

# CE676-Lecture 4

## LiDAR Introduction II

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Bharat Lohani  
Professor, Geoinformatics  
IIT Kanpur

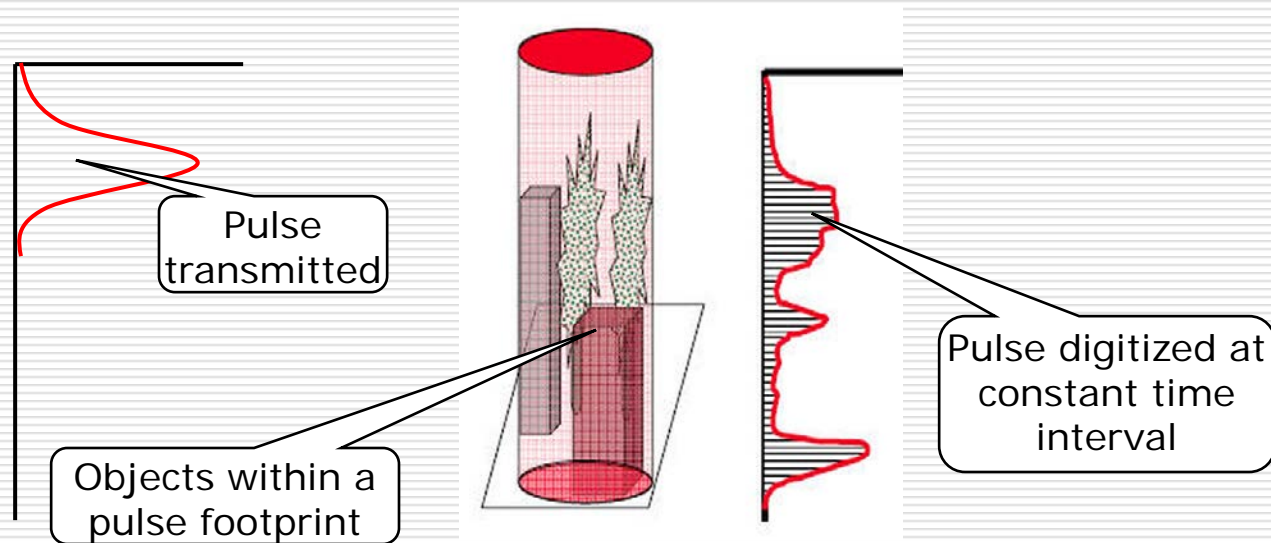
# Recapitulation

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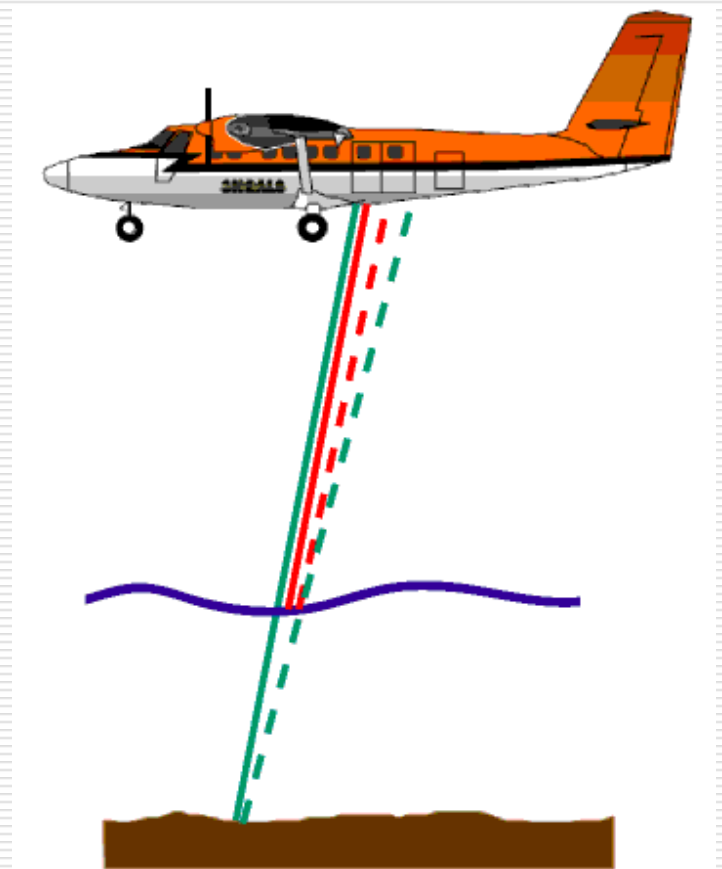
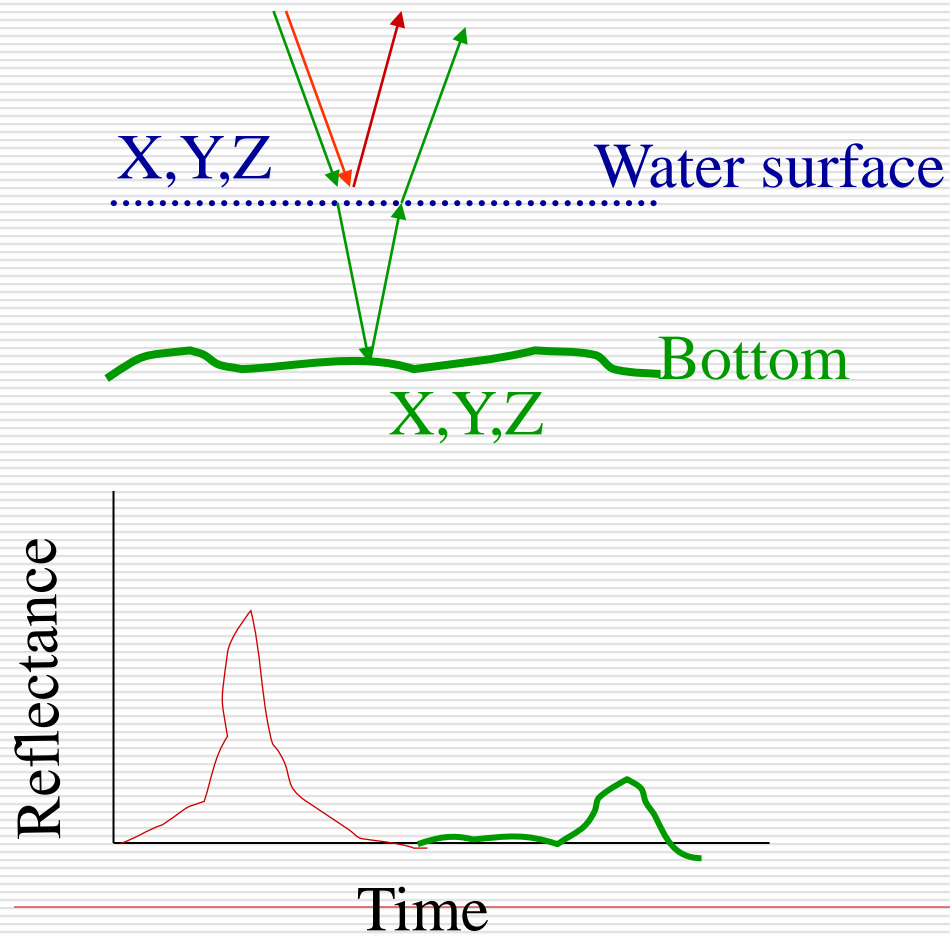
- What is topographic data
  - 3D data
  - 3D geometry
- Principle of operation of LiDAR
- Multiple return
- Steps in initial data processing resulting in (E, N, H, I)
- What is LiDAR Data

