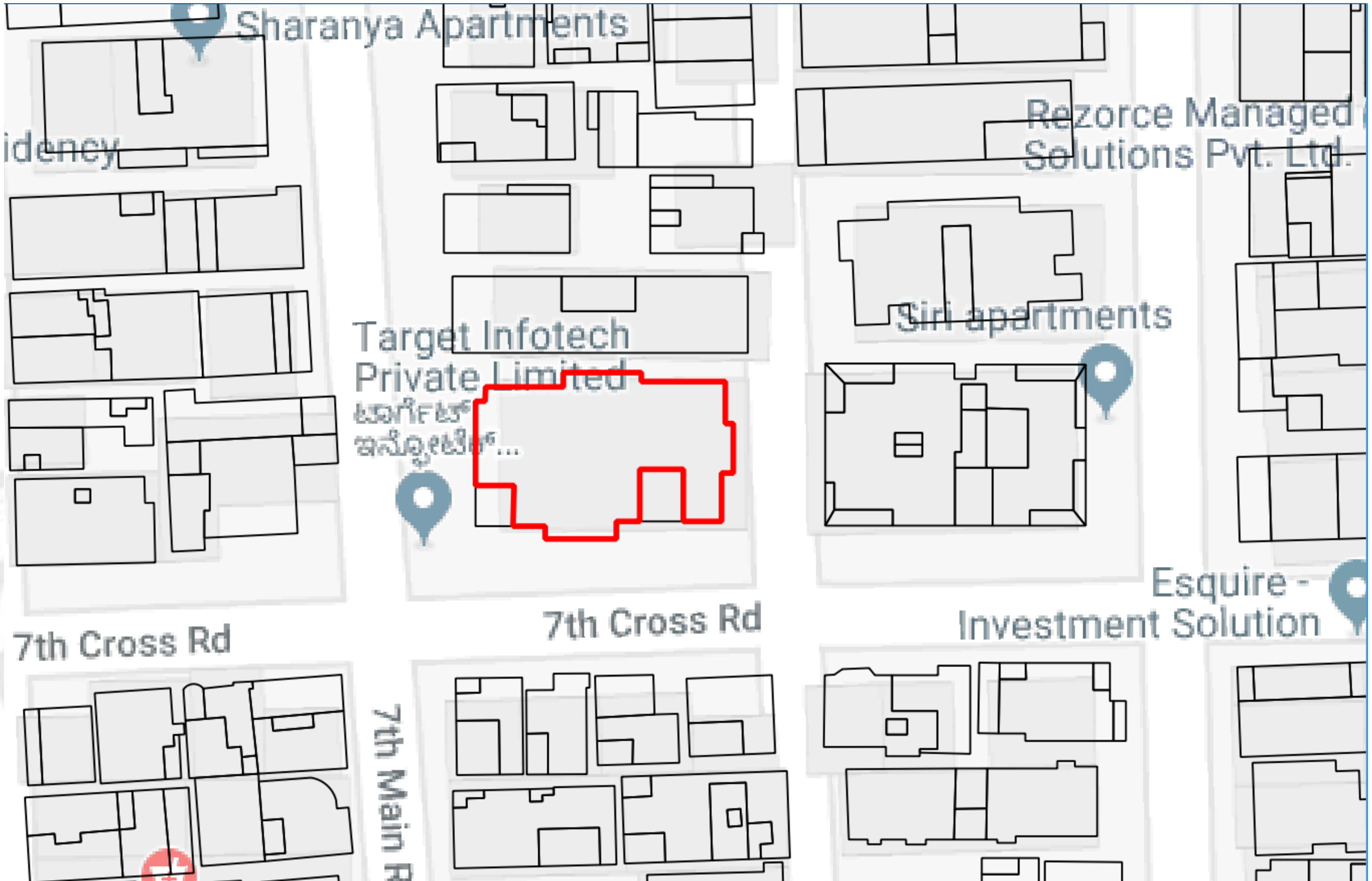
Rooftops on Map Server

Selected Building Map Server



Sr. No.	Attribute	Value
1	Perimeter (m)	94.572
2	Area (m^2)	324.964
3	Building Top Elevation (m)	929.773
4	Building Bottom Elevation (m)	916.984
5	Building Height (m)	12.789

Selected Building on Google Maps



Sr. No.	Attribute	Value
1	Perimeter (m)	94.572
2	Area (m^2)	324.964
3	Building Top Elevation (m)	929.773
4	Building Bottom Elevation (m)	916.984
5	Building Height (m)	12.789

Mean solar insolation 1448 kWhm-2

Selected Building on Ortho+Google Roads

Sr. No.	Attribute	Value
1	Perimeter (m)	94.572
2	Area (m^2)	324.964
3	Building Top Elevation (m)	929.773
4	Building Bottom Elevation (m)	916.984
5	Building Height (m)	12.789

Case Study

3D CHANDIGARH

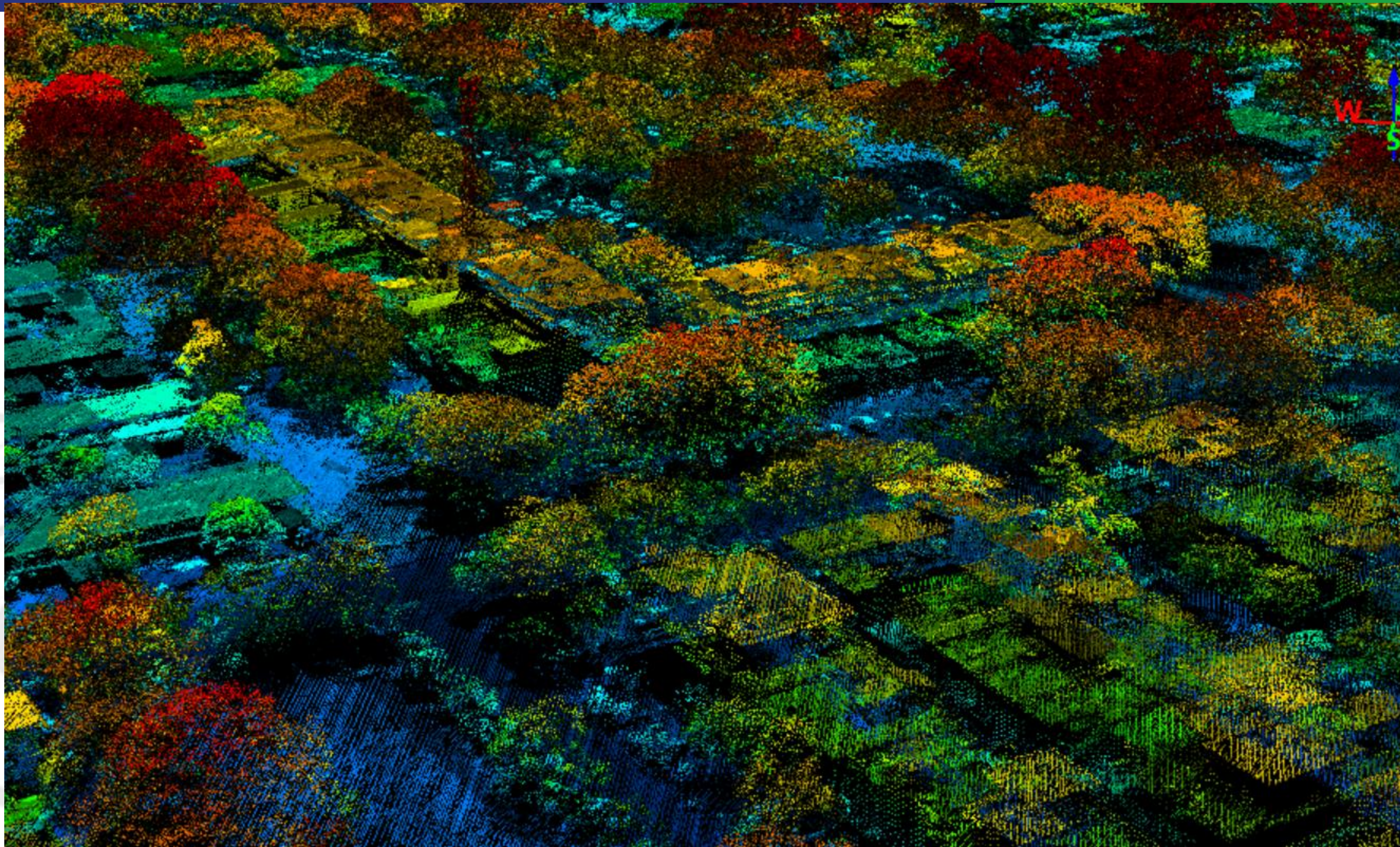
Case Study: Chandigarh City Mapping – Geokno is undertaking India's first project for SMART City Mapping using Mobile & Aerial LiDAR

UT to conduct aerial photography of city with LiDAR technology

Chandigarh: The UT Administration is all set to conduct the real-time aerial photography of the city using the Light Imaging Detection and Ranging (LiDAR) technology. The UT opened the tenders on Monday after which some of the interested companies gave presentations.

The presentations were witnessed by Adviser Parimal Rai, DC Ajit Balaji Joshi, Chief Engineer Mukesh Anand, Chief Architect Kapil Setia, MC Chief Engineer N P Sharma, MC Joint Commissioner Manoj Khatri and AETC Rakesh Popli at the UT Secretariat.

Mukesh Anand said, "We have witnessed presentations on LiDAR technology with which we will take real-time photography of the city buildings and other infrastructure through an airplane and surface vehicles. This will help in detecting the violations in the form of buildings, houses, roads and other such structures. It is a technology using light to detect the structures from air as well as from surface."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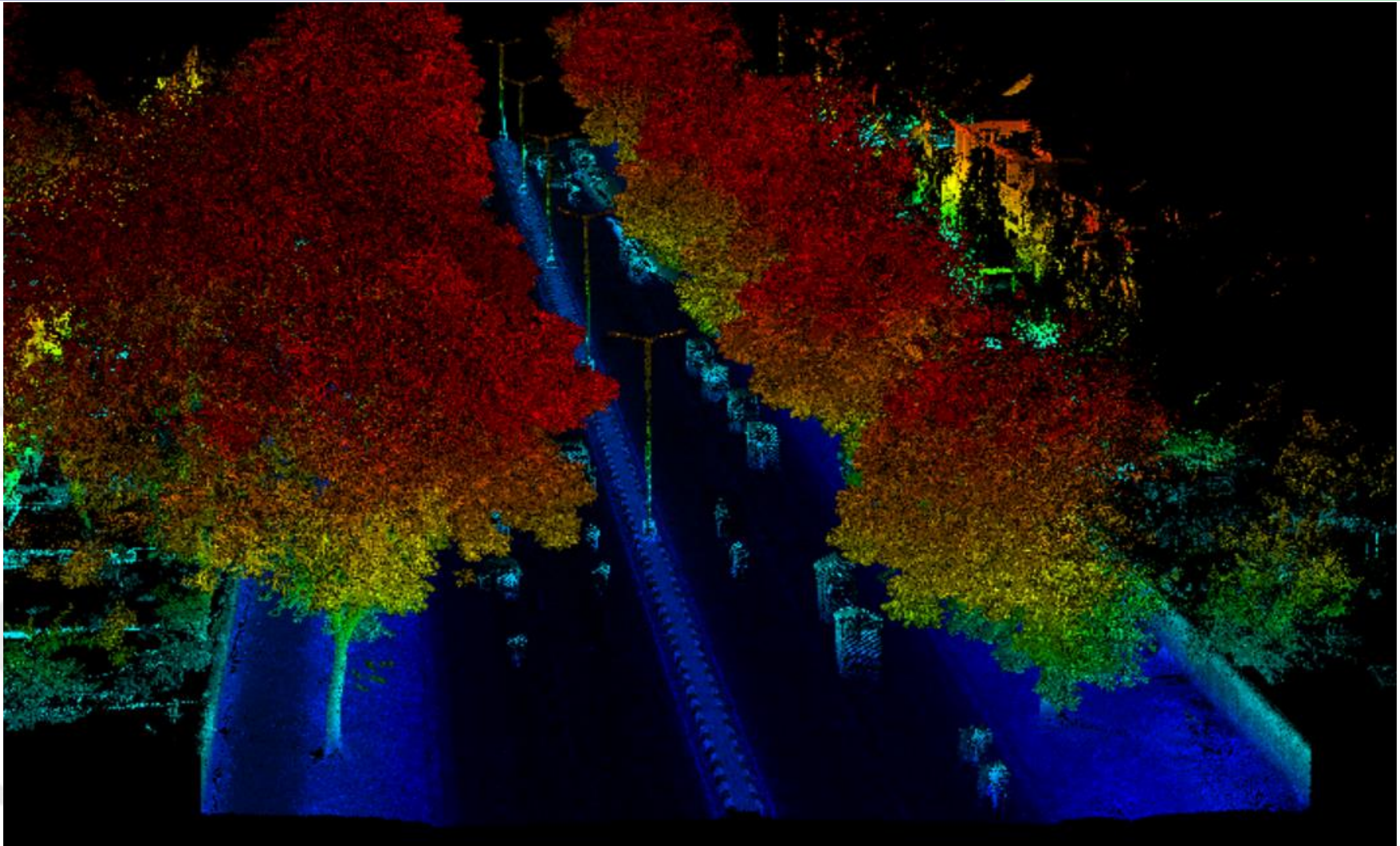
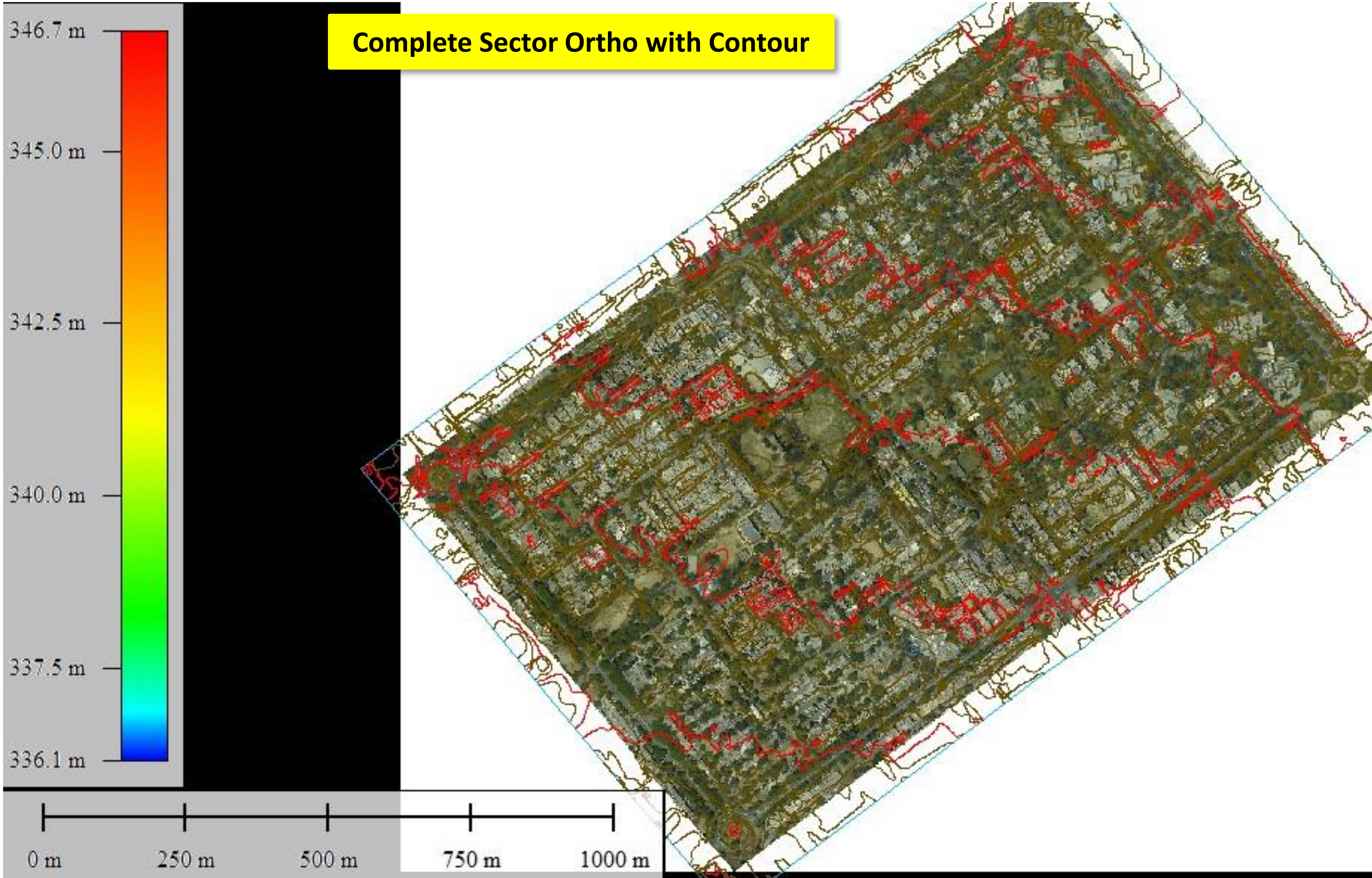
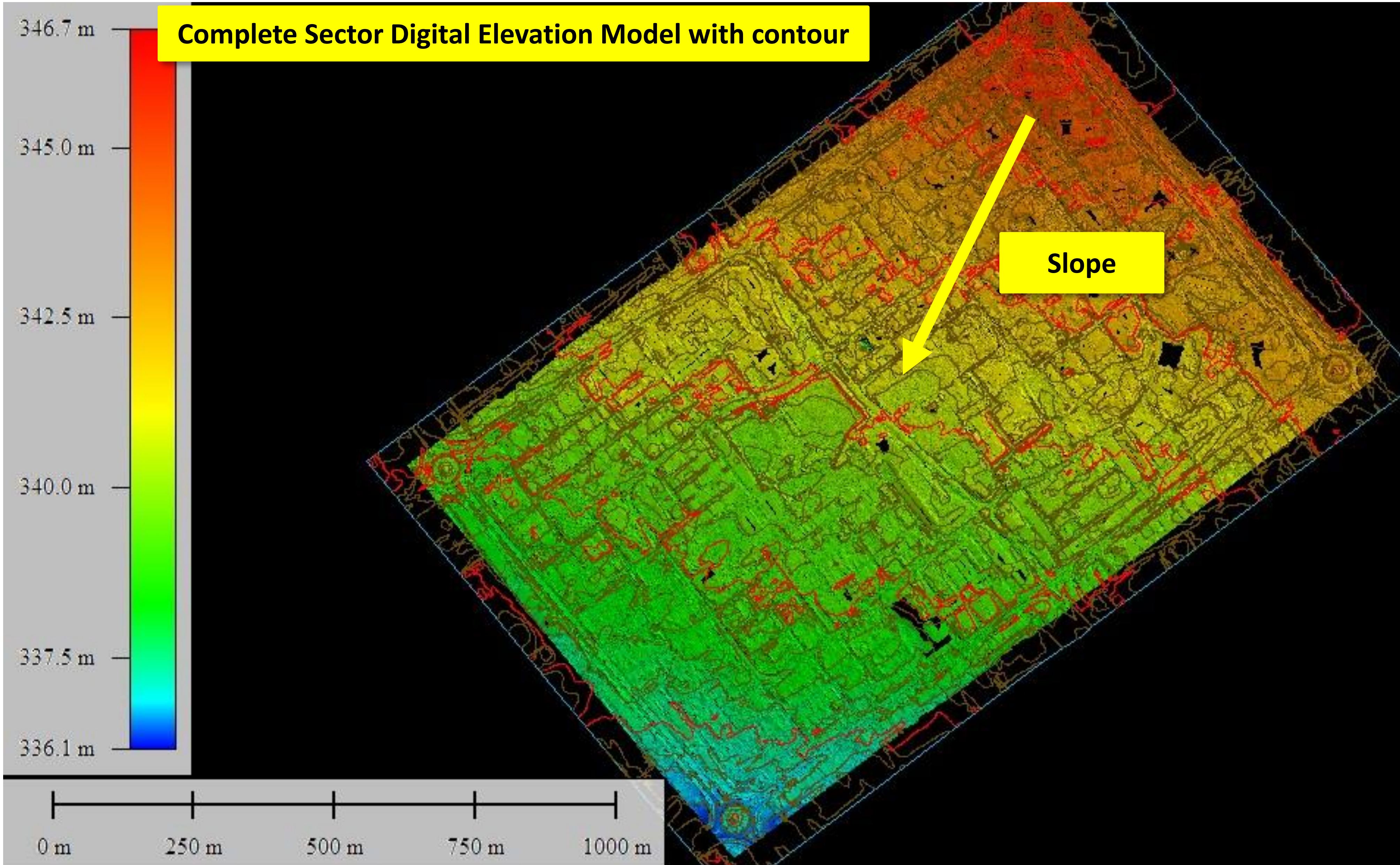
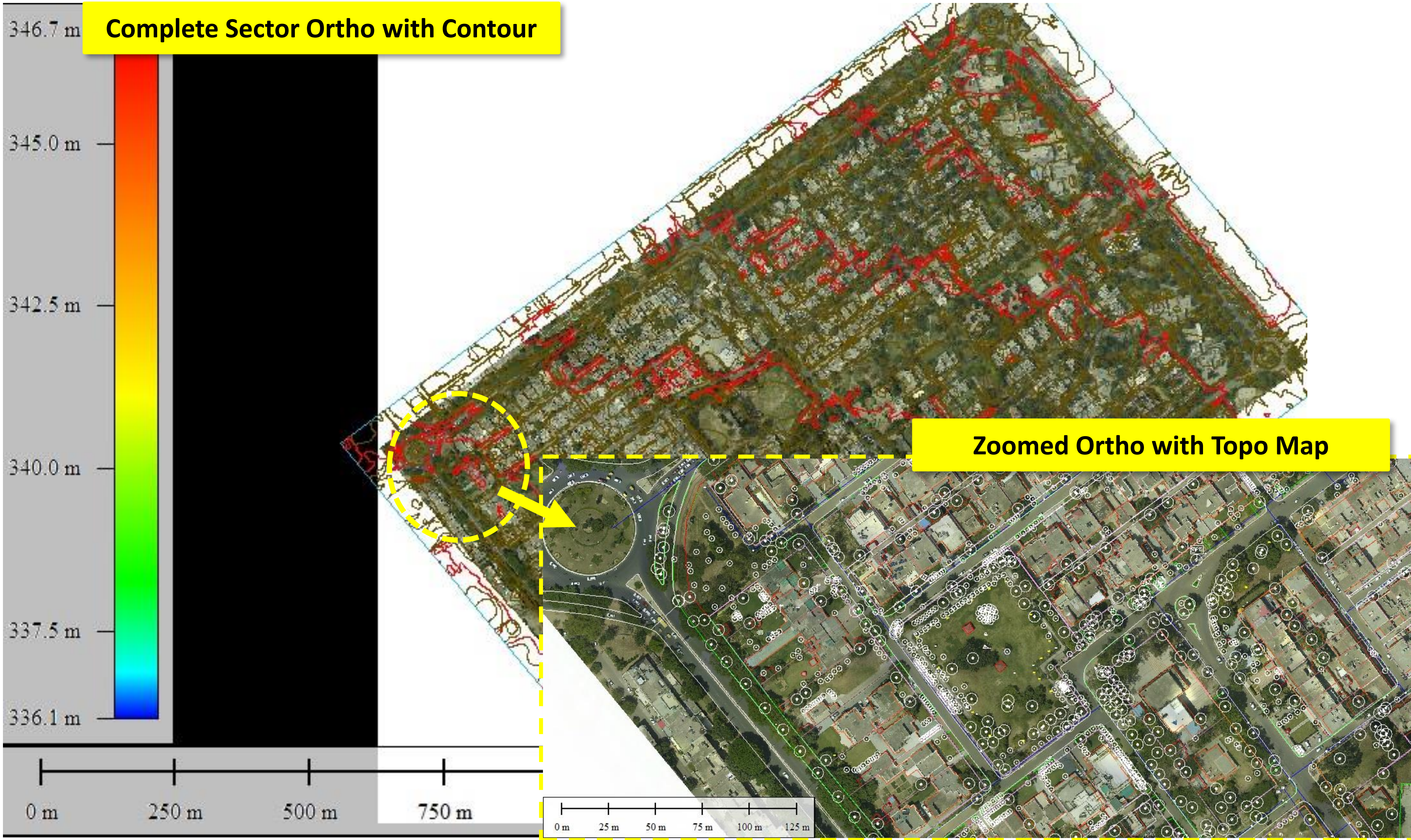




