CE676-Lecture 4
LiDAR Introduction II

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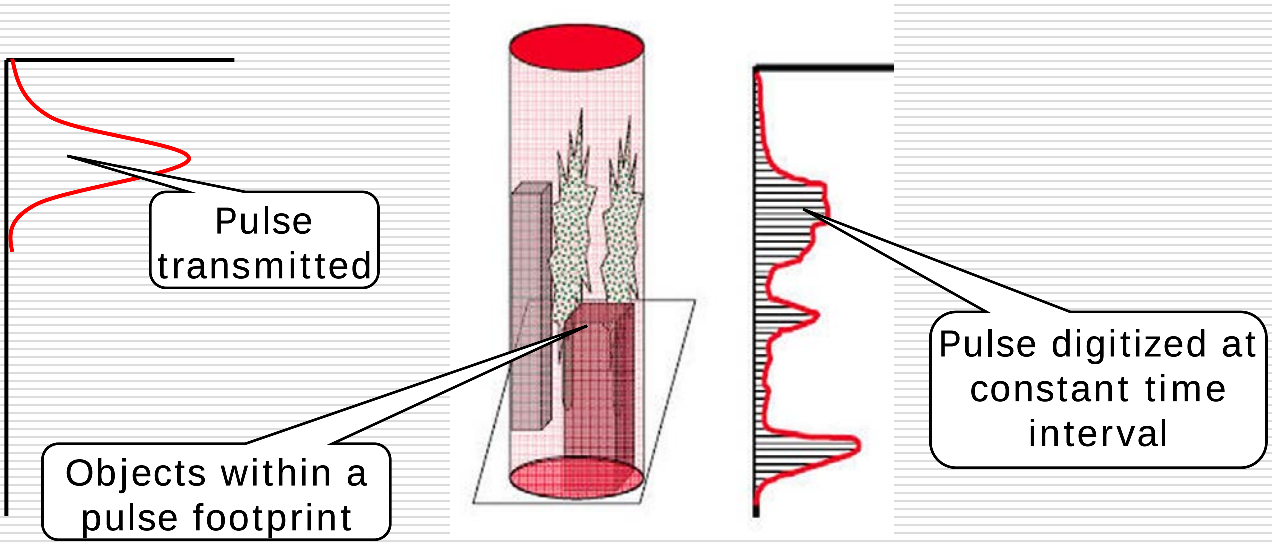
Recapitulation

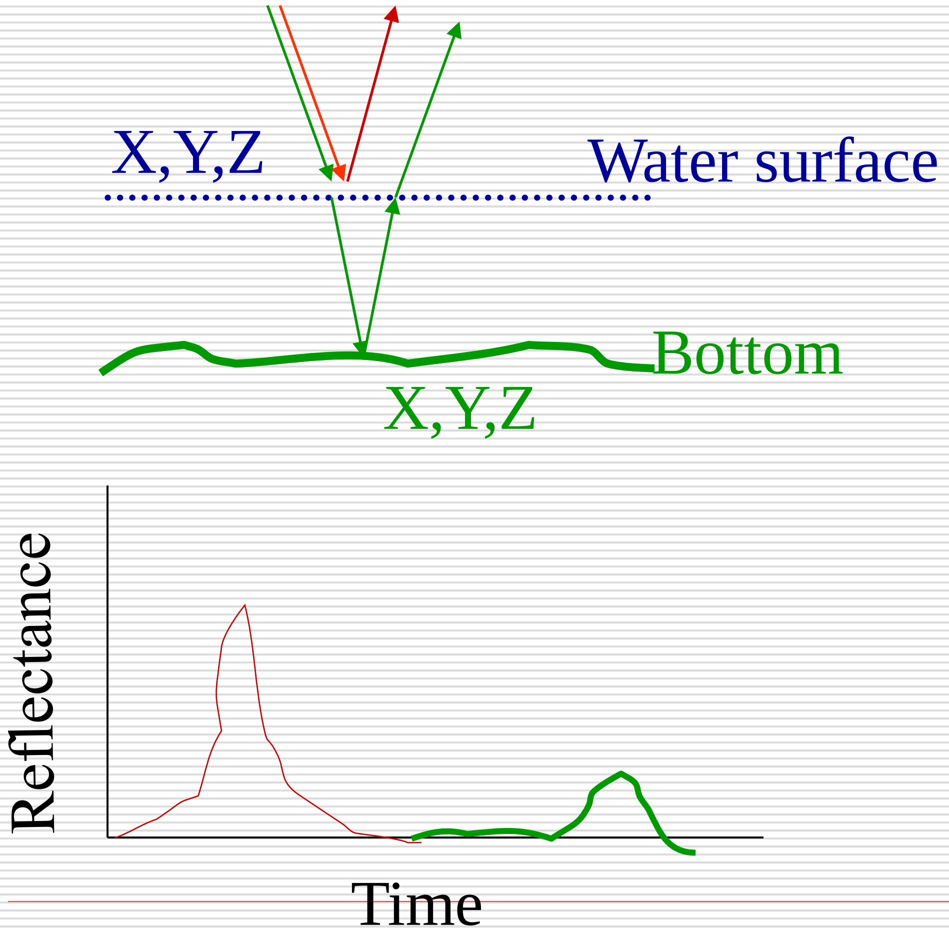
- What is topographic data
  - 3D data
  - 3D geometry
- Principle of operation of LiDAR
- Multiple return
- Steps in initial data processing resulting in (E, N, H, I)
- What is LiDAR Data