# LiDAR full waveform digitization

- Complete waveform to give information on vertical structure of the object

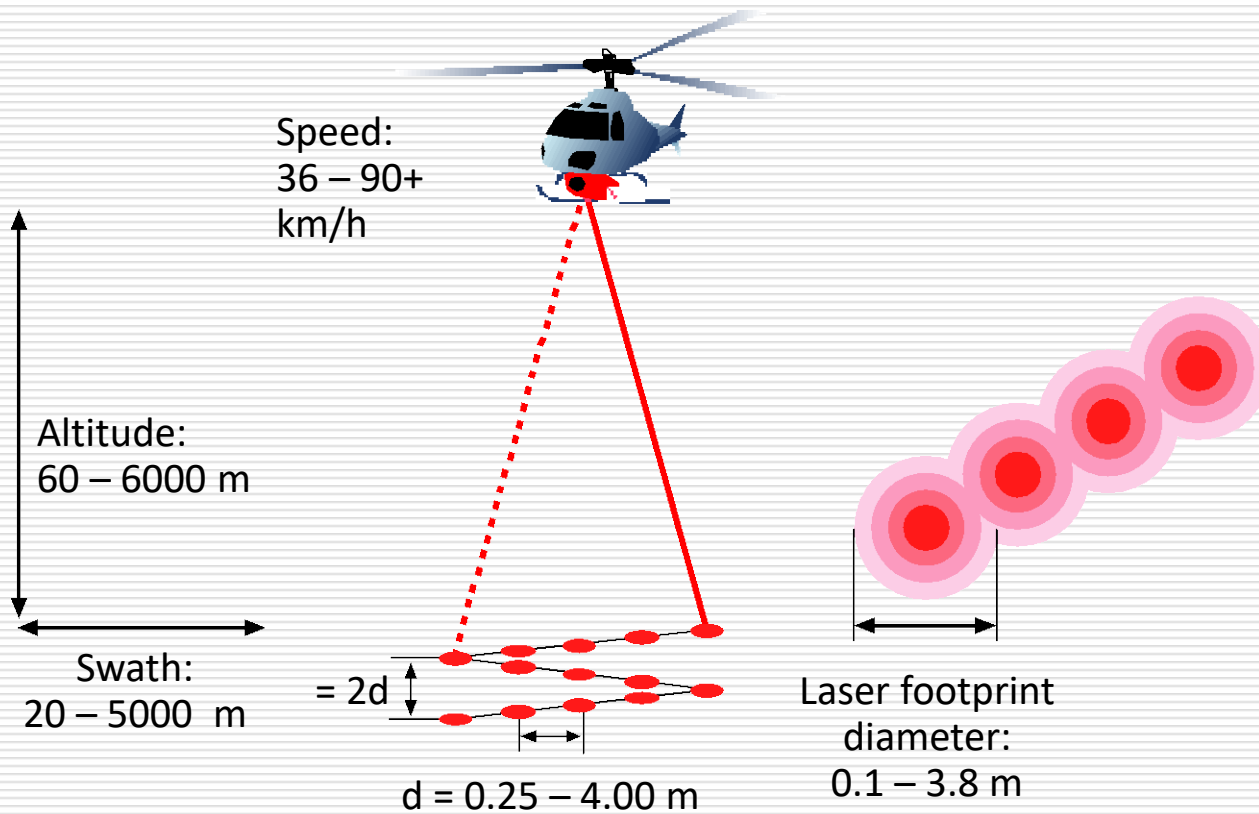


# Bathymetric LiDAR



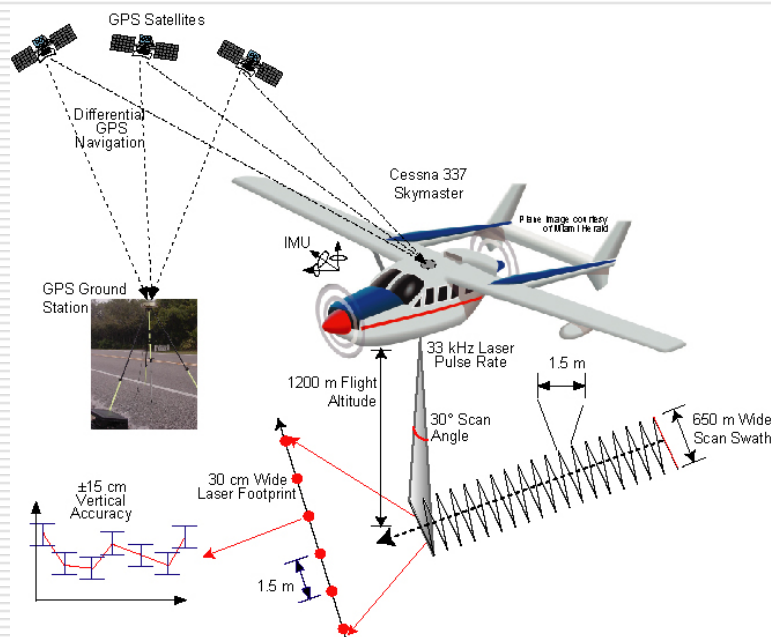
# Principle of LiDAR

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# Flight Planning

- ❑ What controls flight plan ?
- ❑ How to decide where to fly and with what parameters?