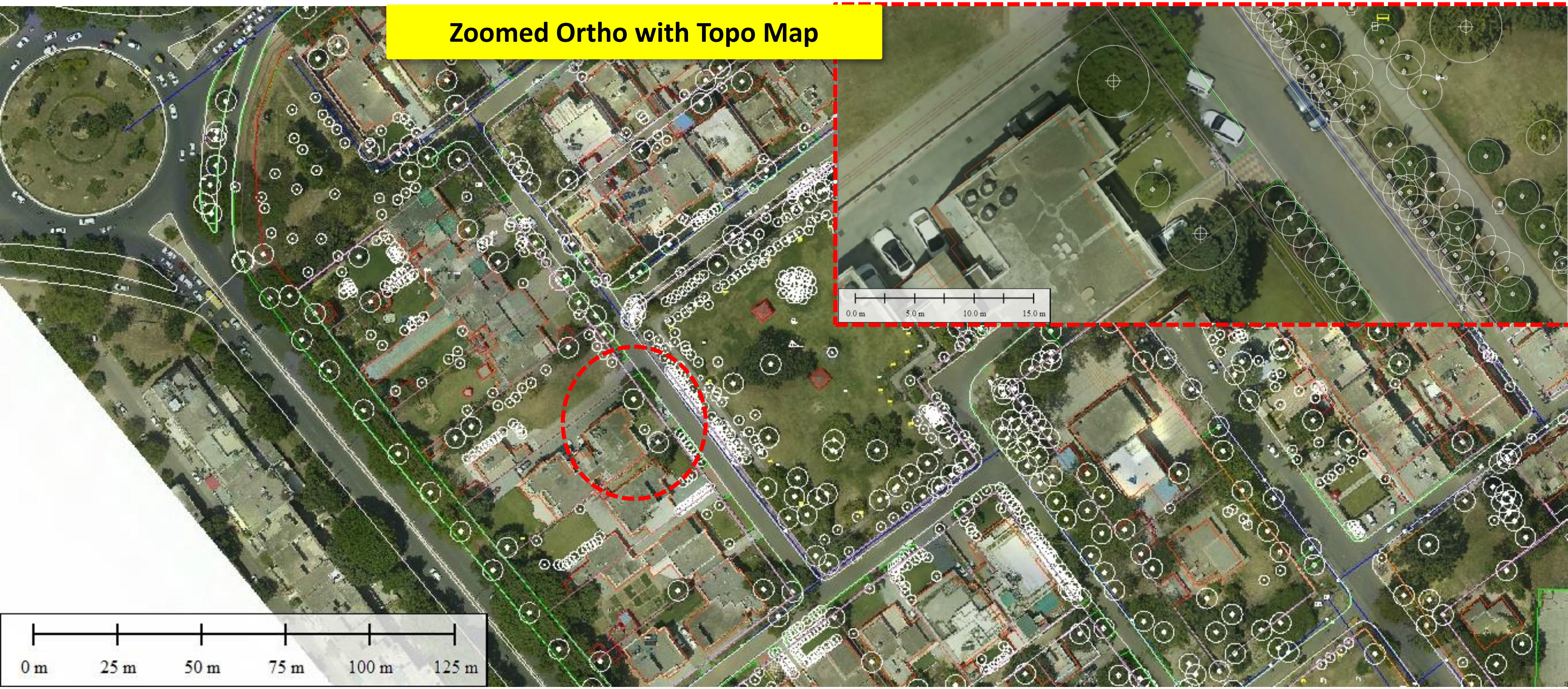
Complete Sector Ortho with Contour
346.7 m
345.0 m
342.5 m
340.0 m
337.5 m
336.1 m
0 m
250 m
500 m
750 m
1000 m

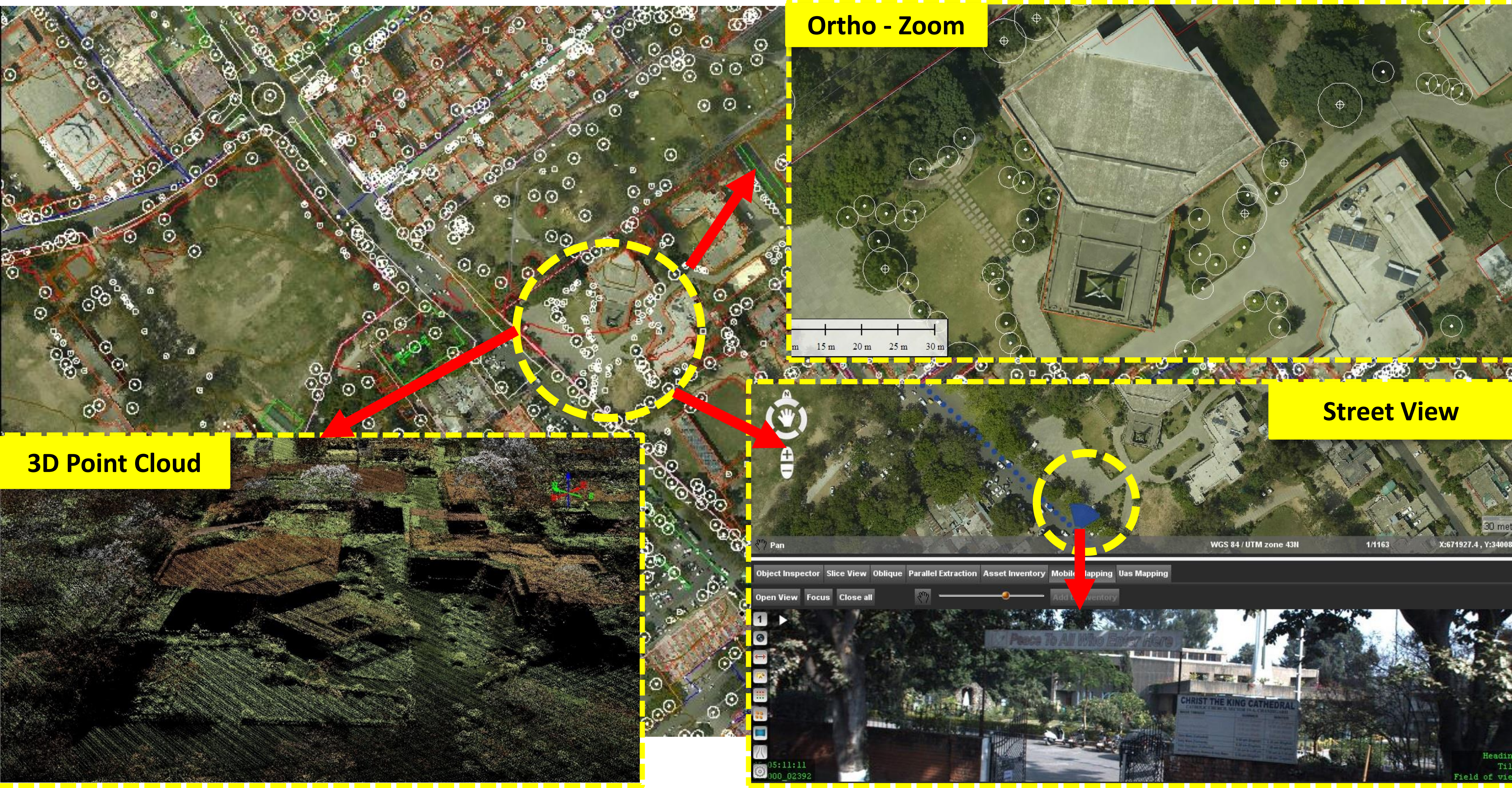


Complete Sector Digital Elevation Model with contour
Slope
346.7 m
345.0 m
342.5 m
340.0 m
337.5 m
336.1 m
0 m
250 m
500 m
750 m
1000 m

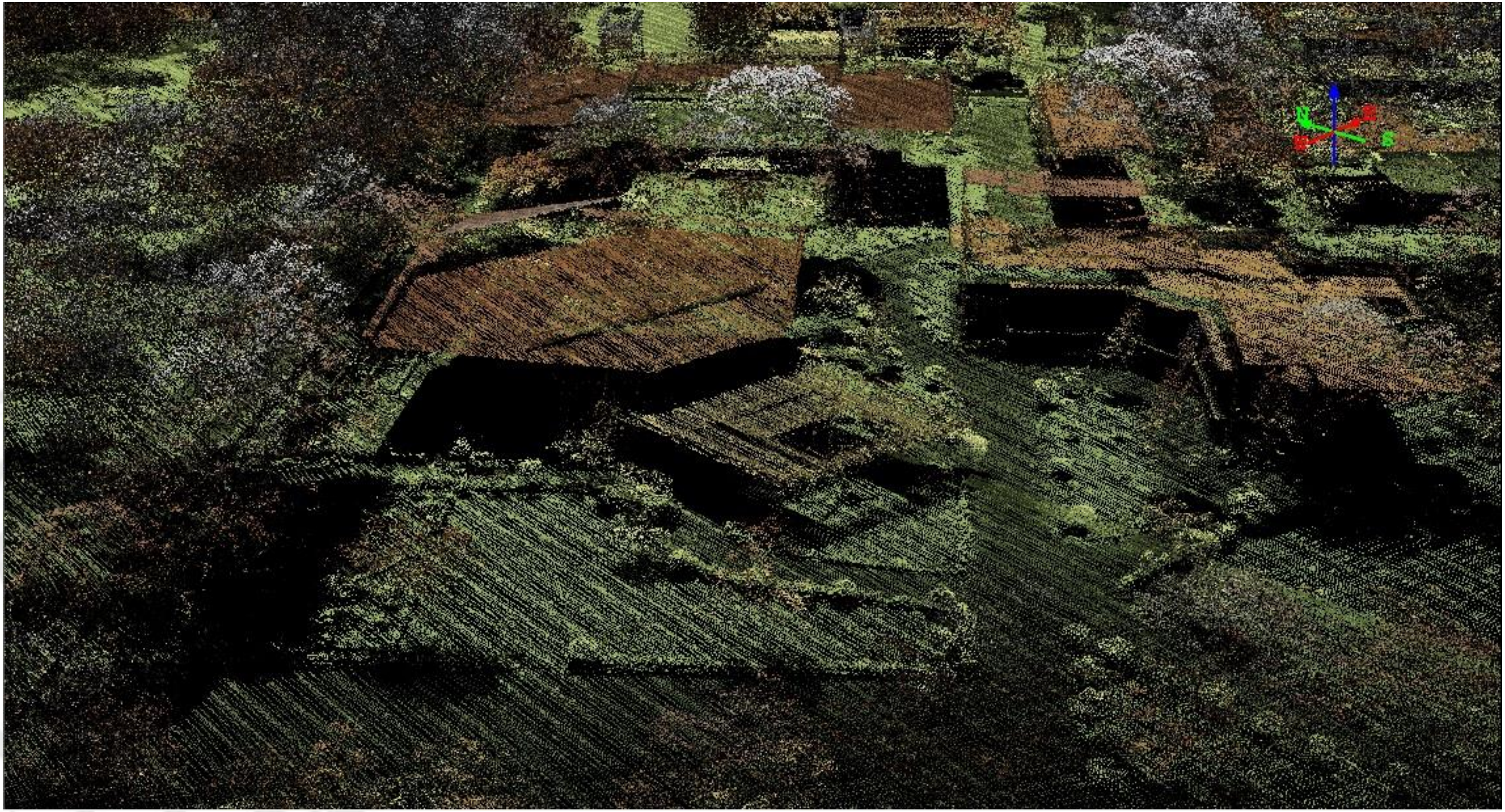

Complete Sector Ortho with Contour
346.7 m
345.0 m
342.5 m
340.0 m
337.5 m
336.1 m
0 m
250 m
500 m
750 m
Zoomed Ortho with Topo Map
0 m
25 m
50 m
75 m
100 m
125 m