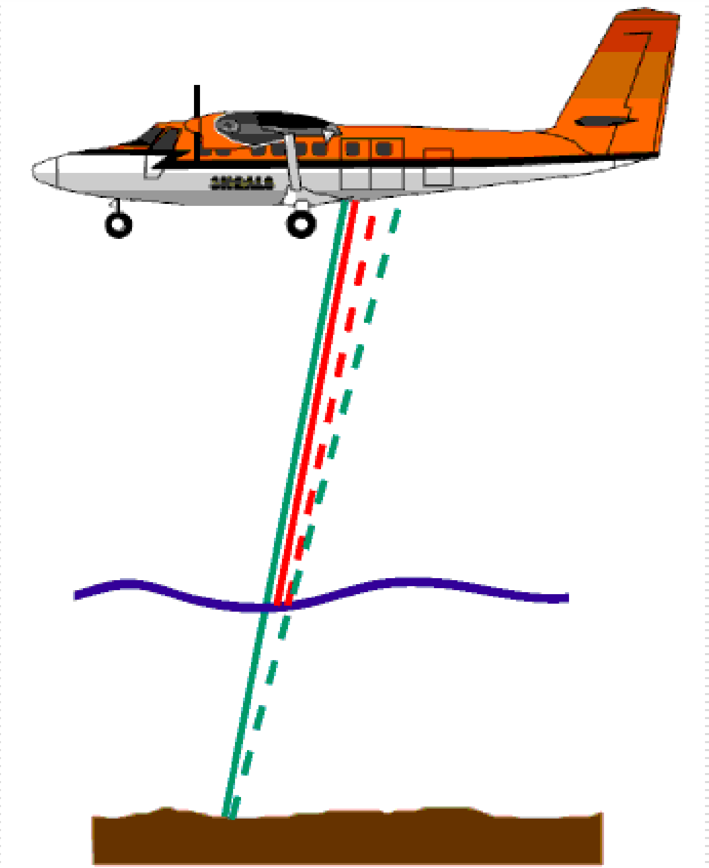
LiDAR full waveform digitization

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

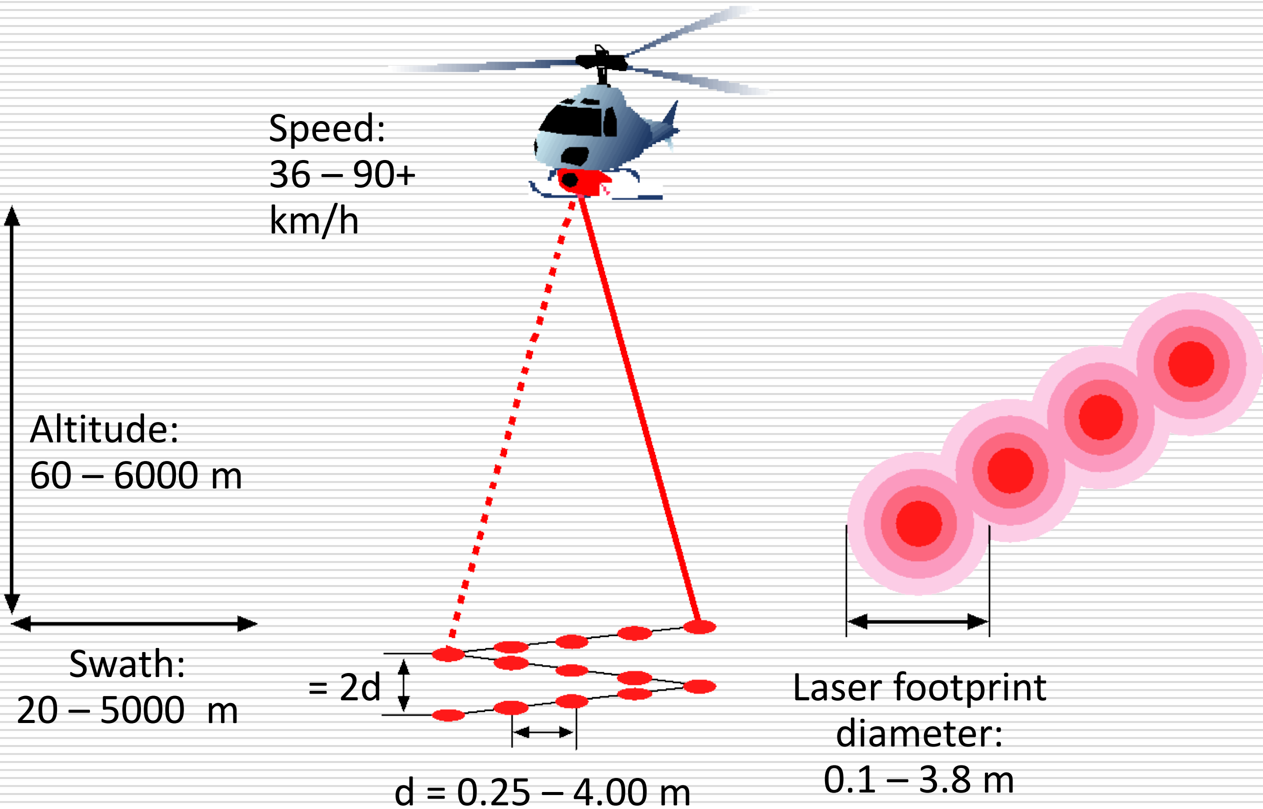