IHRC (2012)

# User Requirements

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- Data density
  - Minimum data density
  - Effect of data density
  
- Overlap and spacing (USGS, 2010)
  - Specific overlap
  - Comparable along track and across track spacing

# User Requirements

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- Accuracy of 3D data
  - Vertical accuracy
  - Horizontal accuracy
  
- Simultaneous photographic data acquisition
  - Ground sampling distance (GSD)
  - Specific sidelap and endlap



# Characteristics of Sensors

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- LiDAR Sensor
  - Scanning pattern (distribution of points)
  - Beam divergence (uncertainty in horizontal position)
  - PRF
  - FOV
  - Scanning frequency
  - Measures: range and scan angle
  
- Camera
  - GIFOV / GSD
  - Exposure interval and exposure time
  - Measures: textural information of ground surface

# Flying Operations

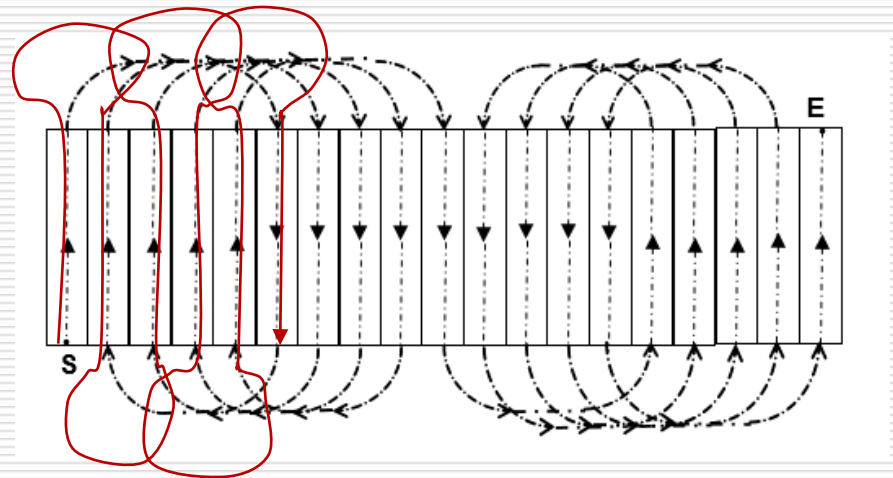
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- Flying direction
  - Longer direction of AOI (economical arrangement)
  - Longer lines to shorter lines
  
- Banking of aerial platform
  - Level turn with constant banking angle
  - Flying crew's comfort
  - GPS lock
  - Minimum flight duration (economic, disturbance, less fatigue)

# Flying Operations

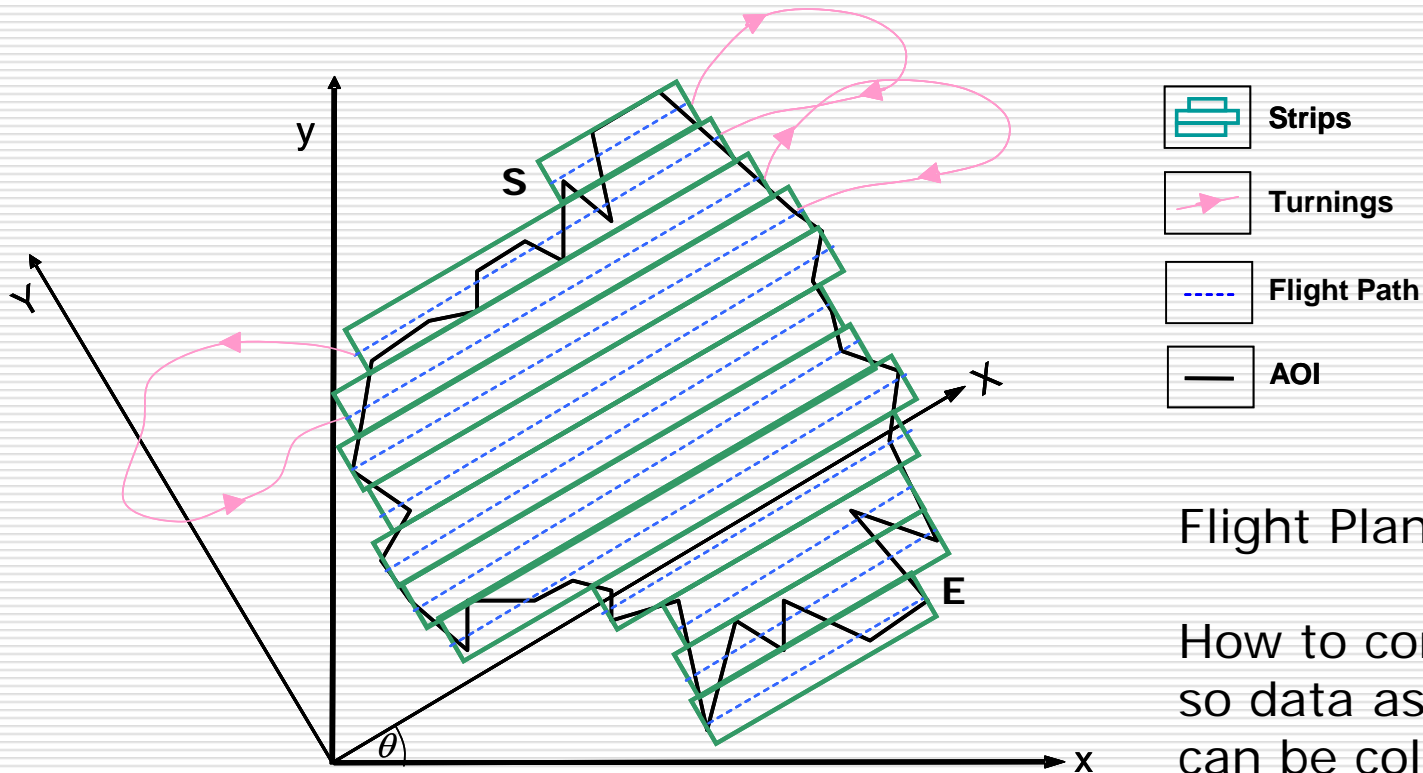
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- Turning
  - Consecutive turning
  - Non-consecutive turning
  