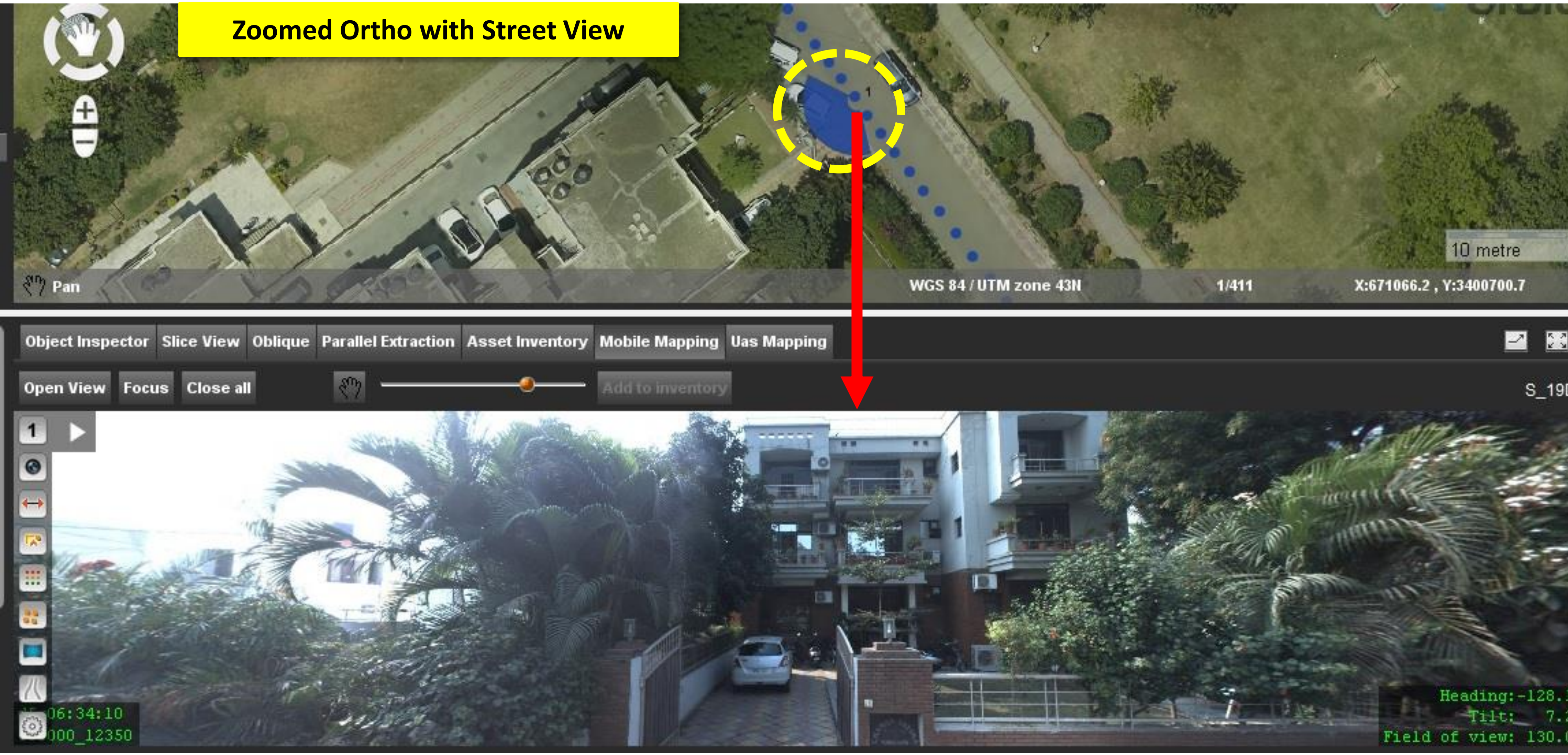
Zoomed Ortho with Topo Map

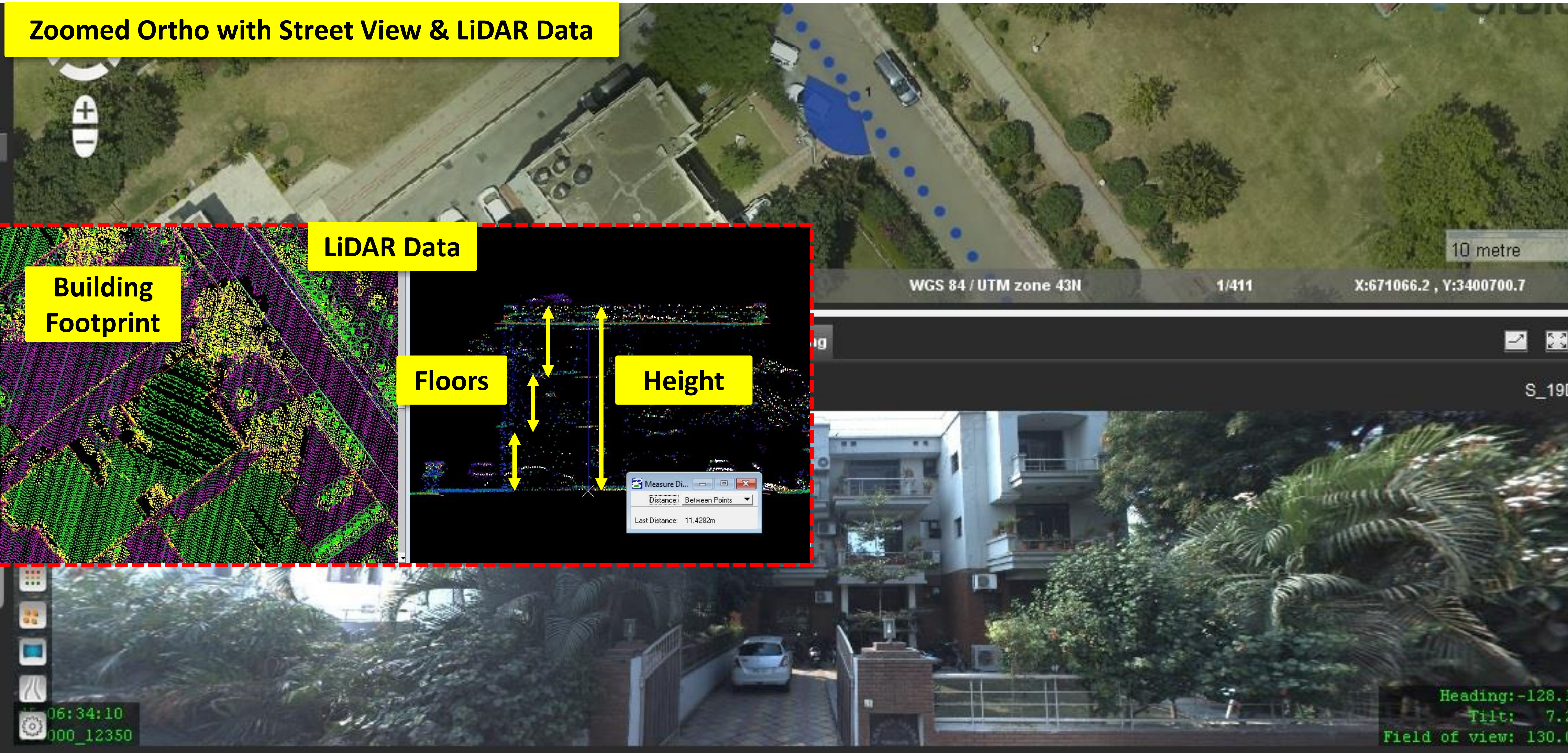



Ortho - Zoom
15 m
20 m
25 m
30 m
Street View
3D Point Cloud
Pan
WGS 84 / UTM zone 43N
1/1163
Object Inspector
Slice View
Oblique
Parallel Extraction
Asset Inventory
Uas Mapping
Open View
Focus
Close all
Peace To All Who Enter Here
CHRIST THE KING CATHEDRAL

0 m
10 m
20 m
30 m
40 m
50 m

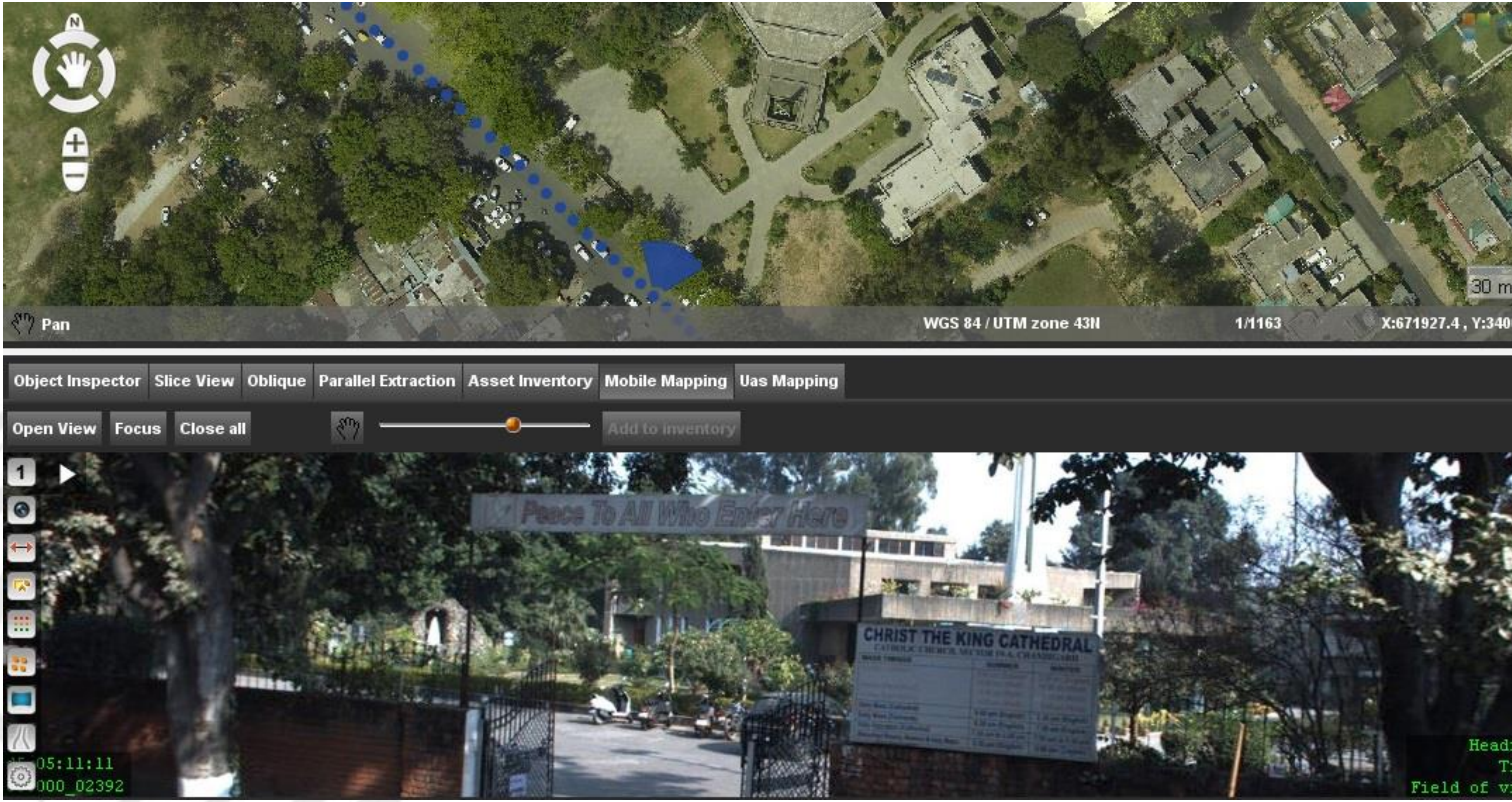


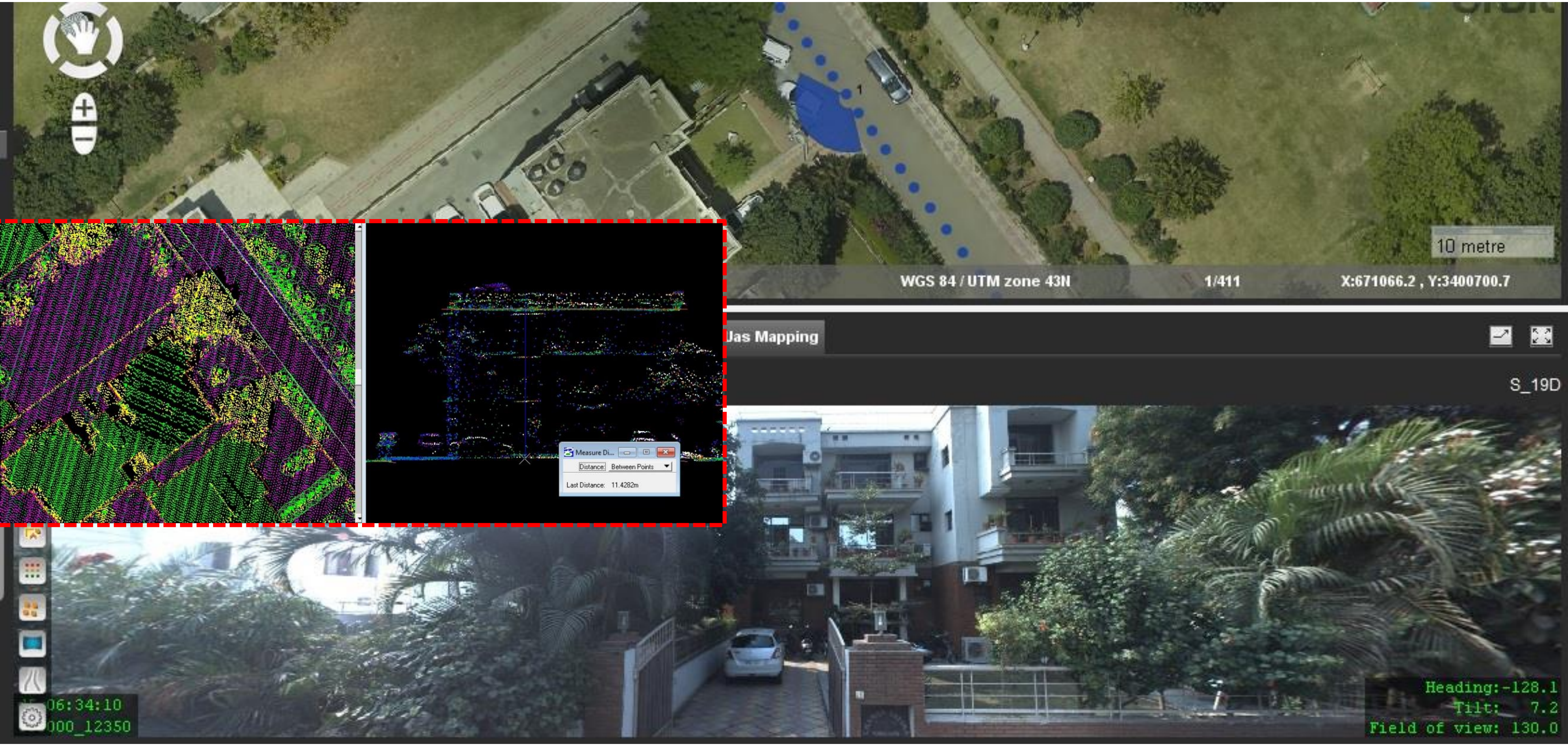

Zoomed Ortho with Street View
10 metre
Pan
WGS 84 / UTM zone 43N
1/411
X:671066.2 , Y:3400700.7
Object Inspector
Slice View
Oblique
Parallel Extraction
Asset Inventory
Mobile Mapping
Uas Mapping
Open View
Focus
Close all
Add to inventory
S_19D
Heading:-128.1
Tilt: 7.2
Field of view: 130.0



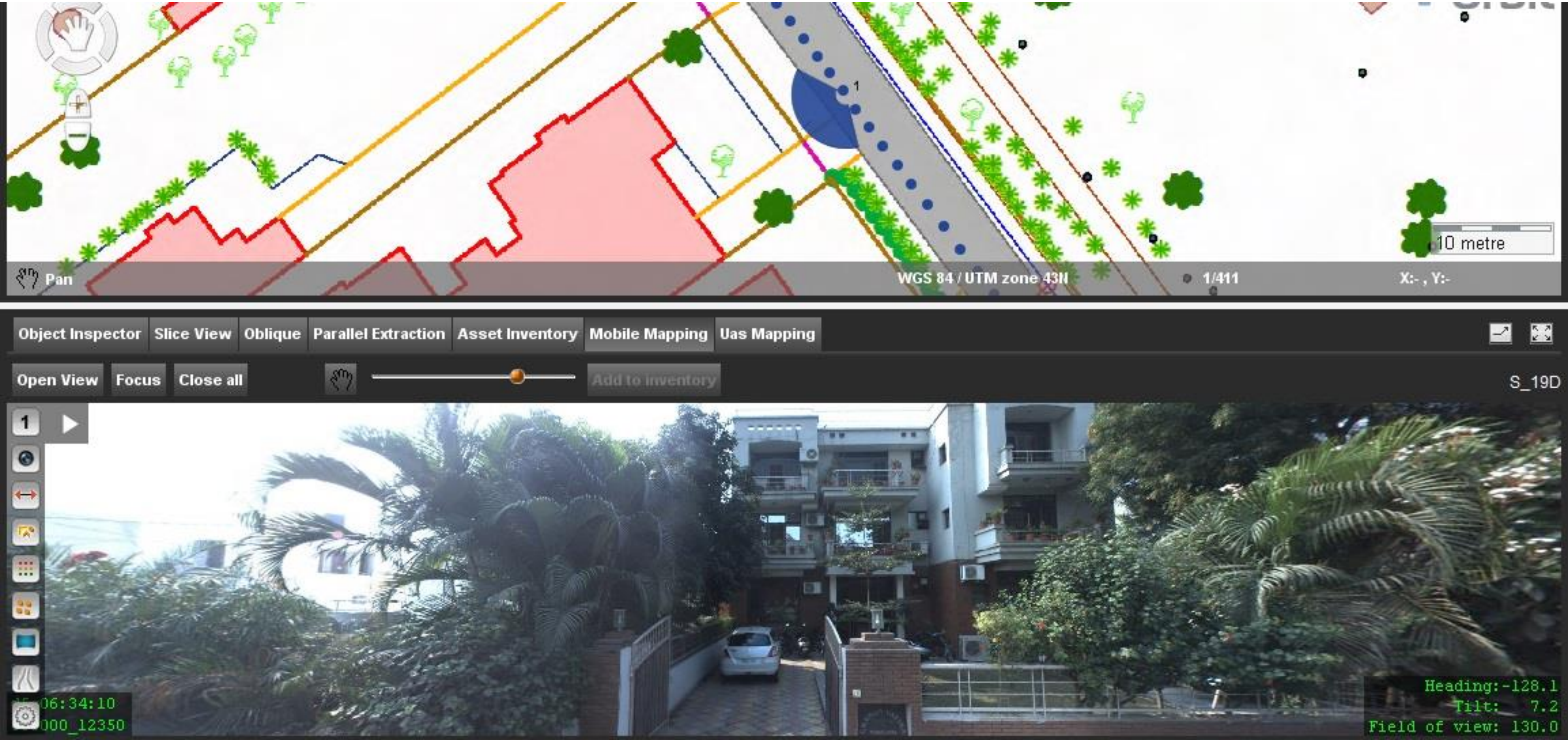
Zoomed Ortho with Street View & LiDAR Data
LiDAR Data
Building Footprint
Floors
Height
Measure Di...
Distance: Between Points
Last Distance: 11.4282m
10 metre
WGS 84 / UTM zone 43N
1/411
X:671066.2 , Y:3400700.7
S_19D
06:34:10
000_12350
Heading: -128.1
Tilt: 7.2
Field of view: 130.0

Geokno
Leaders in LiDAR





WGS 84 / UTM zone 43N
1/411
X:671066.2 , Y:3400700.7
10 metre
Measure Di...
Distance: Between Points
Last Distance: 11.4282m
Jas Mapping
S_19D
Heading:-128.1
Tilt: 7.2
Field of view: 130.0
06:34:10
000_12350



Pan
WGS 84 / UTM zone 43N
1/411
X:- , Y:-
10 metre
Object Inspector
Slice View
Oblique
Parallel Extraction
Asset Inventory
Mobile Mapping
Uas Mapping
Open View
Focus
Close all
Add to inventory
S_19D
Heading:-128.1
Tilt: 7.2
Field of view: 130.0