Bathymetric LiDAR



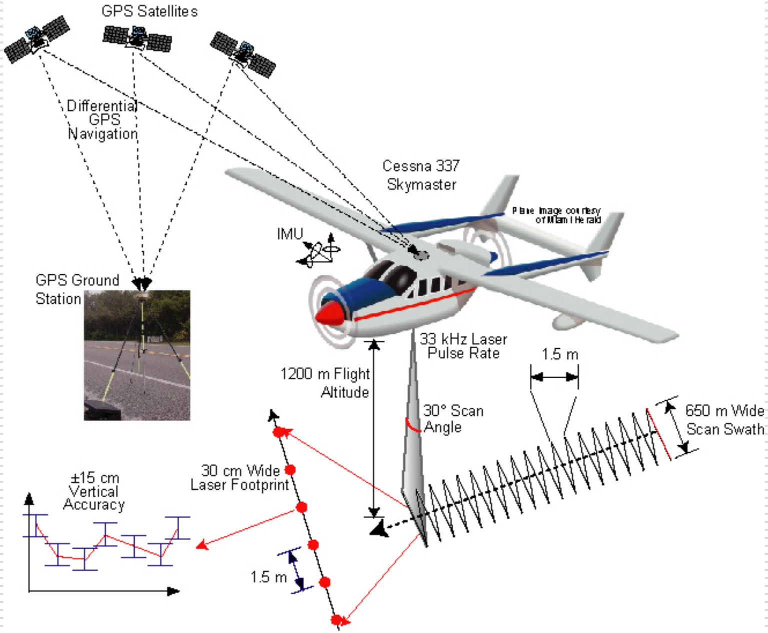


Principle of LiDAR



Flight Planning

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



IHRC (2012)