- Cushion period
  - Smooth flying operations
  - 15-60 seconds



# What controls flight planning

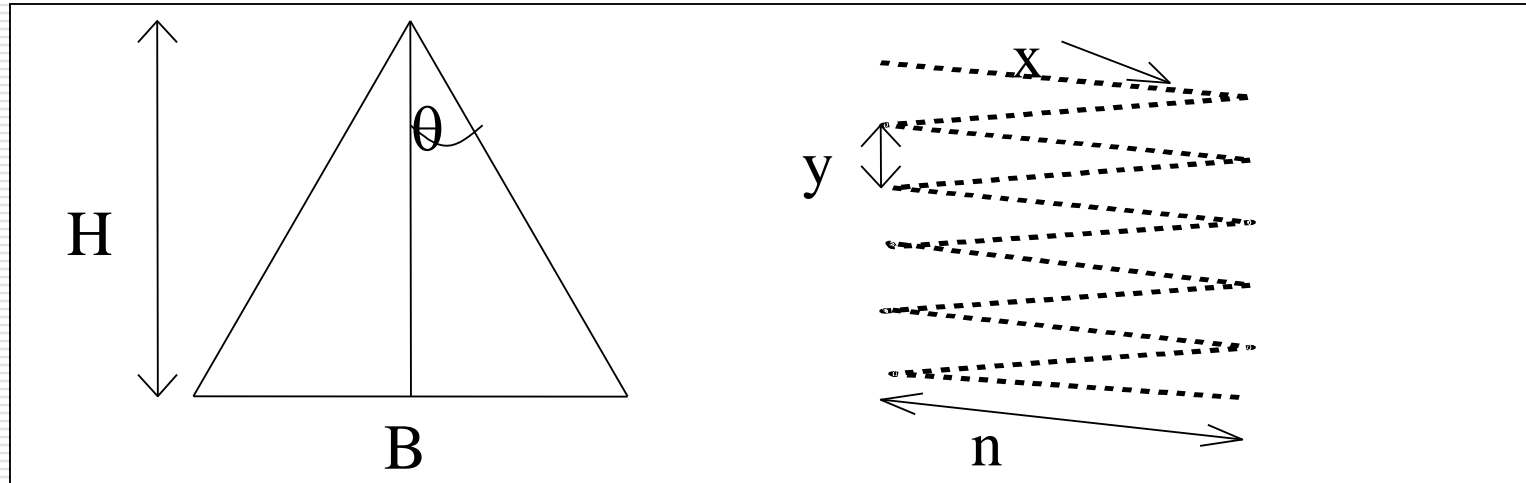
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Flight Planning:

How to conduct flight so data as desired can be collected in least time.

# Flight planning



- ◆ Choice of platform: fixed-wing or helicopter
- ◆ Flying height ' $H$ '
- ◆ Flying speed ' $v$ '
- ◆ Scan and laser-firing frequencies ' $f$  &  $p$ '

- ◆ Scan angle ' $\theta$ '
- ◆ Single and multiple data returns

*Data density and accuracy in 3D space is a function of the above parameters.*

# LiDAR Scanner: ALTM 3100EA

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## Scanning frequency

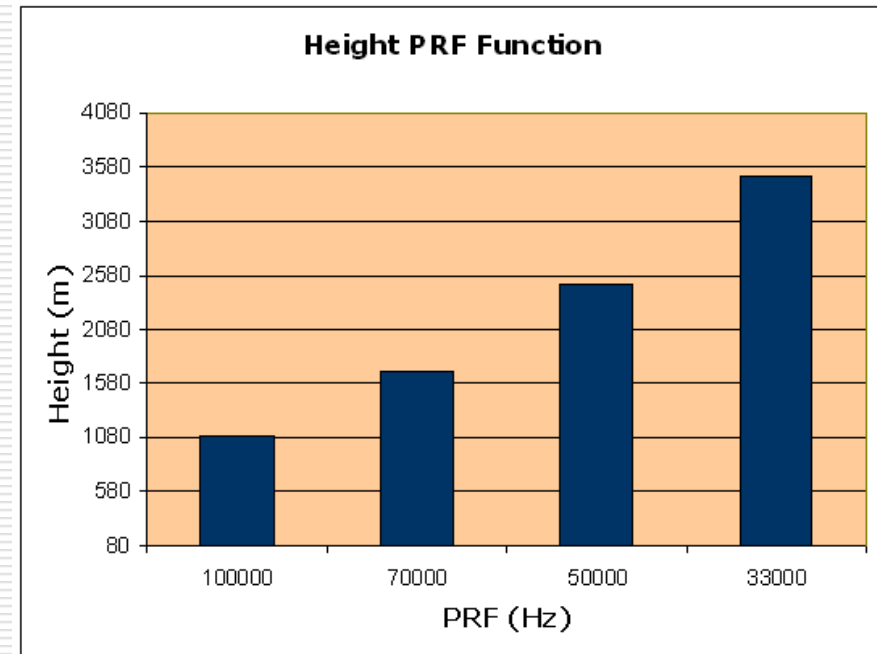
0 – 70 Hz (+1Hz)

## Scan angle

0 - 25° (± 1°)

## PRF

$$F = \begin{cases} 33\text{kHz} & \text{if } (80 \leq H \leq \max 3500\text{m}) \\ 50\text{kHz} & \text{if } (80 \leq H \leq \max 2500\text{m}) \\ 70\text{kHz} & \text{if } (80 \leq H \leq \max 1700\text{m}) \\ 100\text{kHz} & \text{if } (80 \leq H \leq \max 1100\text{m}) \end{cases}$$



# Relations

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$$\text{Data Density } \rho = \frac{F}{BV}$$

$$\text{Spacing in Along Direction } D_A = \frac{V}{f}$$

$$\text{Spacing in Transverse Direction } D_T = \frac{2fB}{F}$$

$$\text{Total time } T = \frac{\sum_i^n L_i}{V} + \text{time for turn}$$

# Current Practices

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## ☐ Manual Approach

- Heuristic information (thumb rules)
- Graphs (May, 2008)
- Manual calculations

## ☐ Semi-Automatic Approach

- Using the available software of flight planning
- Flight planning parameters are given by planner
- Trial and error method
- User requirements are satisfied

## ☐ No optimal solution



# New approach

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- Genetic algorithm based approach
- Objective Function-minimize total time of flight