Individual Tree Mapping

FOREST MAPPING FOR CARBON STOCK ESTIMATION

Raw Images- high resolution up to 5cm GSD

Leaders in LiDAR

Perspective View-Colour by Intensity

Perspective View-Colour by Height

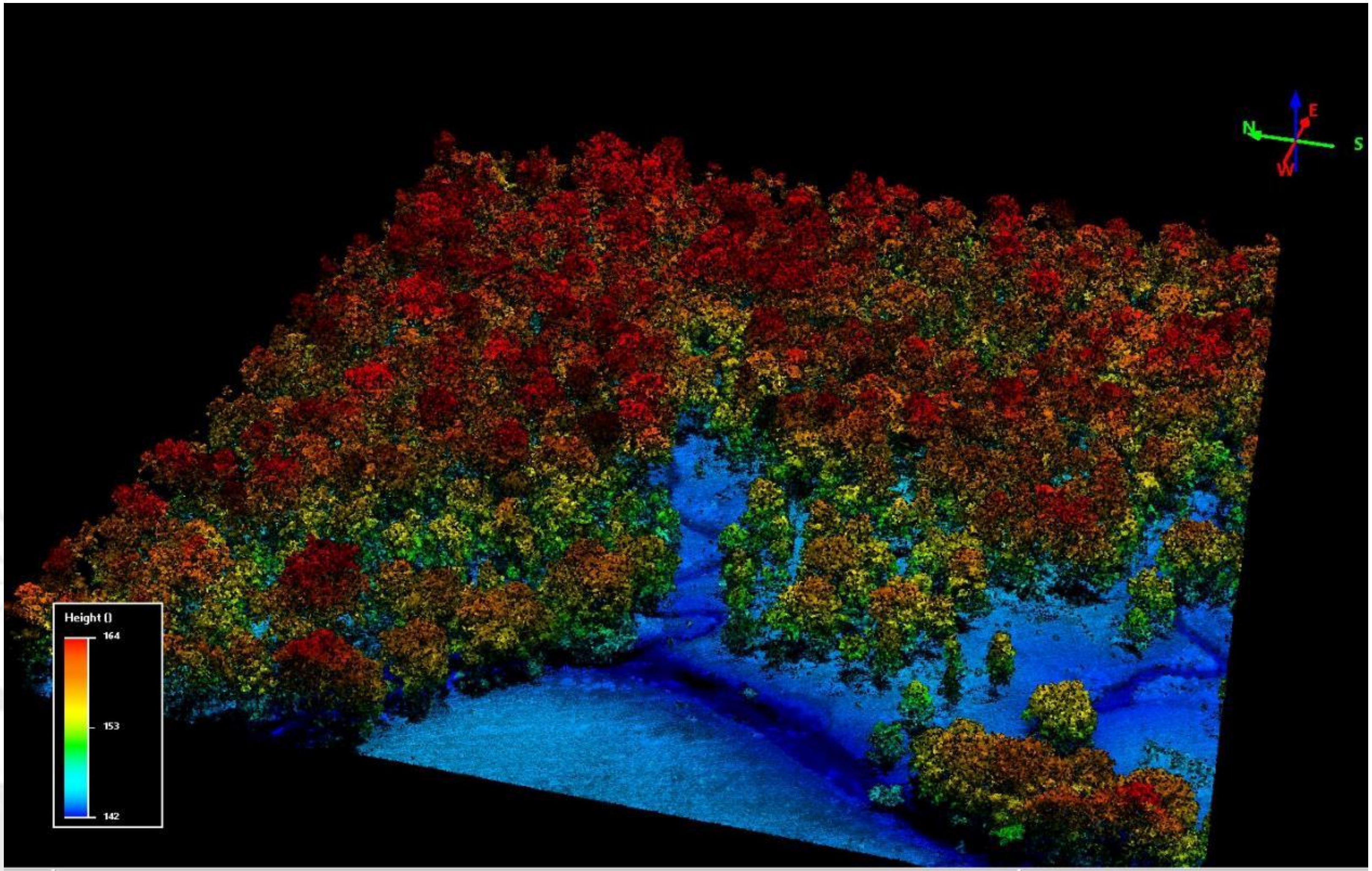


Image and LiDAR Point Cloud

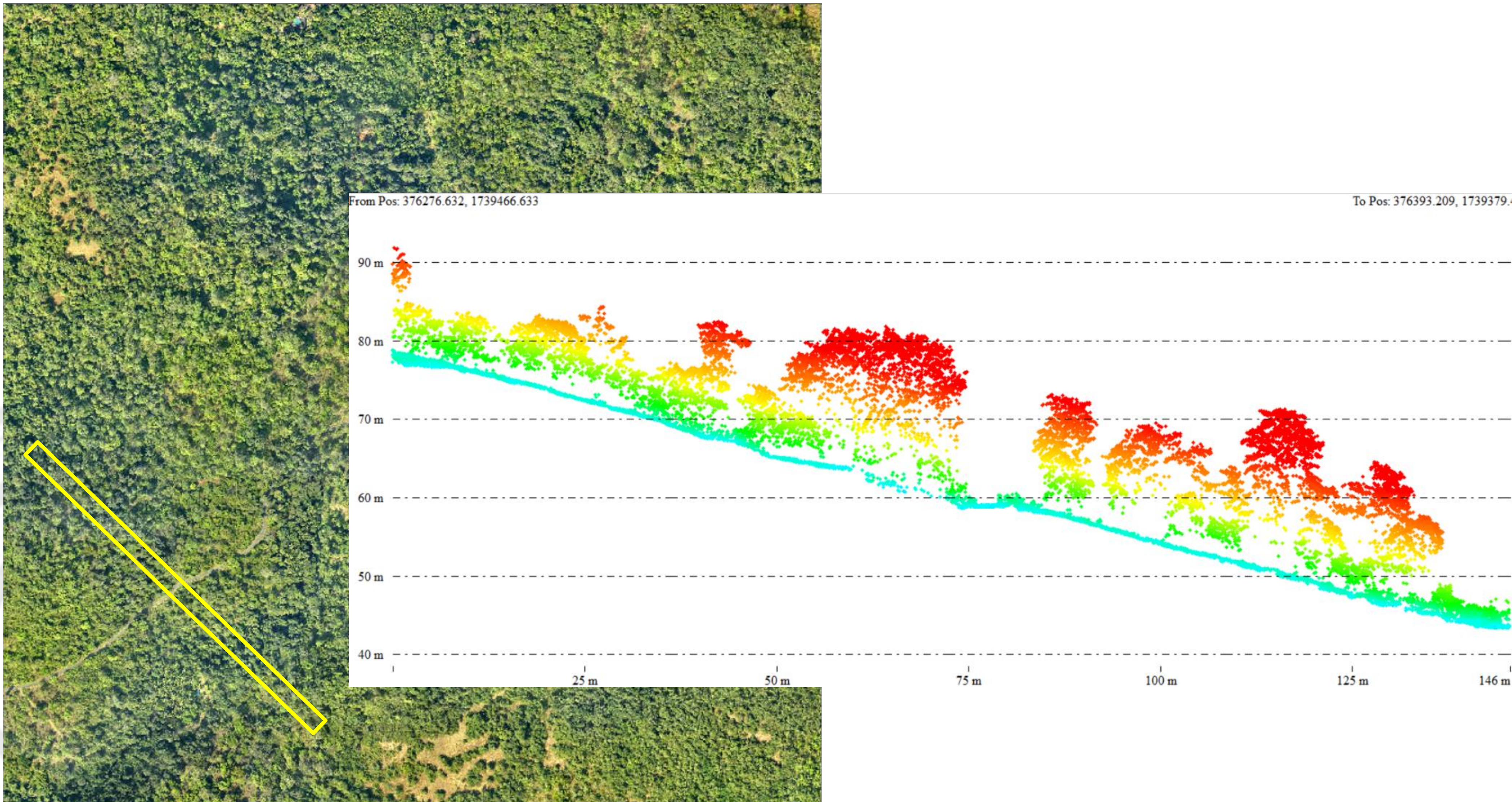
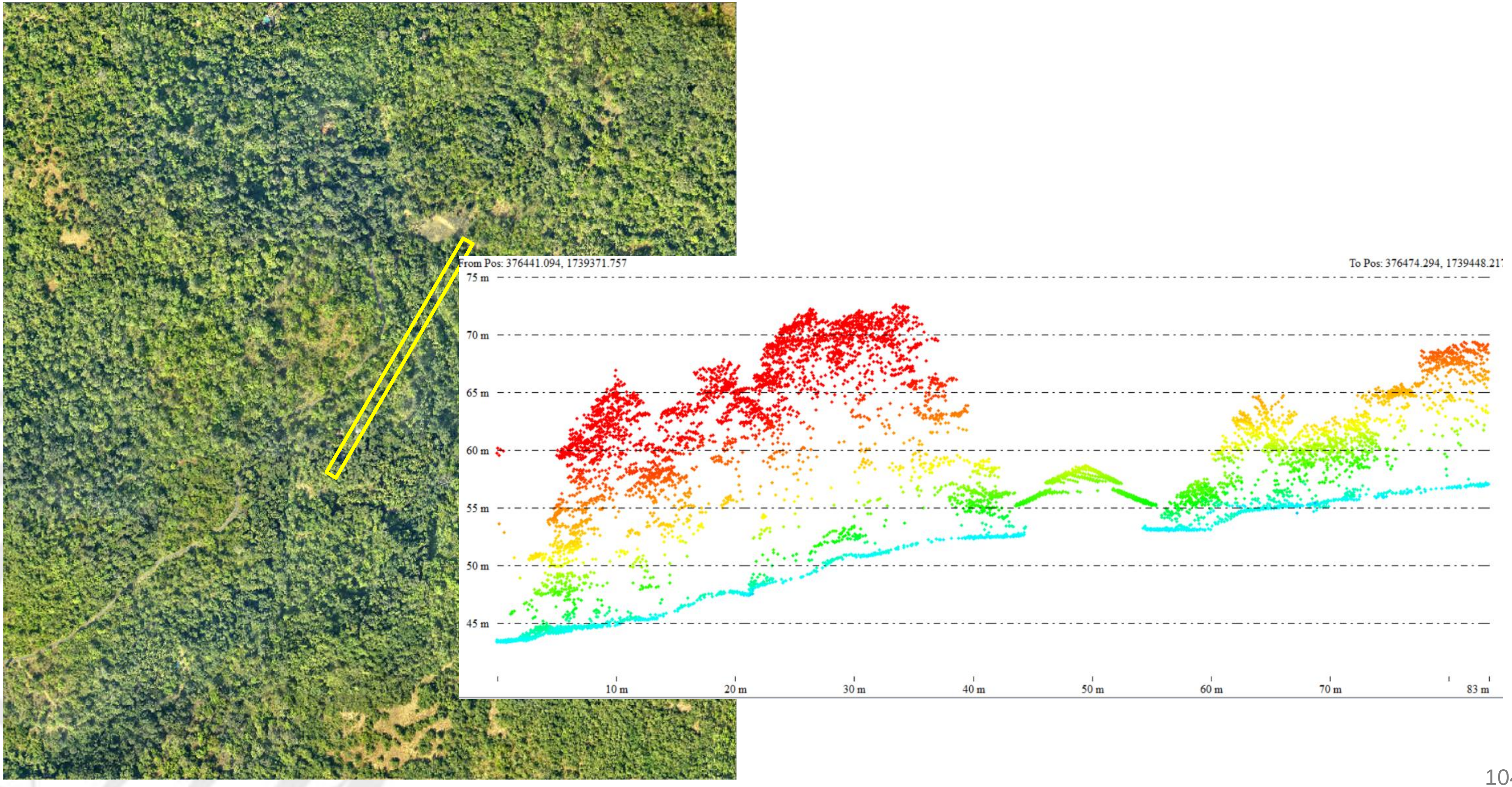


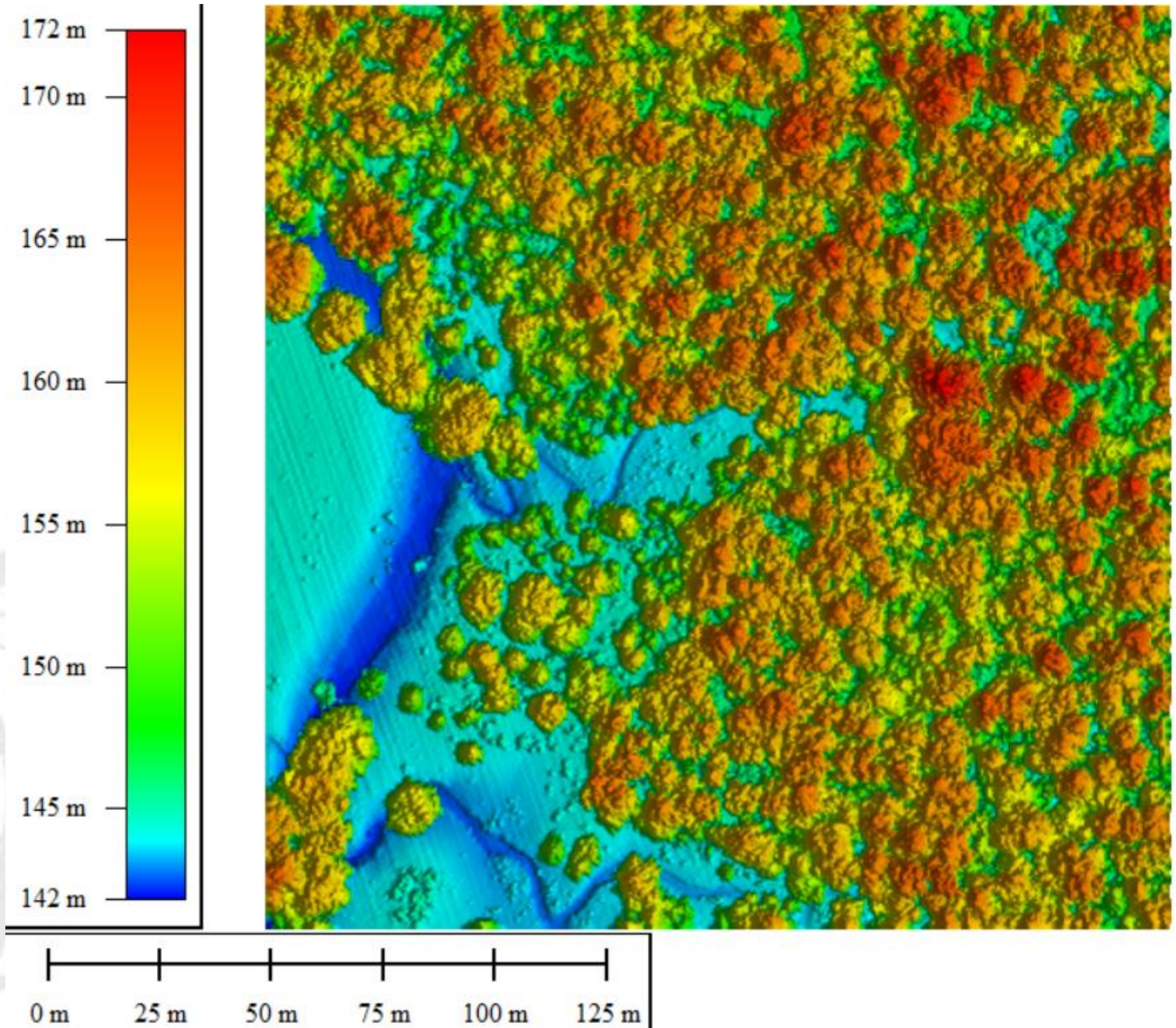
Image and LiDAR Point Cloud



Processing to derive forest related parameters leading to Carbon Stock estimation

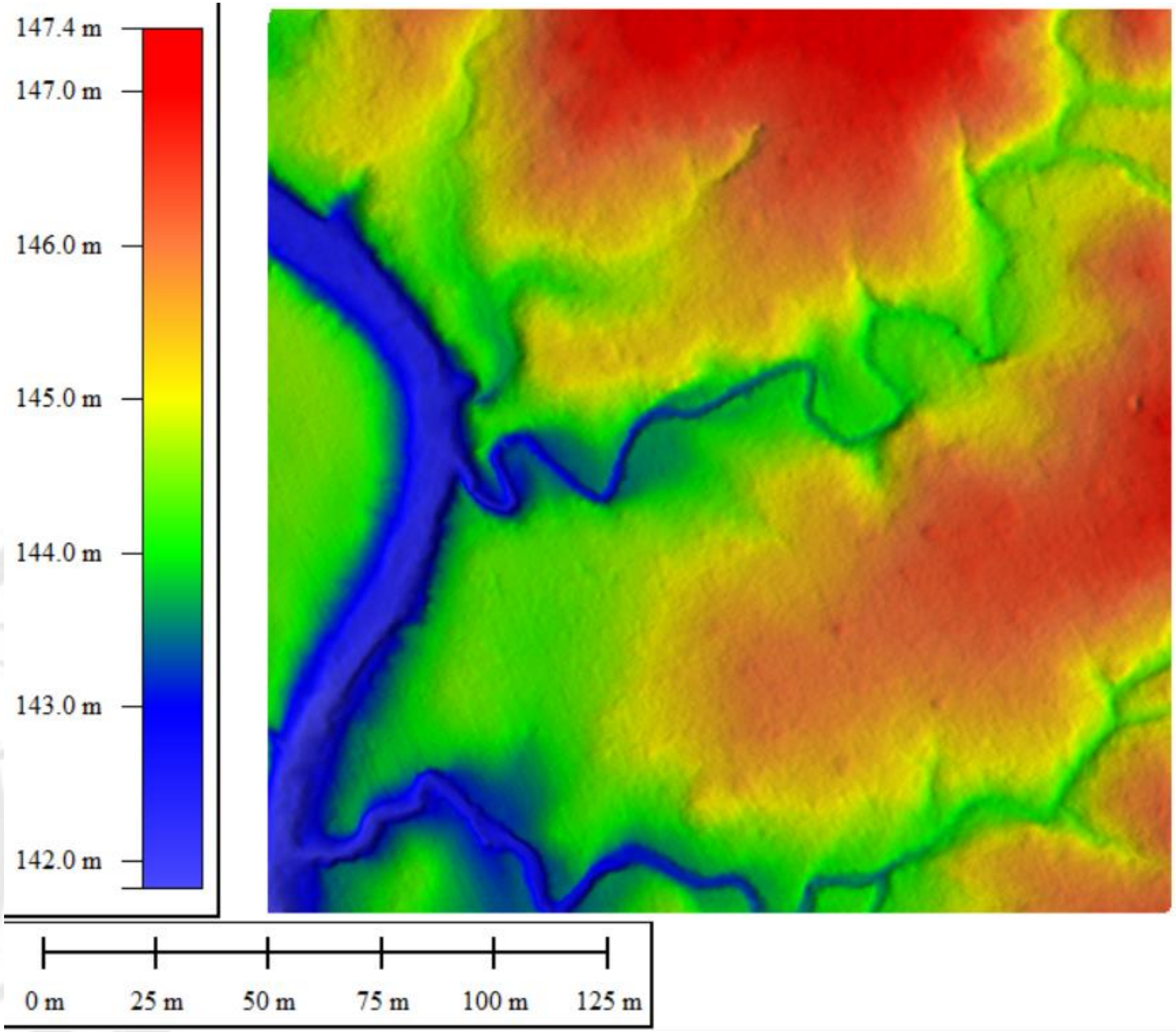
PROCESSING STEPS

Digital Surface Model (DSM)- 0.5m Grid

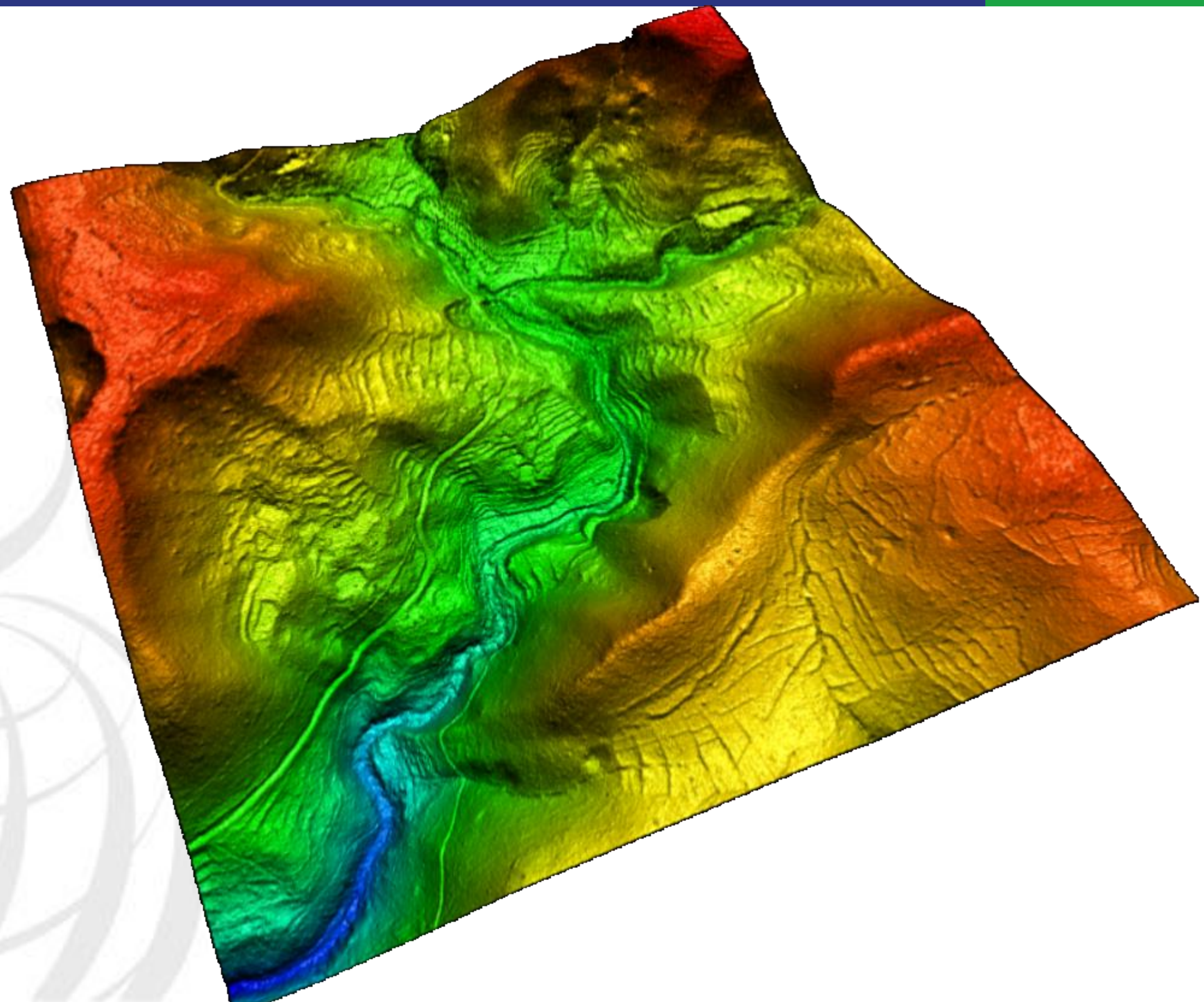


Digital Elevation Model (DEM)- 0.5m Grid

Geokno
Leaders in LiDAR

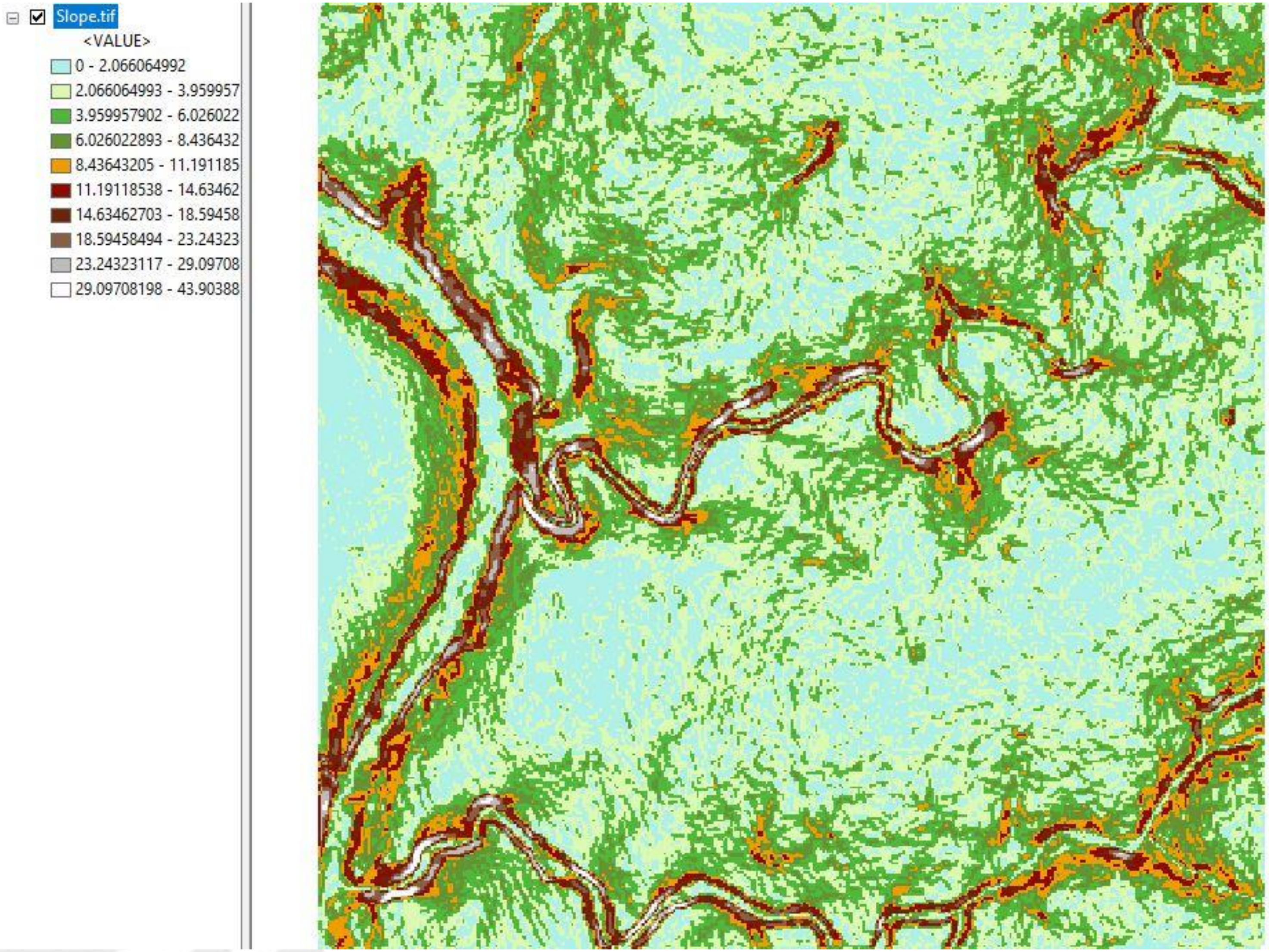


Detailed 3D Model of the DEM of the area

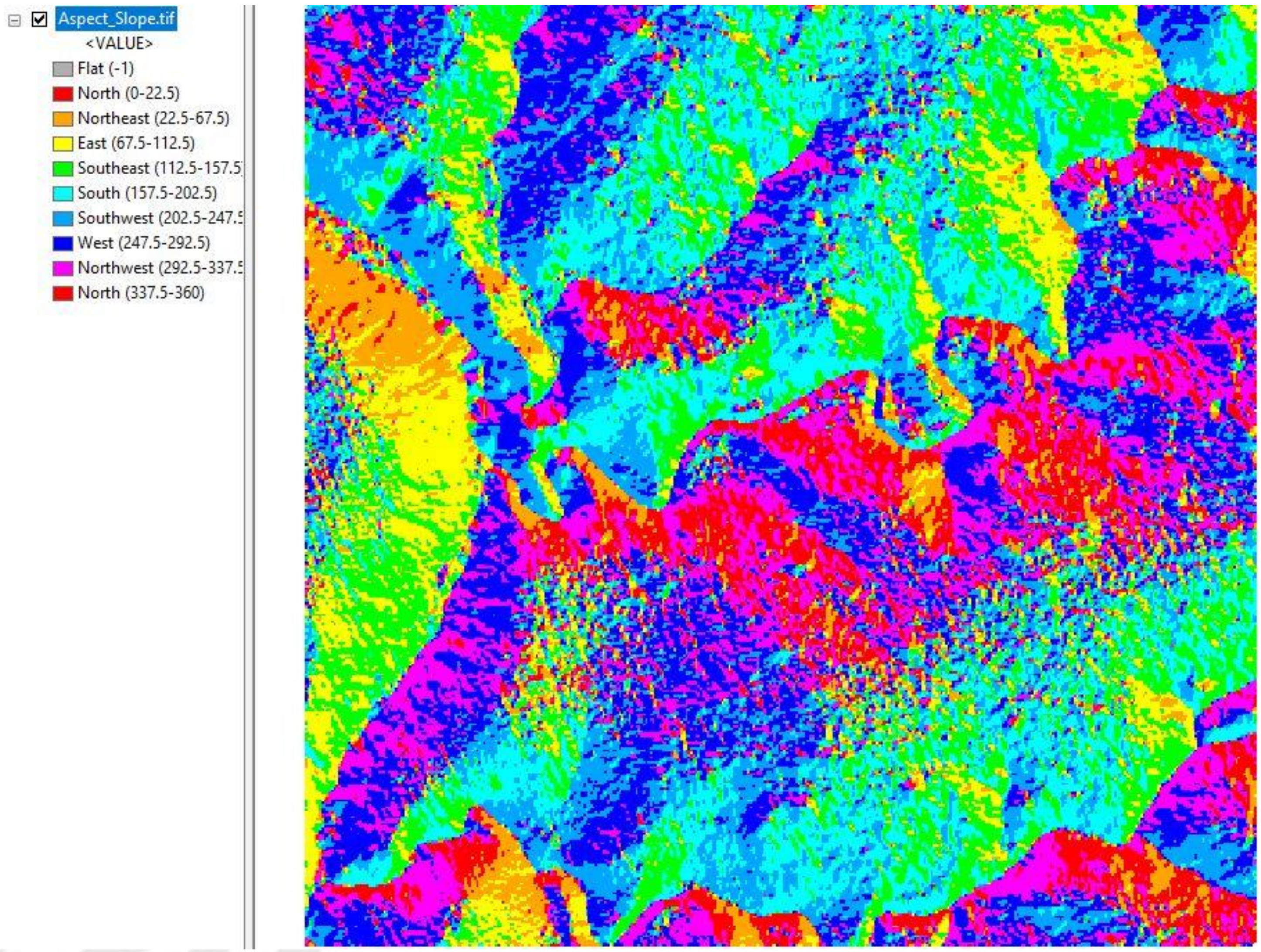


Orthophoto- 5 cm GSD

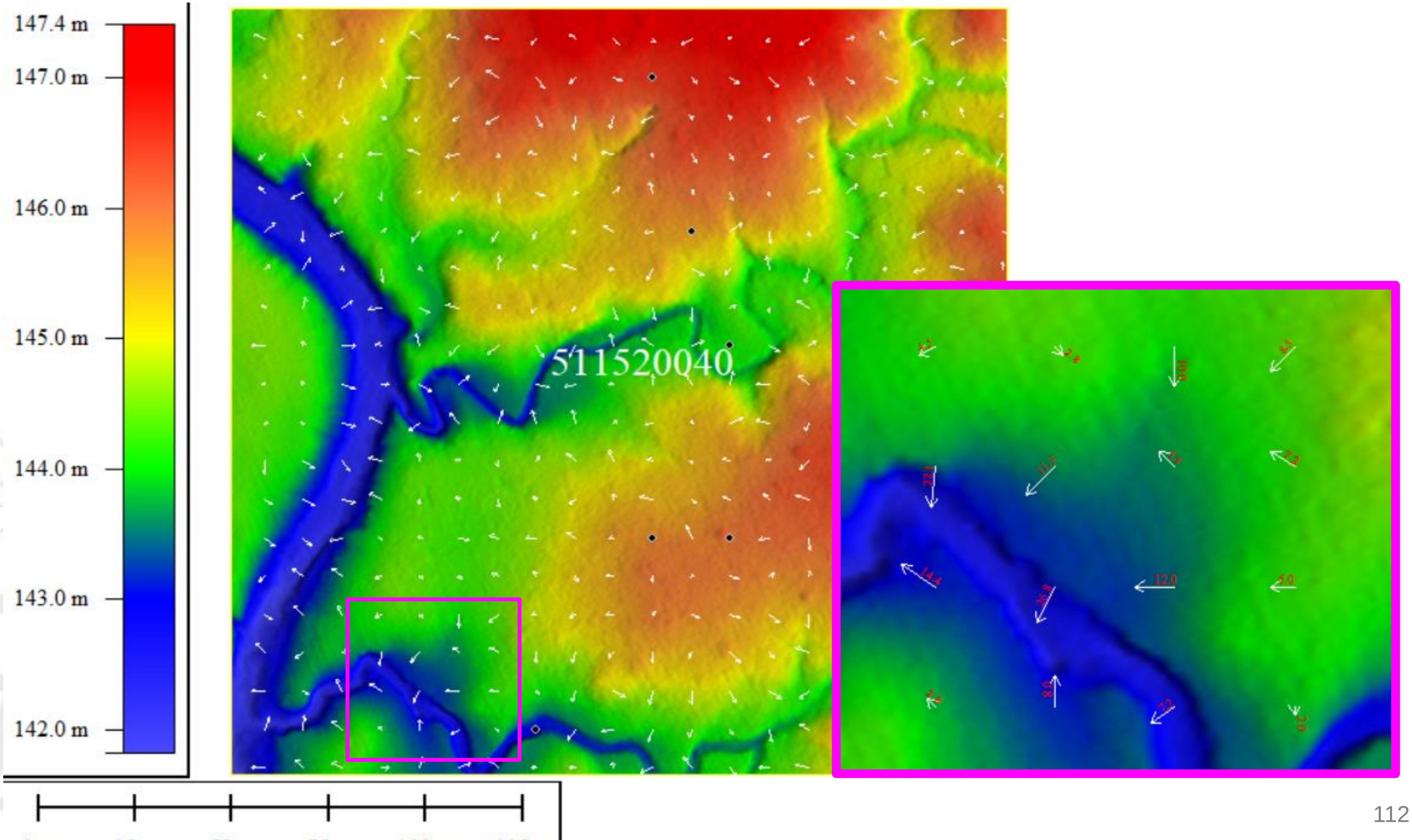
Terrain Slope Map



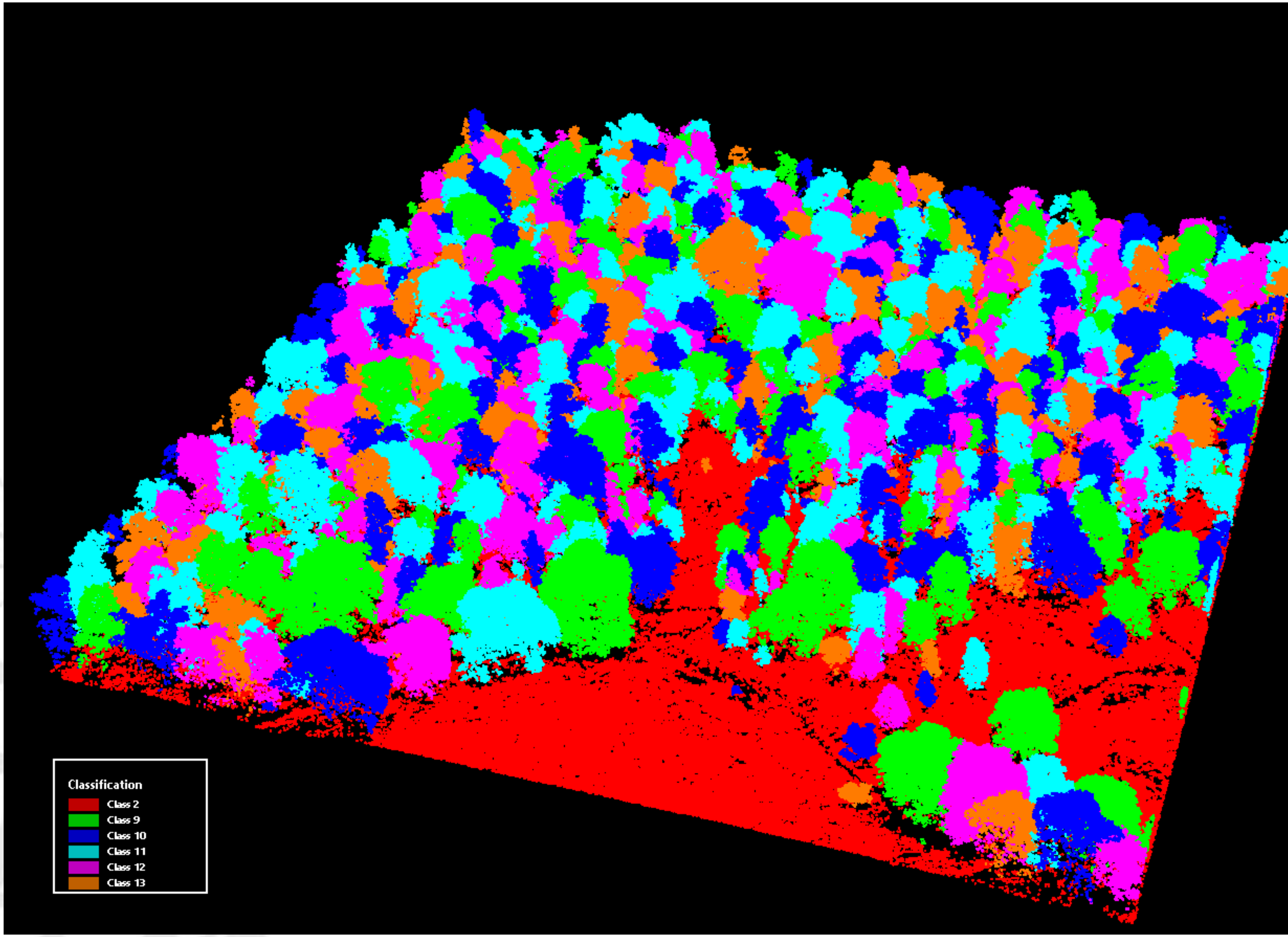
Terrain Aspect Map



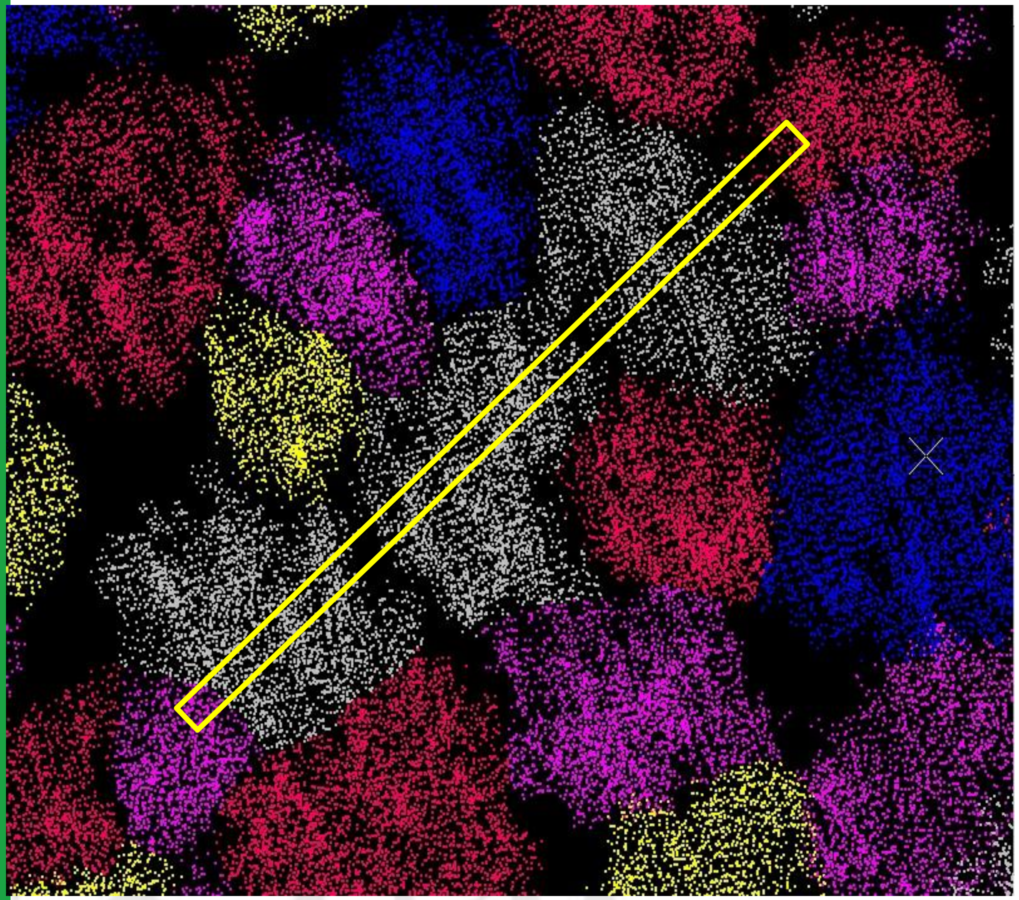