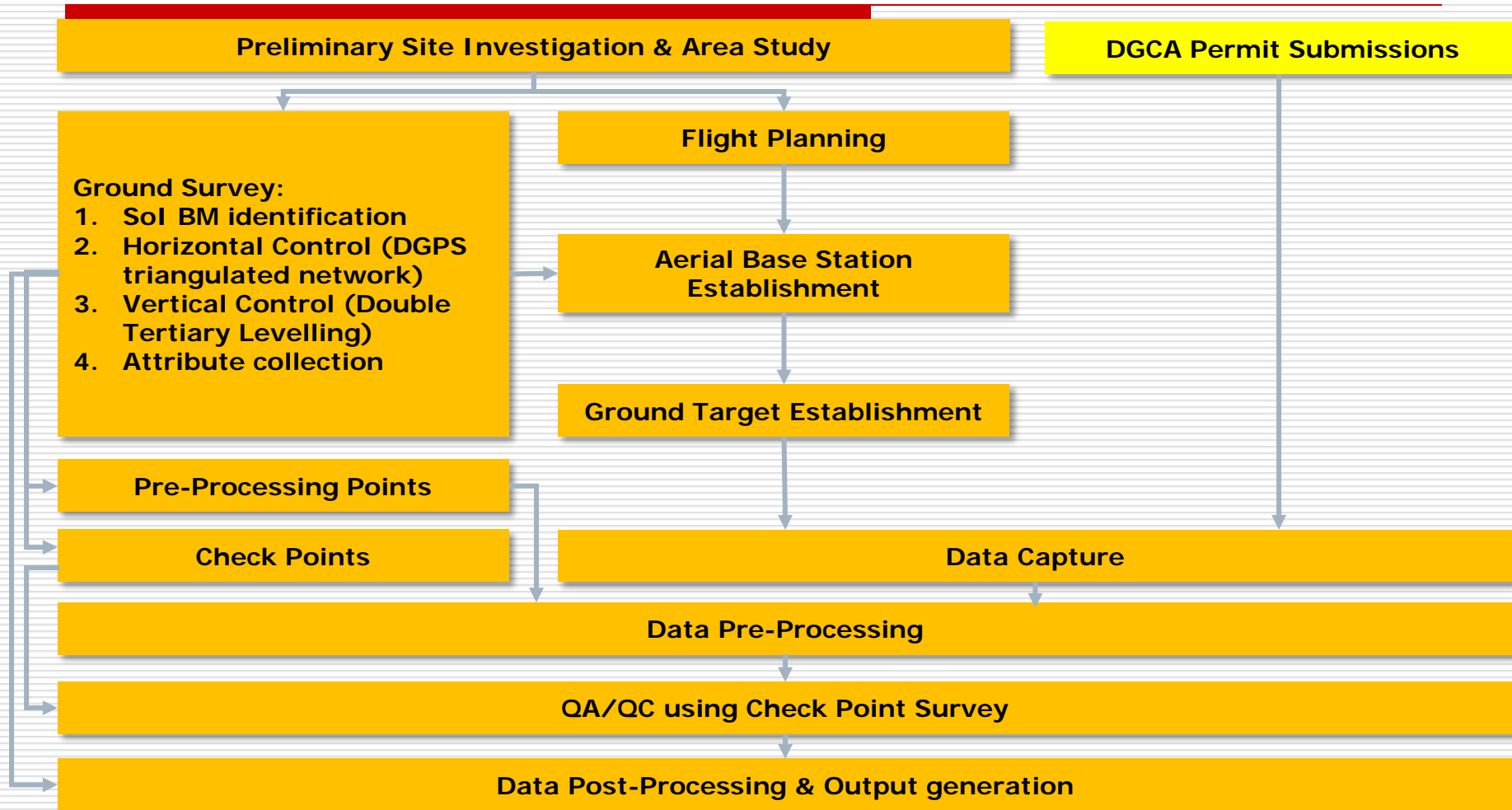
$$\text{Total time } T = \frac{\sum_i^n L_i}{v} + \text{time for turn}$$

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# Project execution Steps

Steps in field to collect LiDAR data

# Methodology



# Sol Bench Mark need to be identified

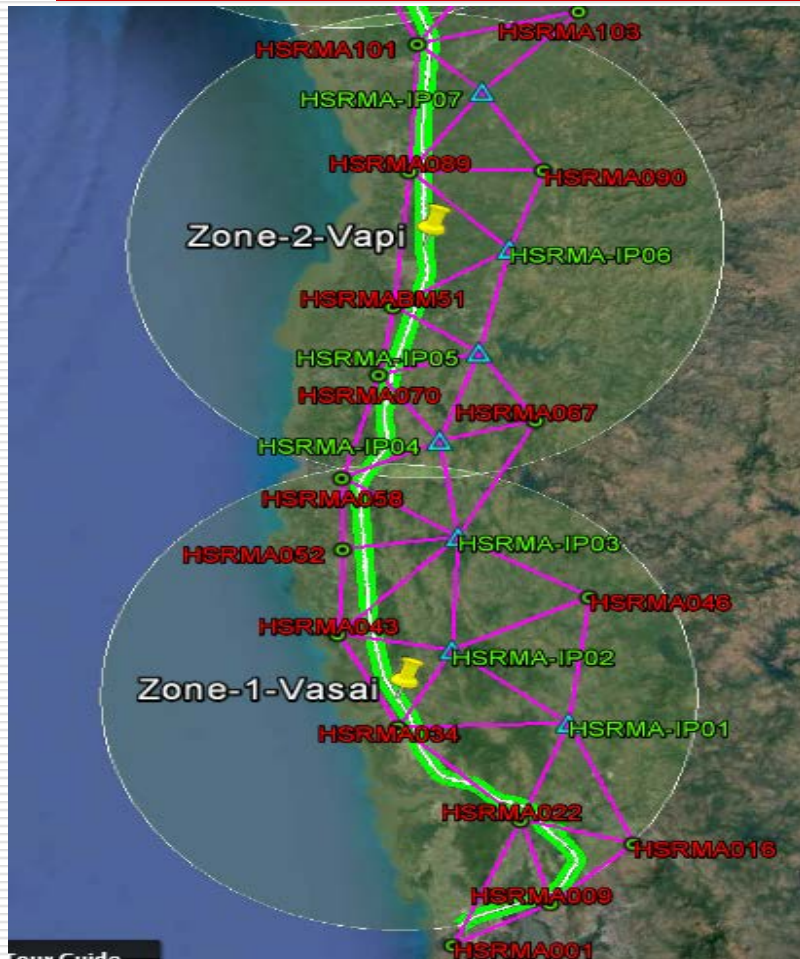
## Sample BM Description

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. on cement on top of masonry reference pillar to type 'B' bench-mark at Kaira.
202	0.00	G.T.S. (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 Dak Bunglow, 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. of the bench-mark.
203	0.92	S.O.M. 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 Ahmadabad-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 Sol GCPs
- Important to check the stability and suitability of Sol BMs
- Levelling network to be established connecting Sol 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