Terrain Slope Direction Map

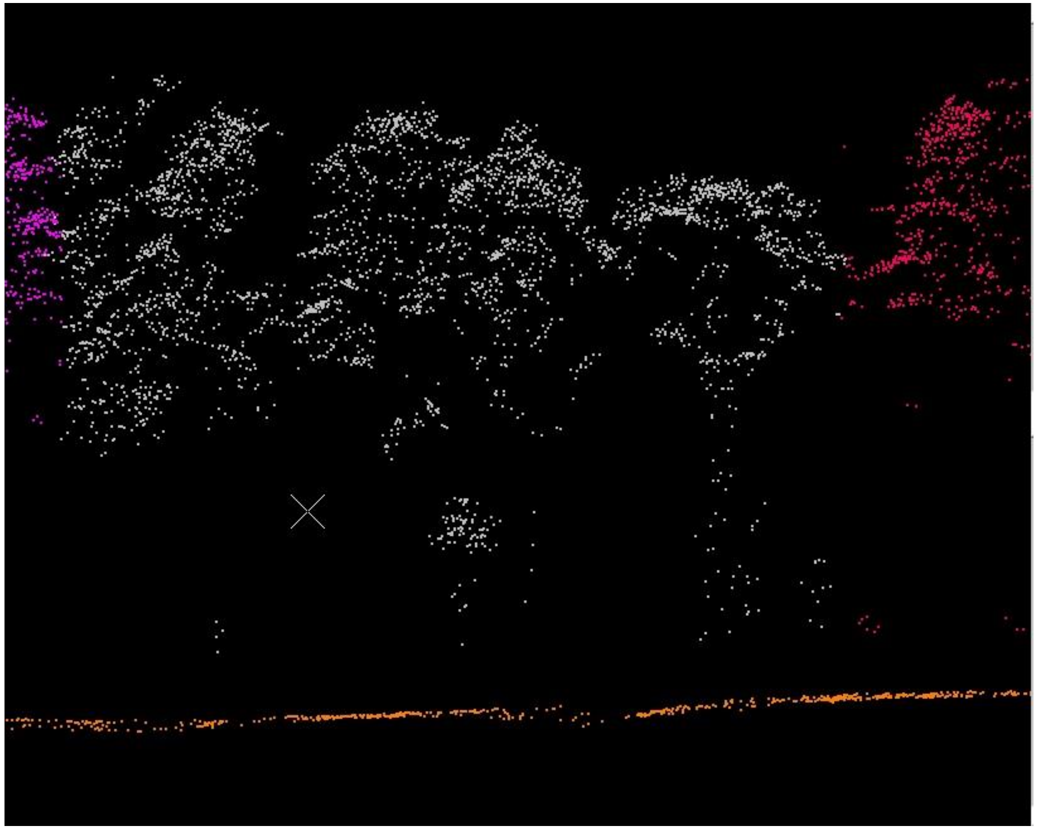


Colour by Segmented Trees

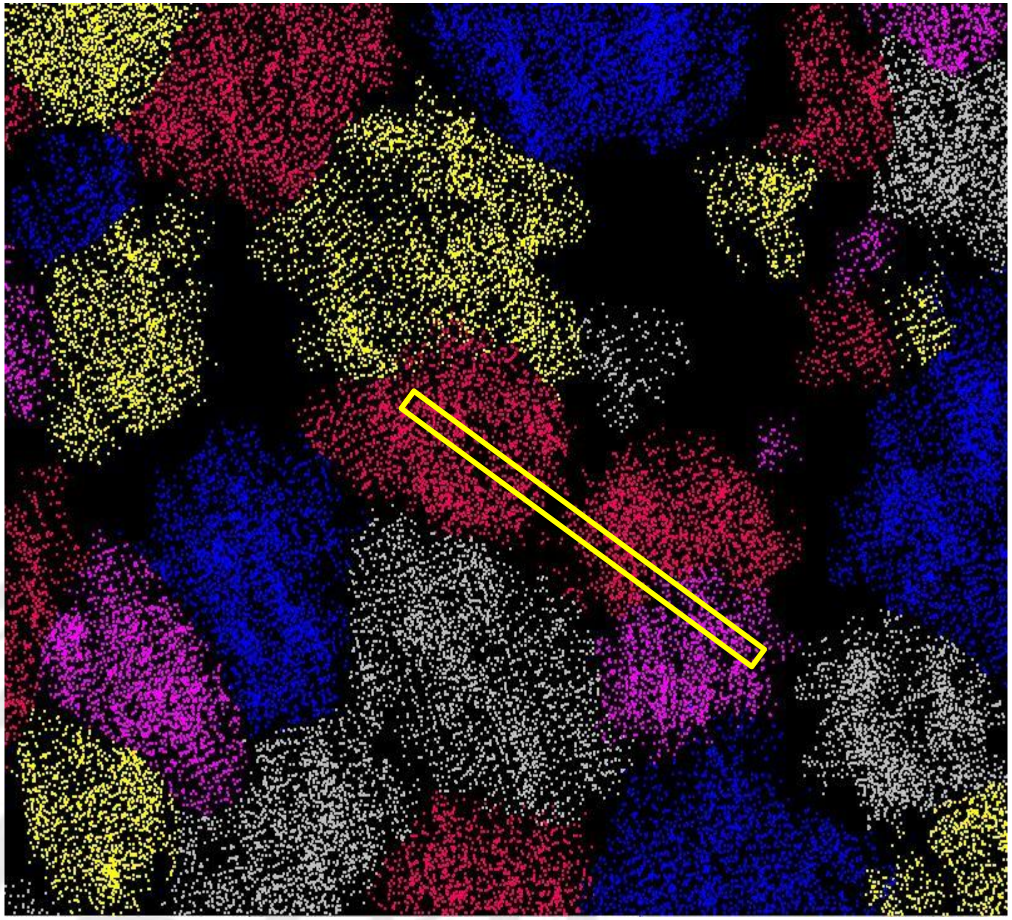


Tree Segmented LiDAR Points- Top View and Cross-section

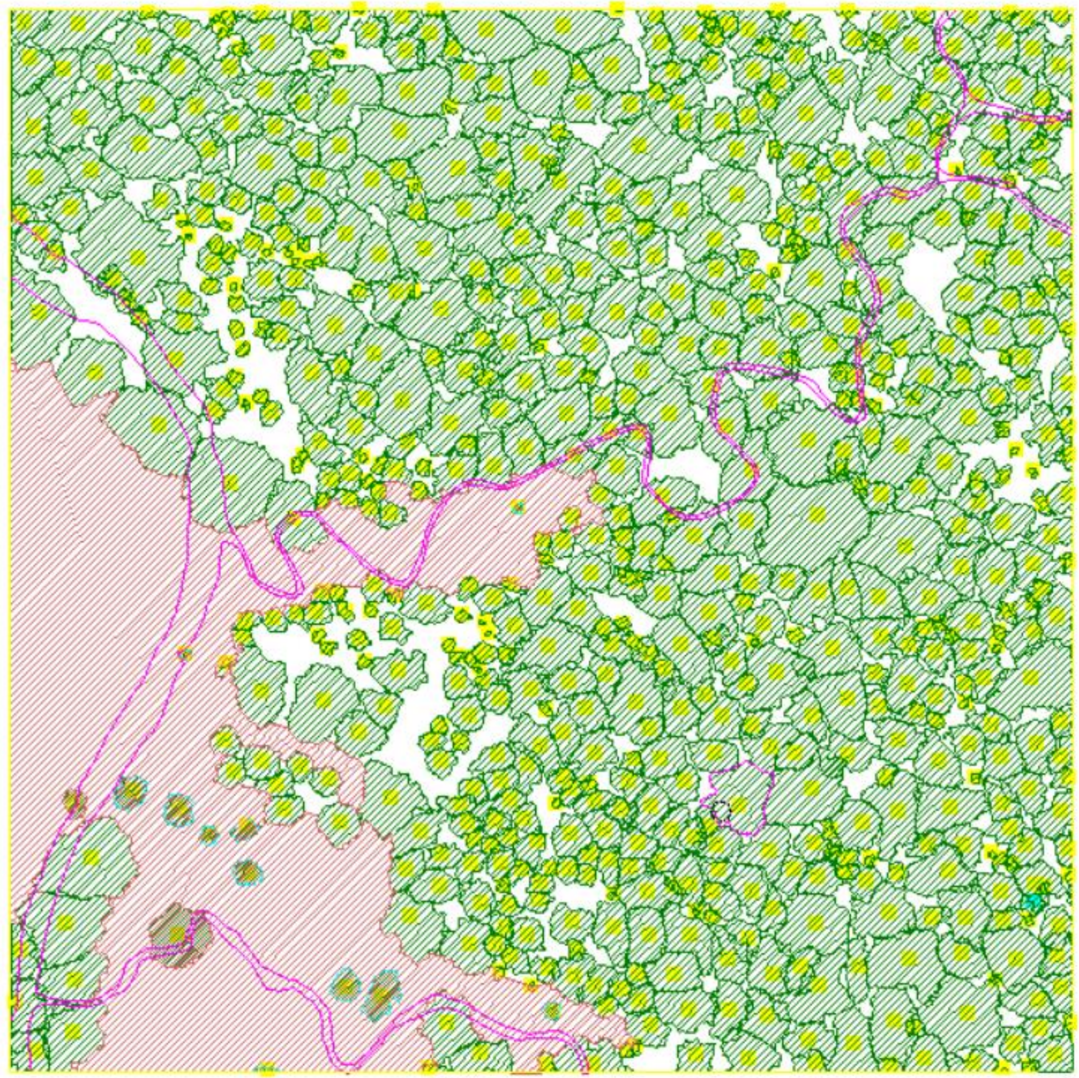




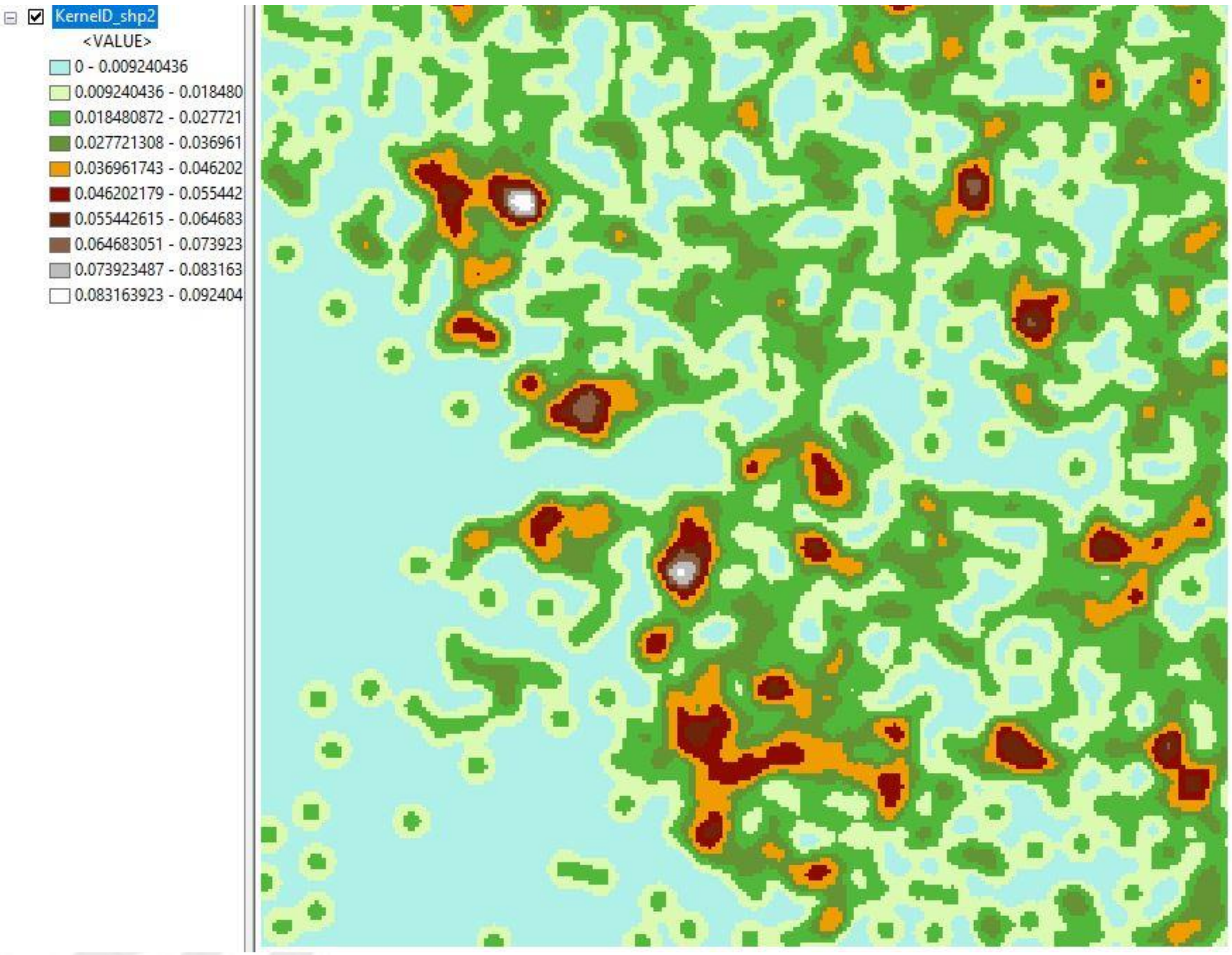
Tree Segmented LiDAR Points-
Top View and Cross-section



Tree Segmented and Open Area

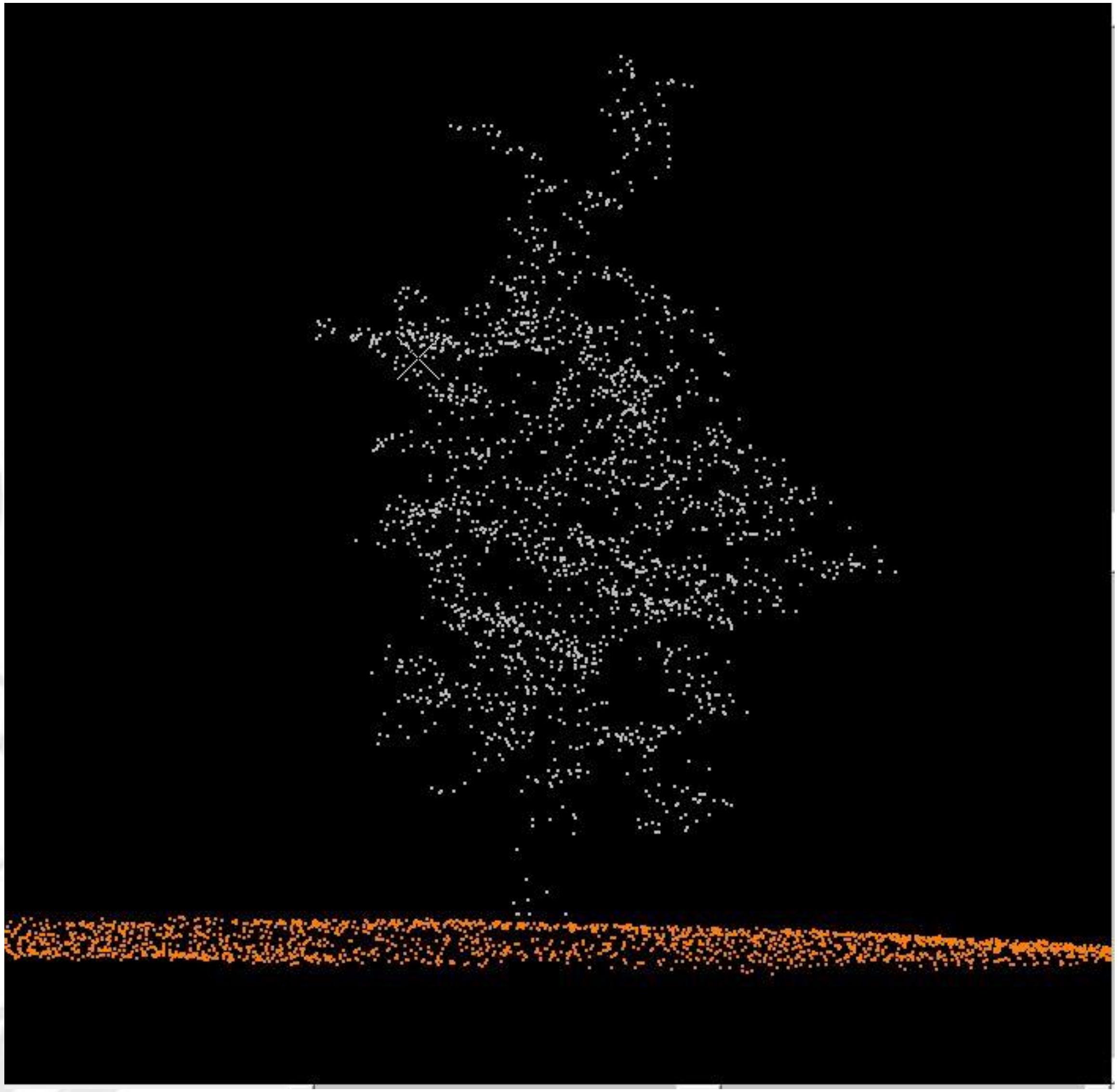


Tree Density Map

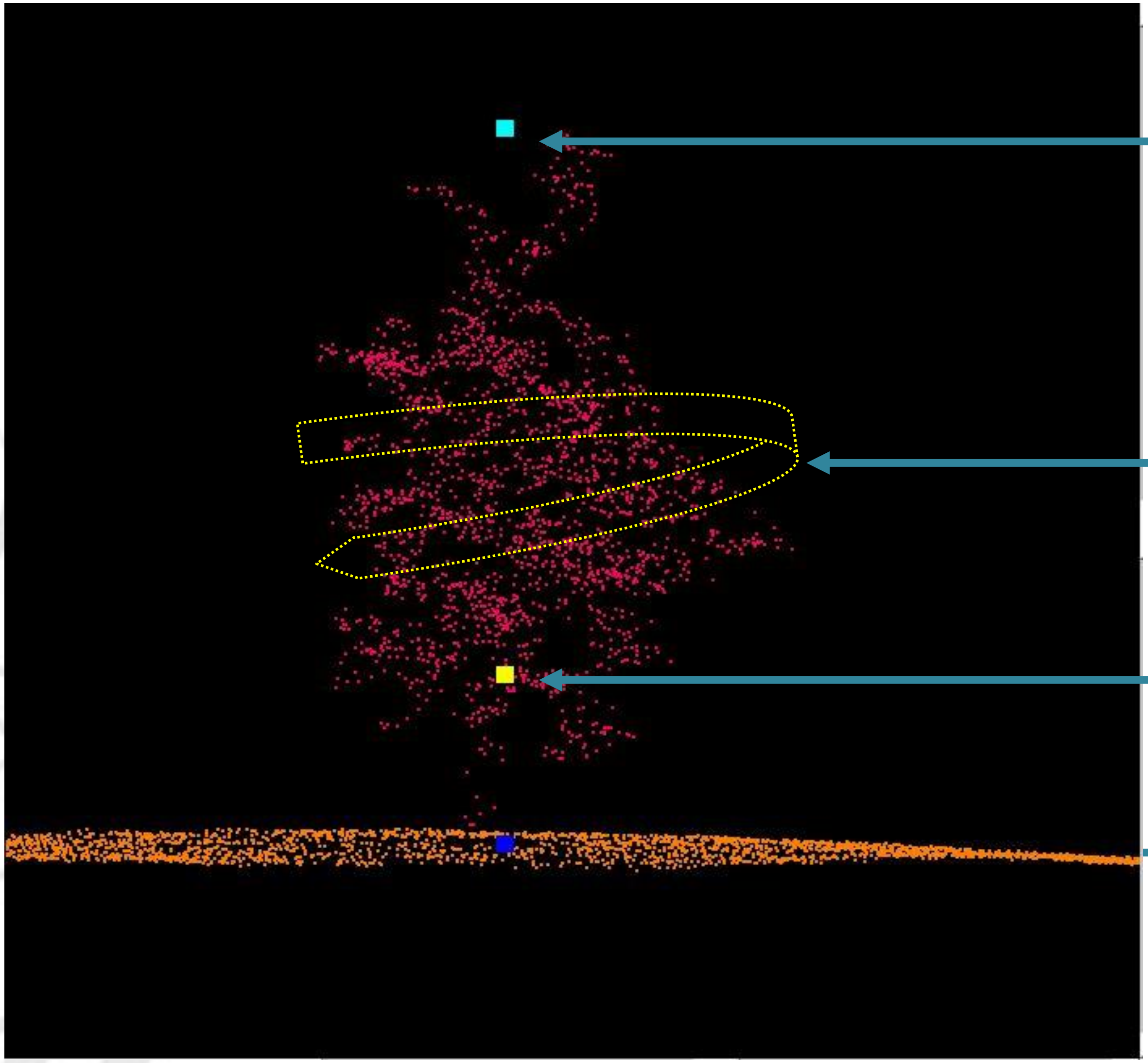


Site to identify trees competing for Sun Light—possible sites for felling.