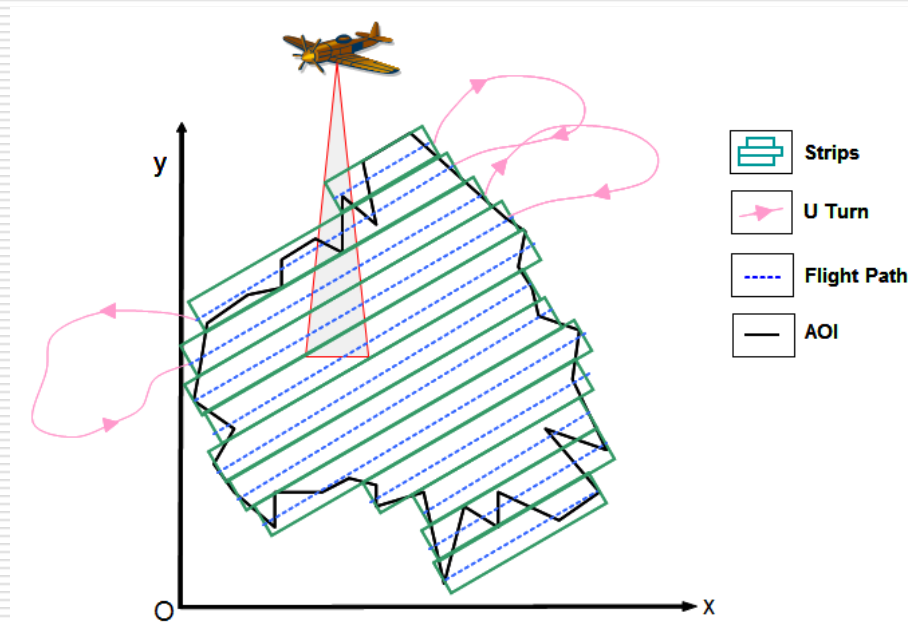
# Flight Planning

## □ Given:

- Data density
- Data accuracy
- Camera GSD

## □ Determine

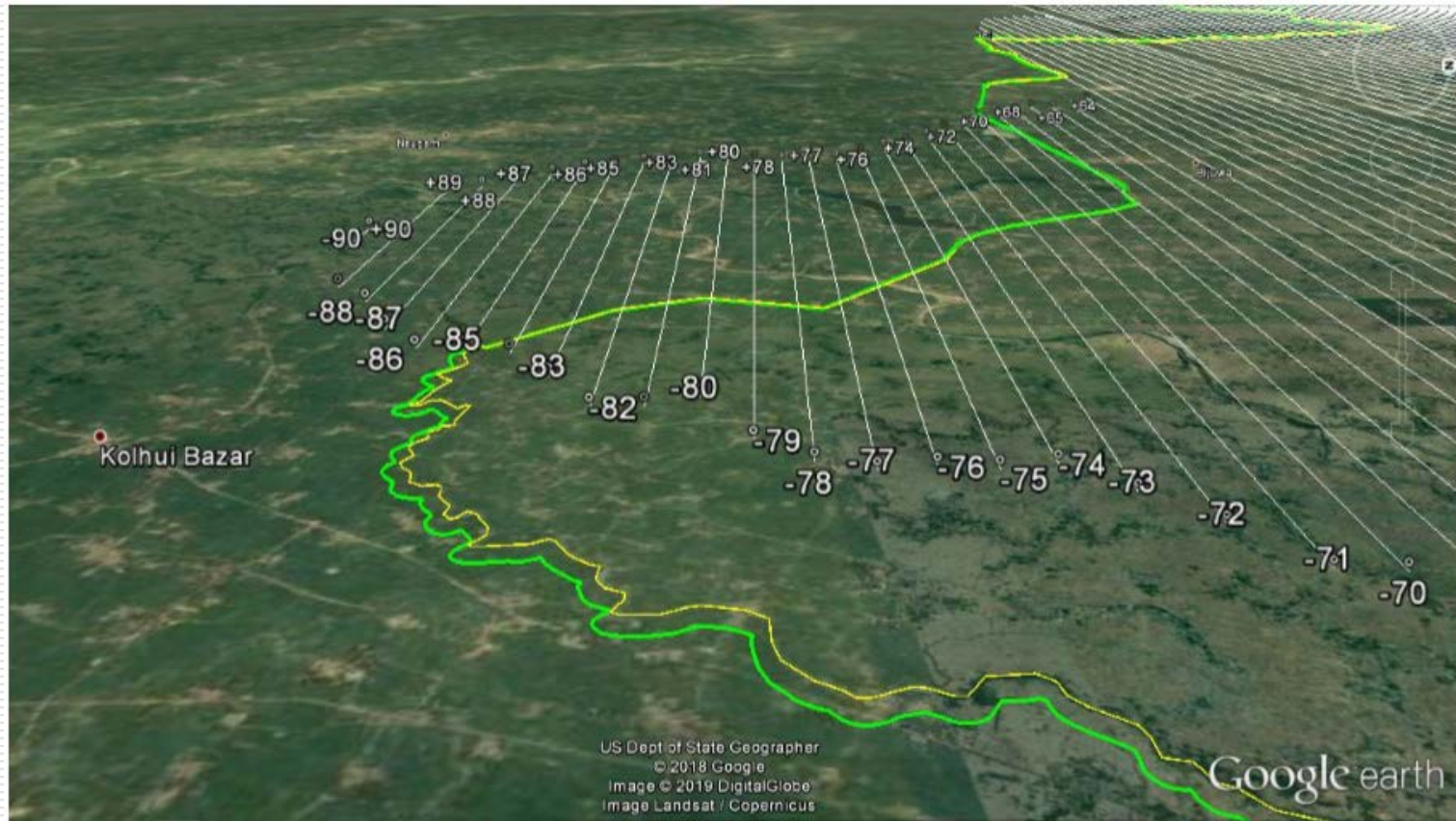
- Flying direction
- Flying height
- Flying speed
- Sensor field of view
- Sensor pulse repetition frequency
- Sensor scanning frequency
- Sensor Scanning angle



Desirable

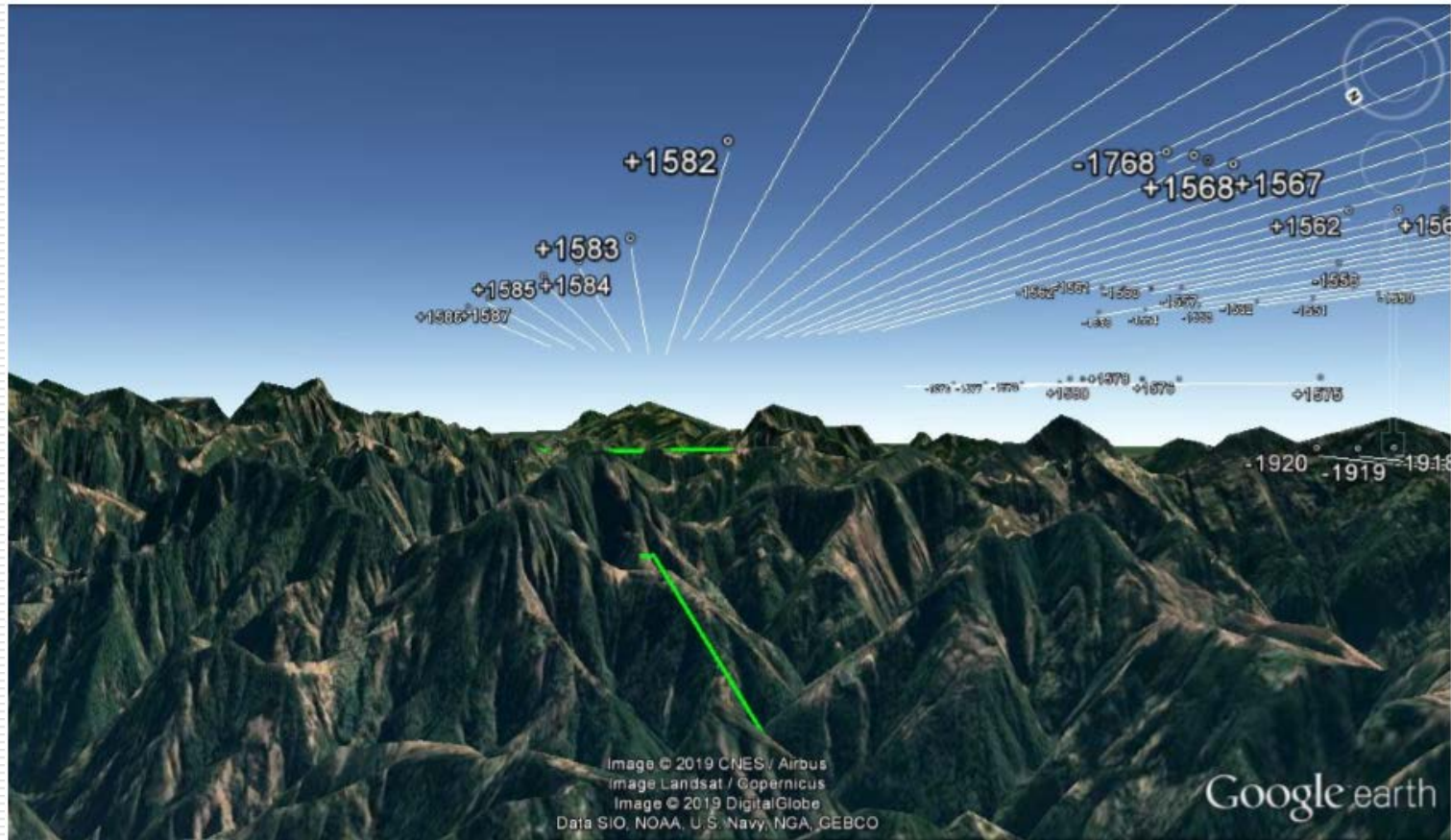
- Minimum cost
- Collect data as desired