Point Cloud of Individual Tree

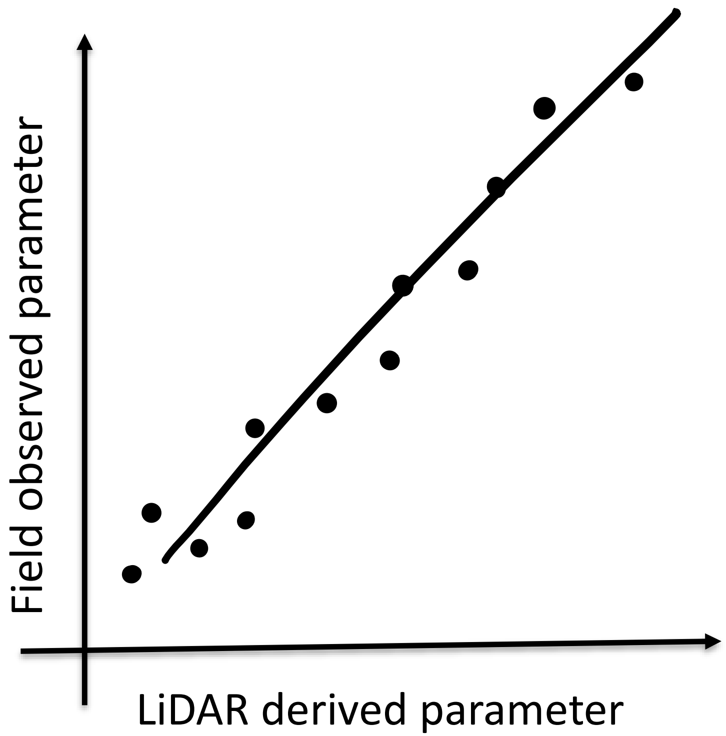


Individual Tree with Details

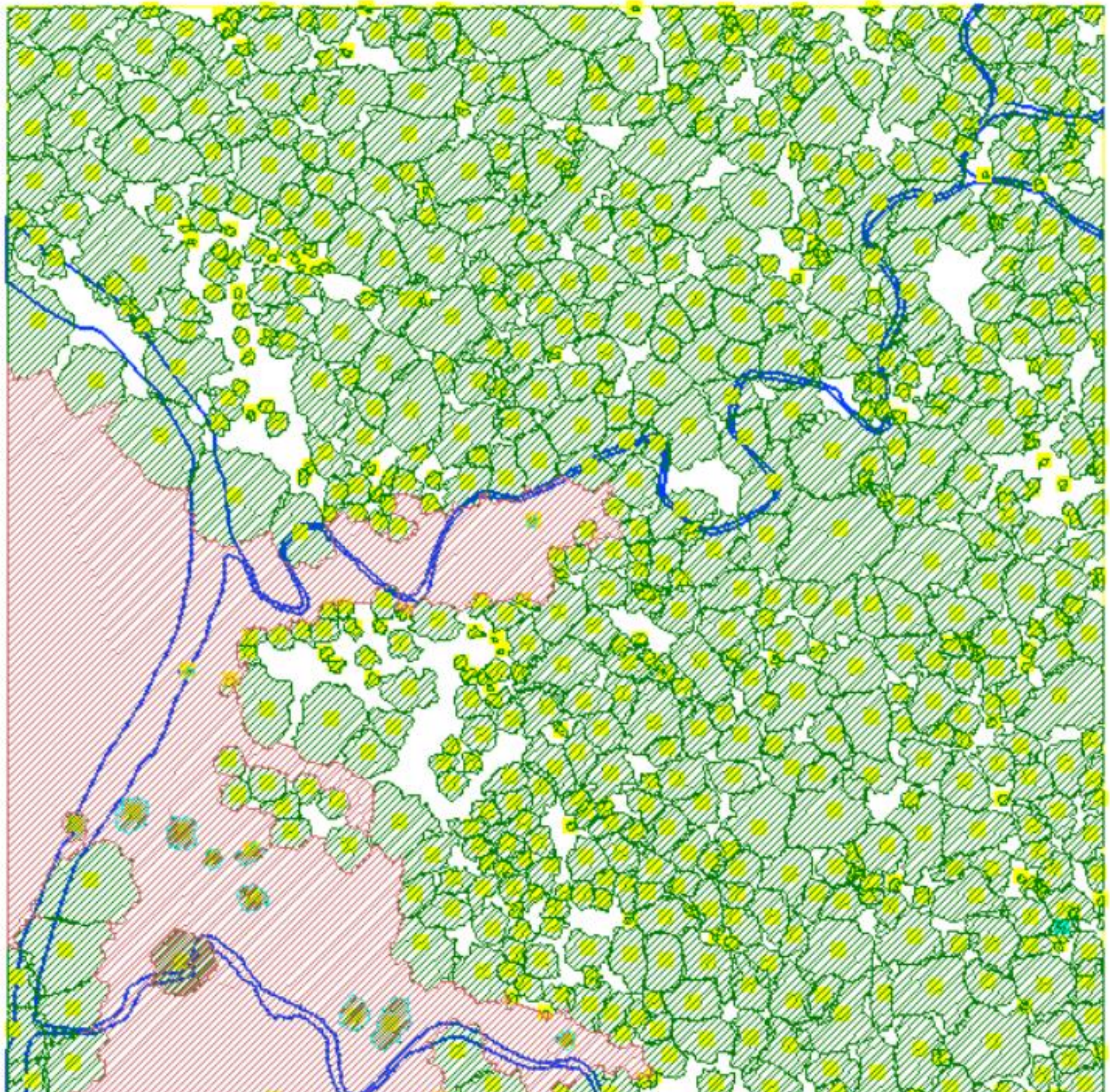


Field Sample Sites and Correlation Matrix

- Field plot for sampling -100 m by 100 m or specified
- Determination of field parameters using Terrestrial Laser Scanning
  - Tree height
  - CBH
  - Girth
  - DBH
  - Tree Specie
- Developing correlation between field observed and LiDAR derived parameters



GIS Layers of Forest Area with Tree Parameters



- Canopy Spread Area
- Open land
- Hydro-Features
- Tree points

Table

Canopy_Poly_final_v4

FID	Shape	ID	Lat	Long	Gnd_Elev	CPA_FS	CPA_LDR	TH_FS	TH_LDR	CBH_FS	CBH_LDR	DBH_FS	Grith_FS
0	Polygon	0	18° 7' 40.681" N	81° 6' 43.237" E	146.15	0	10.812	0	161.155	0	153.776	0	0
1	Polygon	1	18° 7' 36.836" N	81° 6' 40.497" E	145.352	0	9.982	0	149.813	0	147.79	0	0
2	Polygon	2	18° 7' 37.040" N	81° 6' 40.144" E	144.677	0	48.164	0	161.17	0	151.936	0	0
3	Polygon	3	18° 7' 39.450" N	81° 6' 38.452" E	145.631	0	56.448	0	162.821	0	147.937	0	0
4	Polygon	4	18° 7' 39.175" N	81° 6' 38.326" E	145.135	0	1.194	0	150.245	0	146.479	0	0
5	Polygon	5	18° 7' 39.181" N	81° 6' 38.479" E	145.218	0	1.928	0	149.874	0	147.096	0	0
6	Polygon	6	18° 7' 35.510" N	81° 6' 40.345" E	145.917	0	24.465	0	161.154	0	152.27	0	0
7	Polygon	7	18° 7' 35.309" N	81° 6' 40.585" E	145.481	0	60.36	0	164.07	0	153.465	0	0
8	Polygon	8	18° 7' 38.587" N	81° 6' 42.885" E	145.743	0	3.621	0	152.985	0	149.926	0	0
9	Polygon	9	18° 7' 38.414" N	81° 6' 43.283" E	146.212	0	35.398	0	164.174	0	148.424	0	0
10	Polygon	10	18° 7' 38.145" N	81° 6' 42.871" E	145.918	0	5.408	0	149.949	0	147.848	0	0
11	Polygon	11	18° 7' 37.689" N	81° 6' 43.112" E	146.597	0	8.867	0	159.218	0	150.776	0	0
12	Polygon	12	18° 7' 34.774" N	81° 6' 42.811" E	144.727	0	1.971	0	147.967	0	146.55	0	0
13	Polygon	13	18° 7' 34.500" N	81° 6' 43.287" E	145.649	0	4.67	0	148.07	0	146.492	0	0
14	Polygon	14	18° 7' 34.246" N	81° 6' 43.025" E	146.047	0	4.429	0	155.303	0	152.231	0	0
15	Polygon	15	18° 7' 34.522" N	81° 6' 42.161" E	145.603	0	100.128	0	162.284	0	147.842	0	0
16	Polygon	16	18° 7' 34.270" N	81° 6' 42.672" E	145.88	0	29.35	0	162.232	0	154.405	0	0
17	Polygon	17	18° 7' 35.687" N	81° 6' 41.757" E	145.623	0	9.631	0	152.562	0	147.733	0	0
18	Polygon	18	18° 7' 35.194" N	81° 6' 40.895" E	145.322	0	0.974	0	147.935	0	147.208	0	0
19	Polygon	19	18° 7' 34.367" N	81° 6' 40.514" E	143.979	0	3.128	0	148.983	0	146.348	0	0
20	Polygon	20	18° 7' 35.937" N	81° 6' 39.468" E	145.191	0	19.01	0	161.528	0	147.196	0	0
21	Polygon	21	18° 7' 36.421" N	81° 6' 39.931" E	145.501	0	4.051	0	149.396	0	147.807	0	0
22	Polygon	22	18° 7' 36.774" N	81° 6' 39.548" E	144.833	0	14.535	0	154.042	0	146.995	0	0
23	Polygon	23	18° 7' 36.899" N	81° 6' 39.566" E	144.636	0	0.643	0	147.402	0	145.655	0	0
24	Polygon	24	18° 7' 37.014" N	81° 6' 40.977" E	145.57	0	80.523	0	163.992	0	149.788	0	0
25	Polygon	25	18° 7' 36.848" N	81° 6' 41.270" E	146.012	0	1.414	0	151.097	0	148.987	0	0
26	Polygon	26	18° 7' 36.162" N	81° 6' 41.530" E	146.011	0	37.832	0	159.751	0	149.889	0	0
27	Polygon	27	18° 7' 34.834" N	81° 6' 39.635" E	144.051	0	3.279	0	151.649	0	146.544	0	0
28	Polygon	28	18° 7' 35.879" N	81° 6' 38.935" E	144.516	0	117.719	0	157.424	0	147.347	0	0
29	Polygon	29	18° 7' 35.733" N	81° 6' 39.429" E	145.097	0	18.232	0	160.24	0	149.486	0	0
30	Polygon	30	18° 7' 35.743" N	81° 6' 39.610" E	145.311	0	16.337	0	161.086	0	154.856	0	0
31	Polygon	31	18° 7' 35.753" N	81° 6' 39.795" E	145.468	0	22.349	0	159.527	0	151.035	0	0
32	Polygon	32	18° 7' 35.855" N	81° 6' 39.995" E	145.751	0	1.972	0	155.464	0	152.219	0	0
33	Polygon	33	18° 7' 35.692" N	81° 6' 40.306" E	145.9	0	40.527	0	165.61	0	155.086	0	0
34	Polygon	34	18° 7' 35.839" N	81° 6' 40.599" E	145.941	0	48.182	0	160.344	0	153.339	0	0
35	Polygon	35	18° 7' 36.192" N	81° 6' 41.369" E	146.026	0	57.107	0	157.967	0	148.582	0	0
36	Polygon	36	18° 7' 35.841" N	81° 6' 41.165" E	145.822	0	121.462	0	159.588	0	148.292	0	0
37	Polygon	37	18° 7' 36.496" N	81° 6' 41.865" E	146.304	0	98.831	0	160.574	0	148.419	0	0
38	Polygon	38	18° 7' 36.873" N	81° 6' 42.084" E	146.395	0	48.392	0	160.102	0	148.439	0	0
39	Polygon	39	18° 7' 37.147" N	81° 6' 41.680" E	146.246	0	68.97	0	163.829	0	150.409	0	0
40	Polygon	40	18° 7' 36.585" N	81° 6' 41.221" E	146.11	0	17.724	0	163.096	0	151.513	0	0
41	Polygon	41	18° 7' 36.680" N	81° 6' 40.692" E	145.588	0	14.678	0	162.592	0	155.685	0	0
42	Polygon	42	18° 7' 36.820" N	81° 6' 40.997" E	145.851	0	18.745	0	155.451	0	147.994	0	0

1 (0 out of 700 Selected)

Canopy_Poly_final_v4

Extracted Tree Parameters- GIS Database

Leaders in LiDAR

FID	Shape	ID	Lat	Long	Gnd_Elev	CPA_LDR	TH_LDR	CBH_LDR
0	Polygon	0	18° 7' 40.681" N	81° 6' 43.237" E	146.2	10.8	15.0	7.6
1	Polygon	1	18° 7' 36.836" N	81° 6' 40.497" E	145.4	10.0	4.5	2.4
2	Polygon	2	18° 7' 37.040" N	81° 6' 40.144" E	144.7	48.2	16.5	7.3
3	Polygon	3	18° 7' 39.450" N	81° 6' 38.452" E	145.6	56.4	17.2	2.3
4	Polygon	4	18° 7' 39.175" N	81° 6' 38.326" E	145.1	1.2	5.1	1.3
5	Polygon	5	18° 7' 39.181" N	81° 6' 38.479" E	145.2	1.9	4.7	1.9
6	Polygon	6	18° 7' 35.510" N	81° 6' 40.345" E	145.9	24.5	15.2	6.4
7	Polygon	7	18° 7' 35.309" N	81° 6' 40.585" E	145.5	60.4	18.6	8.0
8	Polygon	8	18° 7' 38.587" N	81° 6' 42.885" E	145.7	3.6	7.2	4.2
9	Polygon	9	18° 7' 38.414" N	81° 6' 43.283" E	146.2	35.4	18.0	2.2
10	Polygon	10	18° 7' 38.145" N	81° 6' 42.871" E	145.9	5.4	4.0	1.9

Carbon Stock Estimation – Allometric Equation

- Carbon Stock = f(TH, CBH, CPA, Tree Specie)

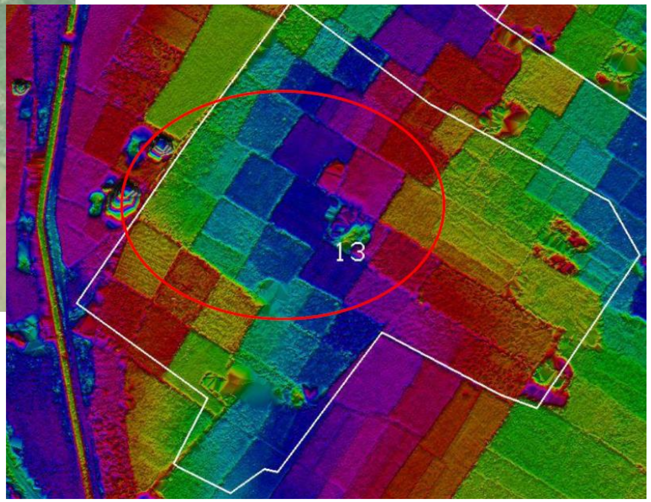
- Allometric equations are to be developed
  - Using the parameters derived from LiDAR
  - With the help of existing allometric equations with FSI

LiDAR and Photograph together prove best solution

LAND RECORD MAPPING SURVEY AND RESURVEY

Identification of field boundaries

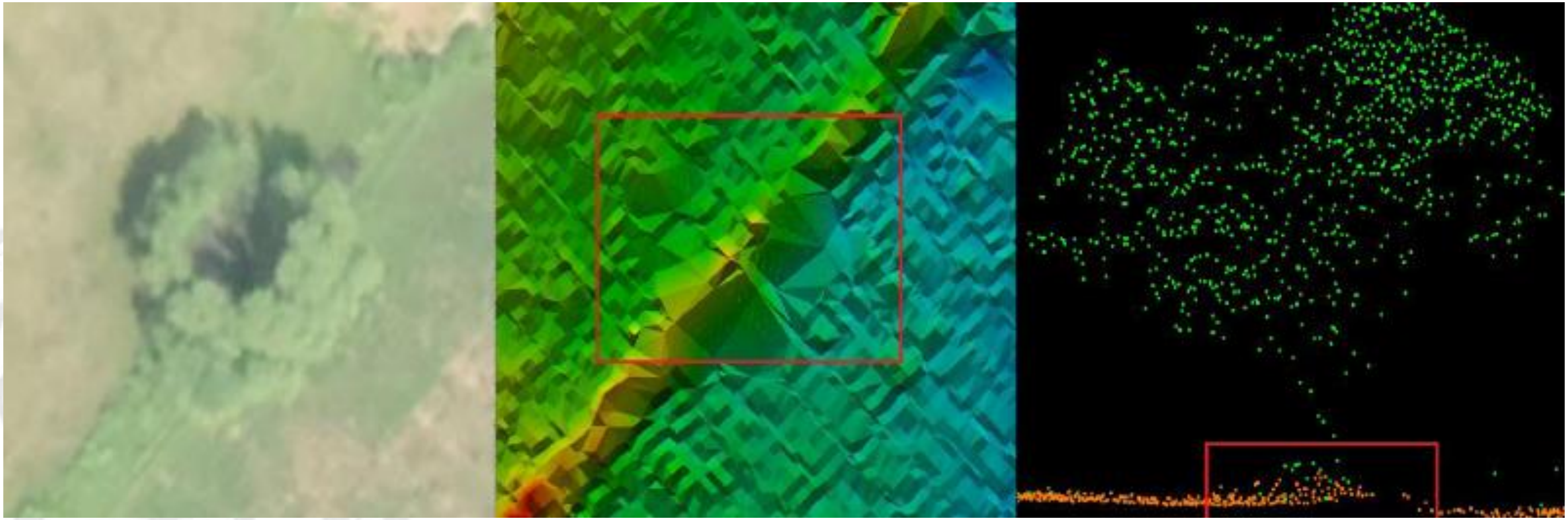
Invisible boundaries identified due to elevation differences



Identification of field boundaries

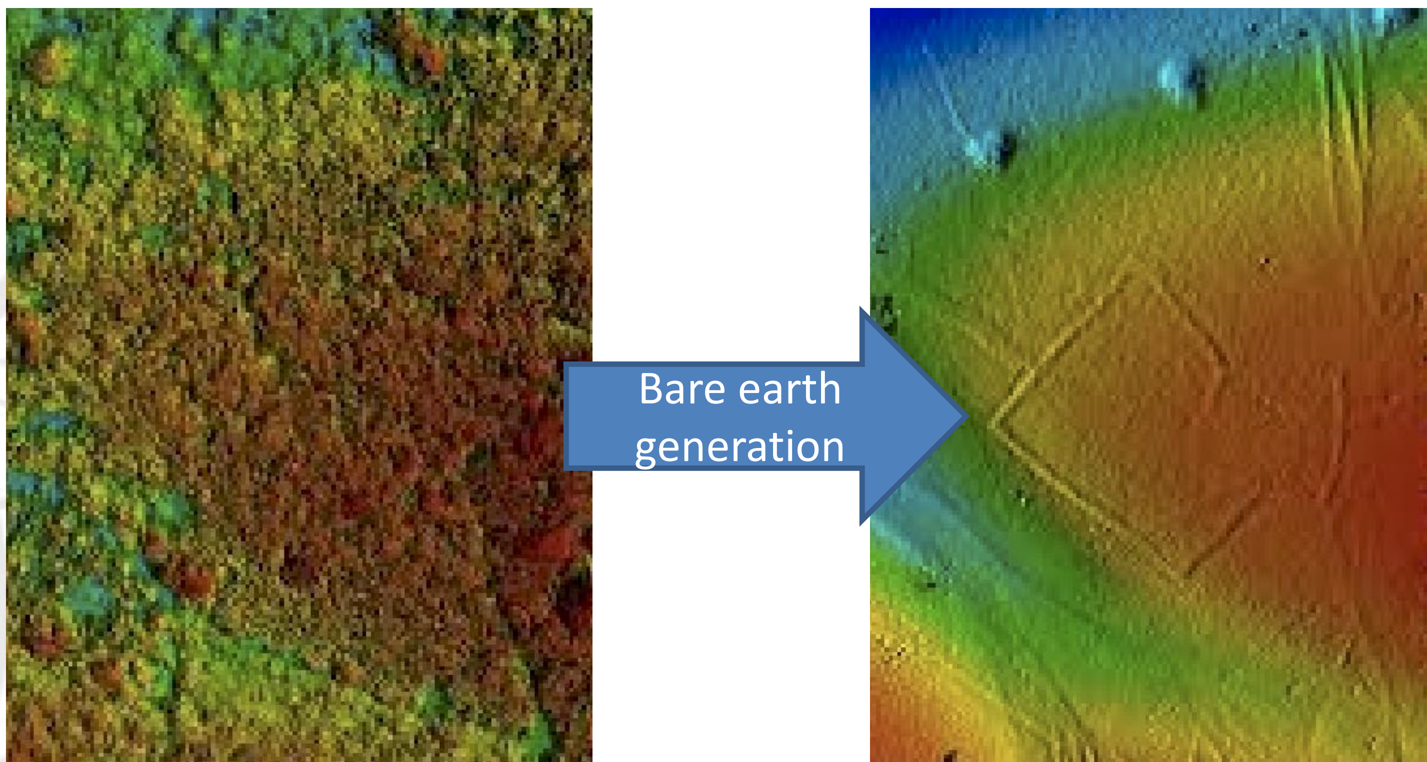
Mapping boundaries under foliage

- Field boundary invisible in photograph is seen in LiDAR data



Mapping boundaries under foliage

- Objects underneath foliage can be mapped by removing over-ground foliage

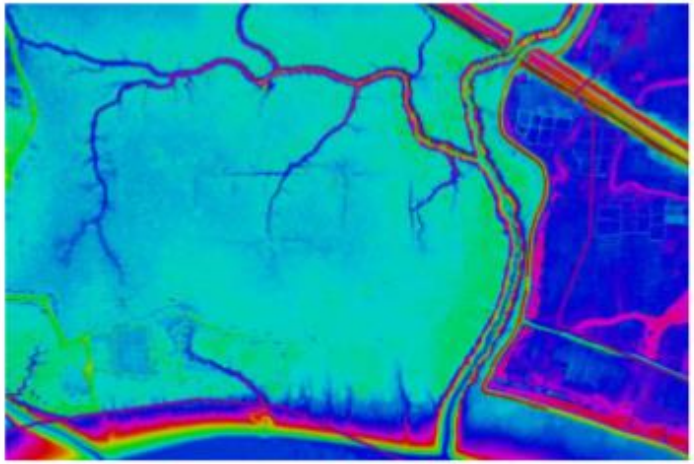


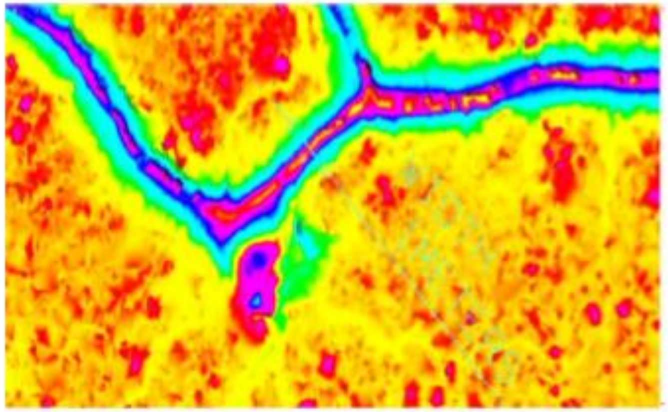
LiDAR and Dam Reservoir Analysis

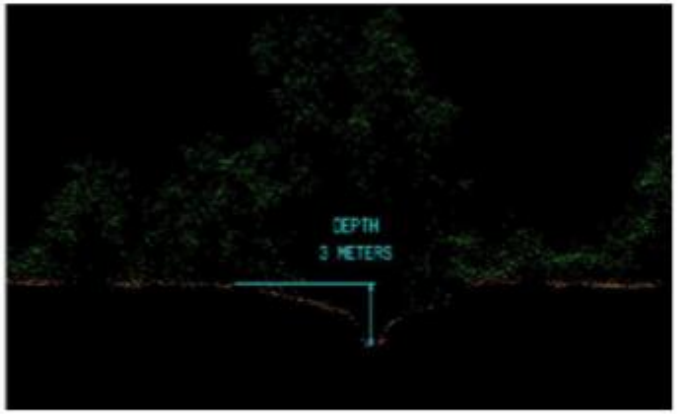
Channel Mapping Using LiDAR Data

- LiDAR measures channels even if these are under forest
  - Dry channel depth
  - Channel width
  - Side slopes

- No need of a separate survey for this

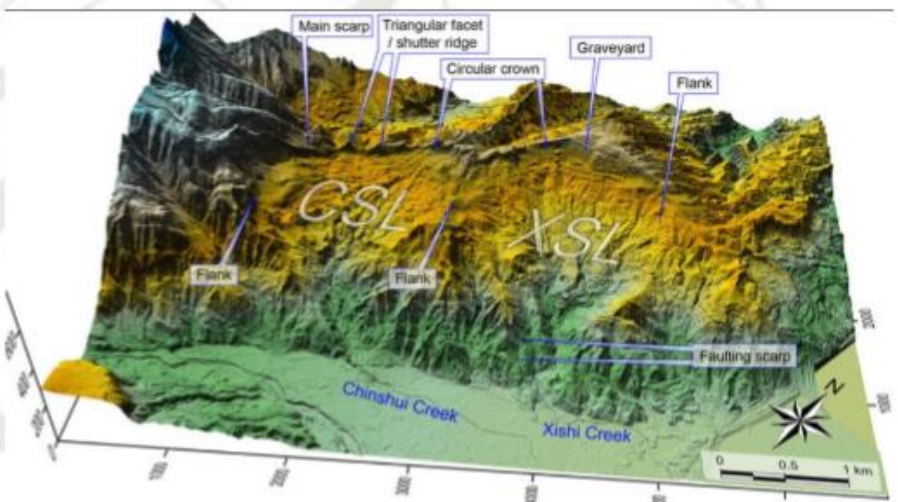






Geological Mapping Using LiDAR Data

- LiDAR is ideal tool for
  - Geomorphological studies
  - Fault identification and mapping
  - Lithological mapping
  - Tectonic geomorphology



Dong, J Geol Geosci 2012, 1:1
http://dx.doi.org/10.4172/2329-6755.1000e102

Geology & Geosciences

Editorial | Open Access

Editorial: Applications of Light Detection and Ranging (LiDAR) in Geosciences

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Airborne discrete-return LiDAR can acquire (x, y, z) coordinates of ground objects with sub-meter level accuracy for generating high-resolution Digital Elevation Models (DEM). The major applications of discrete-return LiDAR in geosciences can be summarized in the following six fields. (1) Changes in geomorphic surfaces, including a) fundamental topographic signatures such as the formation of evenly spaced ridges and valleys [1]; b) alluvial fan formative processes and debris flow deposits [2,3]; c) volumetric changes of costal dunes and beach erosion [4,5]; d) changes in glaciers/ice sheets and glacial sediment redistribution [6,7]; and e) lava flow dynamics and rheology [8-10]. (2) Surface hydrology and flood models [11-15]. (3) Tectonic geomorphology [16-20]. (4) Lithological mapping [21,22]. (5) Rock mass structural analysis [23-25]. (6) Natural hazards, such as landslides, debris flows, and earthquake damage [26-31].

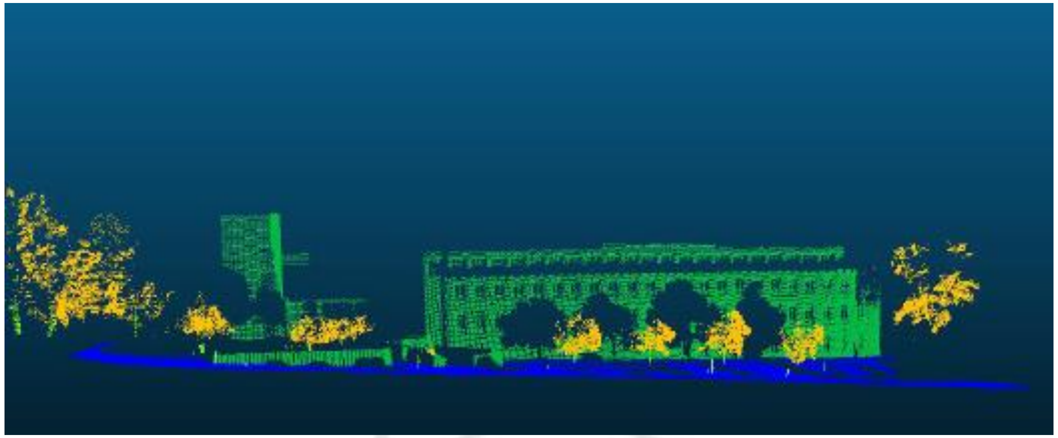
Research being pursued at IIT Kanpur

Sample papers in last few months

Kumar, B., Pandey, G., Lohani, B.,	2018	A **multi-faceted CNN architecture** for automatic classification of mobile LiDAR data and an algorithm to reproduce point cloud samples for enhanced training	ISPRS, 147 (2019) 80-90
Kumar, B., Lohani, B., Pandey, G.,	2018	Development of **deep learning architecture for automatic classification of outdoor mobile LiDAR** data	IJRS, DOI: 10.1080/01431161.2018.1547929
Lohani, B., Singh, S., Chaudhary, D. and Nagarajan, B.	2018	A New Approach for Determination of **Solar Potential** Using Terrestrial Images	Remote Sensing Letters, 2018 VOL. 9, NO. 7, 636–645 https://doi.org/10.1080/2150704X.2018.1452061
Kumar, B., Yadav, M., Lohani, B., Singh, A. K.,	2018	A two-stage algorithm for **ground filtering of airborne laser scanning** data	International Journal of Remote Sensing. DOI: 10.1080/01431161.2018.1466074
Yadav, M., Singh, A. K., Lohani, B.,	2018	Computation **of road geometry parameters** using mobile LiDAR system	Remote Sensing Applications: Society and Environment, https://doi.org/10.1016/j.rsase.2018.02.003
Lohani, B. and Ghosh, S.	2017	**Airborne LiDAR Technology**: A Review of Data Collection and Processing Systems	Proc. Natl. Acad. Sci., India, Sect. A Phys. Sci. https://doi.org/10.1007/s40010-017-0435-9
Yadav, M., Singh A., and Lohani, B.,	2017	Extraction **of road surface from mobile LiDAR** data of complex road environment	International Journal of Remote Sensing 38(16), 4645-4672
A.Kealy, S. Goel; . V.Gikas,G. Retscher, c.	2017	**Cooperative localization** of unmanned aerial vehicles using GNSS, MEMS inertial and UWB	ASCE Journal of Surveying Engineering, Vol. 143, Issue 4 (November 2017)

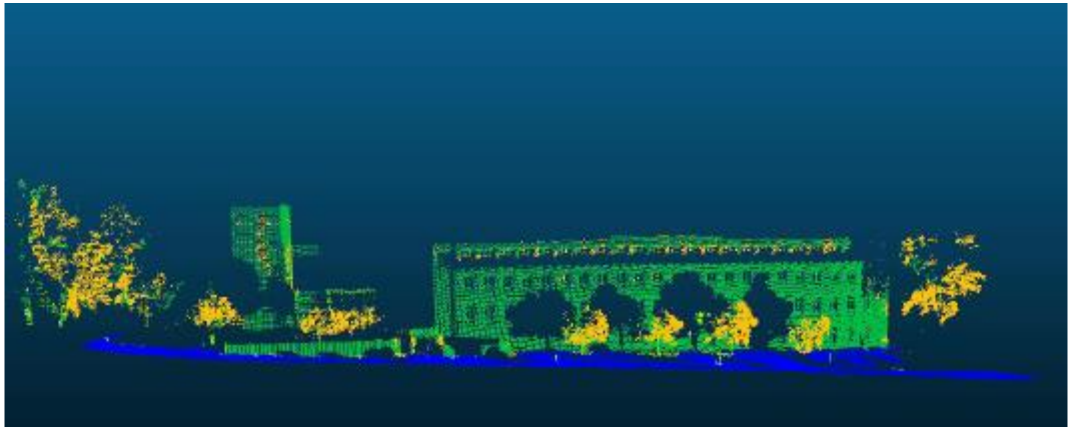
Some results of Deep Learning Classification realized

Oakland data set

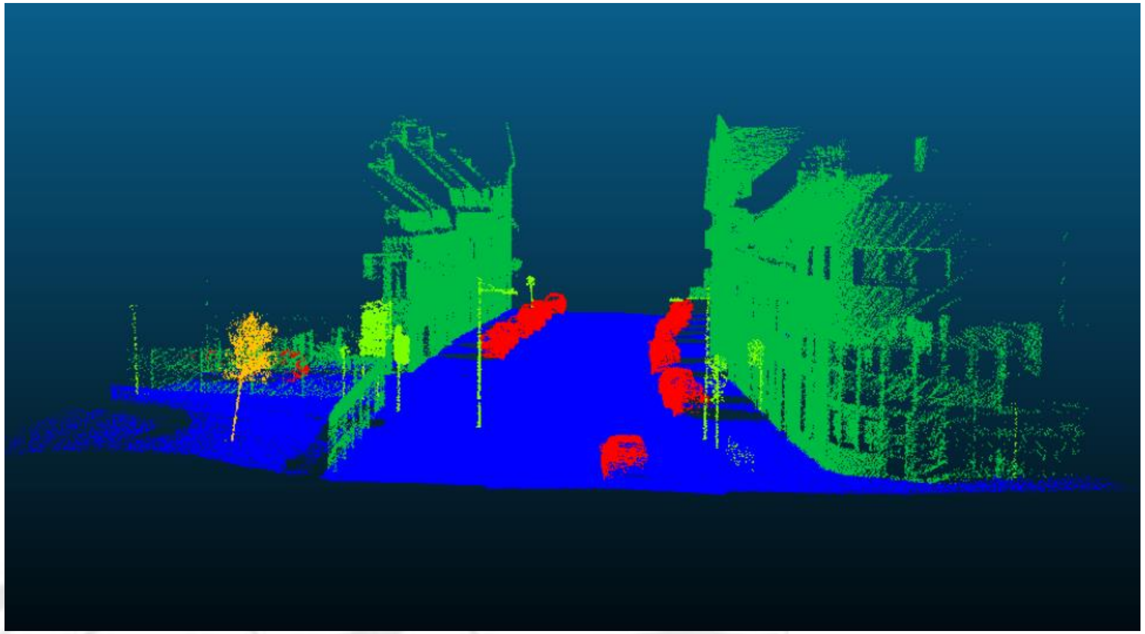


Classes: Ground, House, Pole, Tree

Accuracy 96.5%, Kappa 91.9%



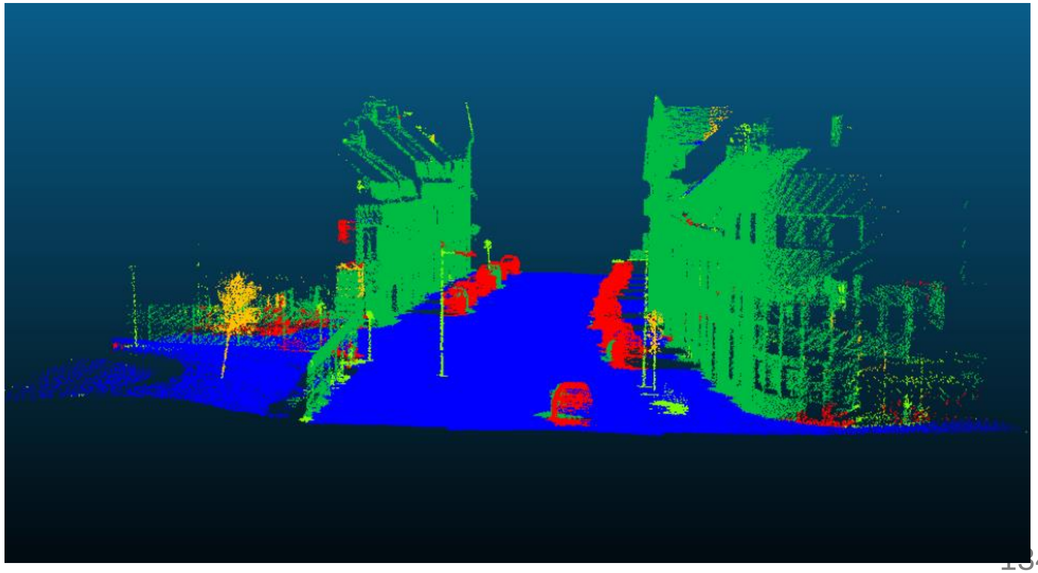
Some results of Deep Learning Classification realized



Lille data set

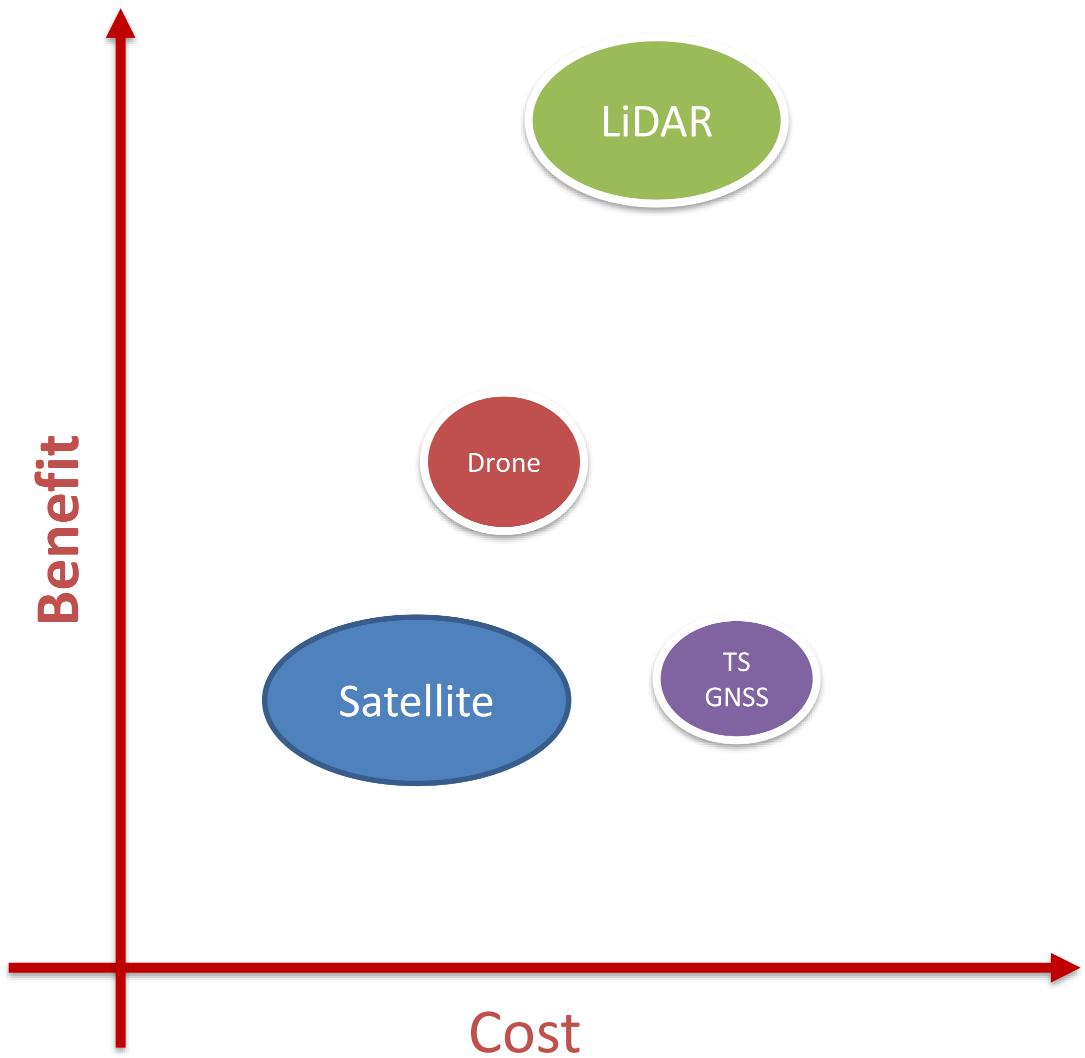
Classes: Ground, House, Pole, Tree

Accuracy 96.2%, Kappa 92.5%



What about the cost?

- Cost is similar to Total Station / GPS Survey
- Satellite data can be cheaper-but with poorer accuracy and not complete coverage of terrain
- LiDAR most cost-effective in terms of cost/benefit



Thank You

Geokno on YouTube:
https://www.youtube.com/channel/UCTcHSwRhGvusB3NxACelY3g/videos