# Example of Flight Plan Done

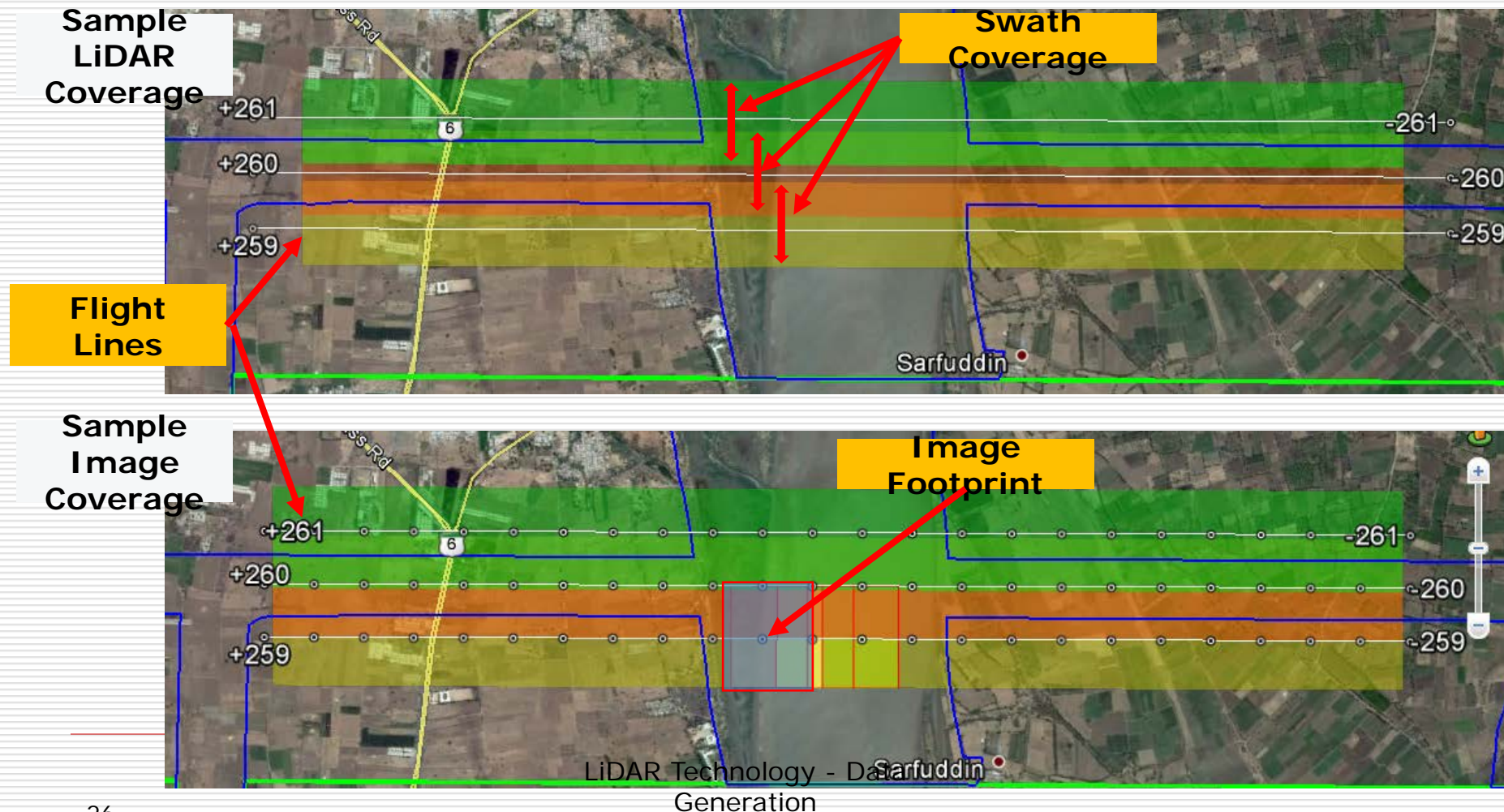




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Algeria	2010	0.0000
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Algeria	2113	



# Flight Path planning – Sample Flight Plan







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

**LiDAR  
Sensor  
Riegl LMS  
Q780**



Minimum Range <sup>11)</sup>  
Accuracy <sup>12) 13)</sup>  
Precision <sup>12) 14)</sup>  
Laser Pulse Repetition Rate  
Effective Measurement Rate  
Laser Wavelength  
Laser Beam Divergence <sup>15)</sup>  
Number of Targets per Pulse

50 m  
20 mm  
20 mm  
up to 400 kHz  
up to 266 kHz @ 60° scan angle  
near infrared  
≤ 0.25 mrad  
digitized waveform processing: unlimited <sup>16)</sup>  
monitoring data output: first pulse

Scanner Performance  
Scanning Mechanism  
Scan Pattern  
Scan Angle Range  
Scan Speed

rotating polygon mirror  
parallel scan lines  
± 30° = 60° total  
14 - 200 lines/sec<sup>17)</sup> @ laser power level ≥ 50%  
10 - 200 lines/sec<sup>18)</sup> @ laser power level < 50%  
Δθ ≥ 0.012° @ laser power level ≥ 50%  
Δθ ≥ 0.006° @ laser power level < 50%  
0.001°  
Option for synchronizing scan lines to external timing signal

Angular Step Width Δθ <sup>19)</sup>

Angle Measurement Resolution  
Scan Sync

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

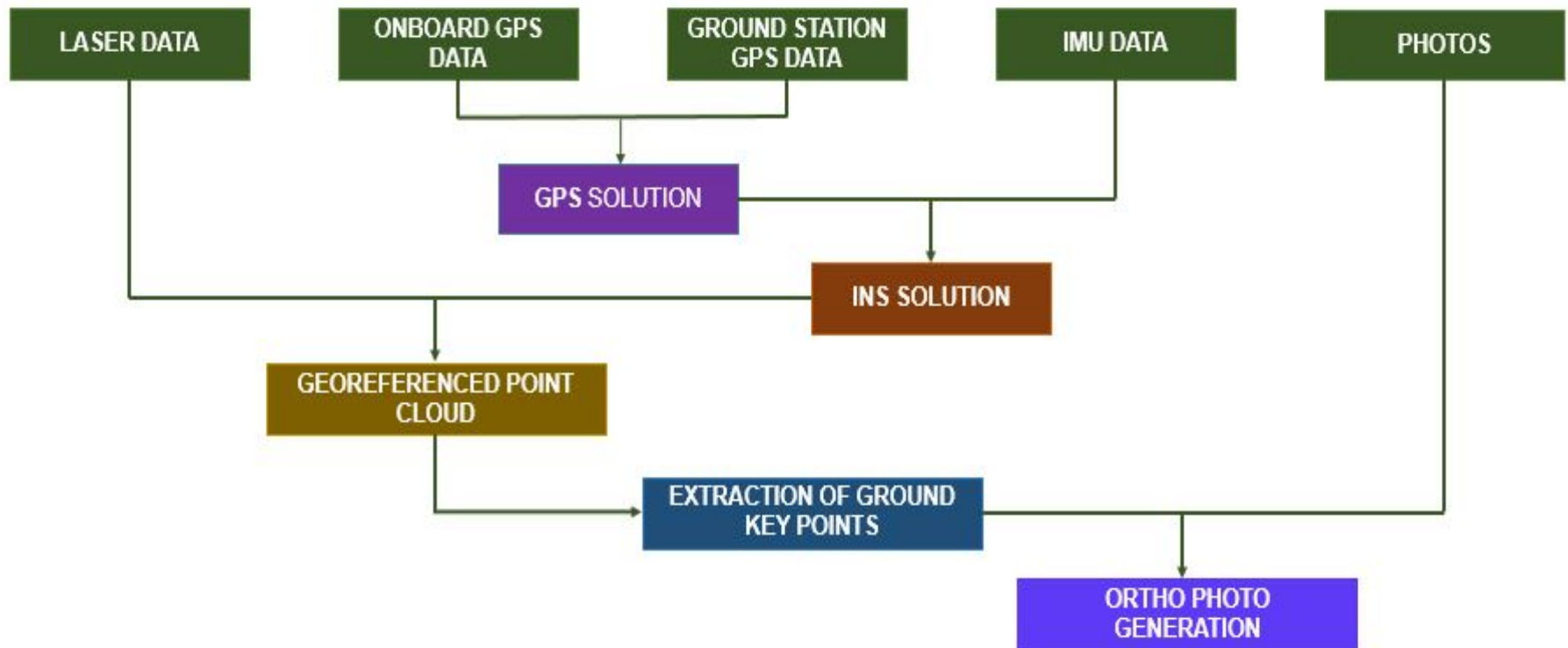
**Positional  
System  
IGI  
AeroControl**



LiDAR Technology - Data  
Generation

# Data Pre-Processing

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# Thanks

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