User Requirements

- 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

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

Characteristics of Sensors

- 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

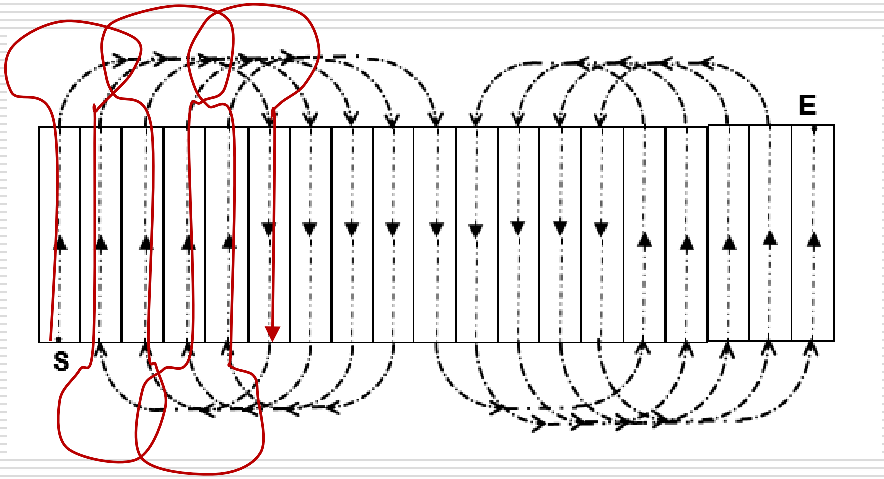
Flying Operations

- 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)

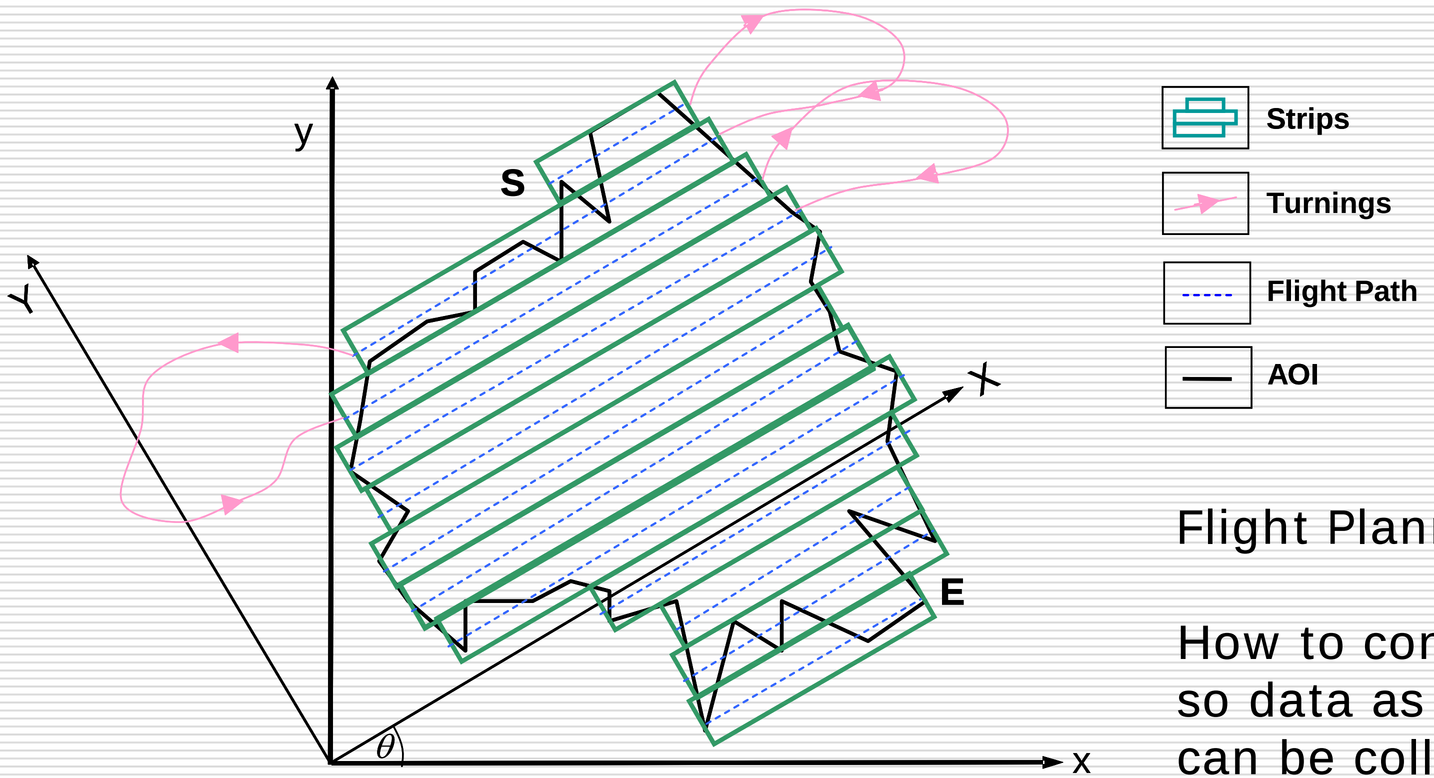
Flying Operations

- Turning
  - Consecutive turning
  - Non-consecutive turning



- Cushion period
  - Smooth flying operations
  - 15-60 seconds

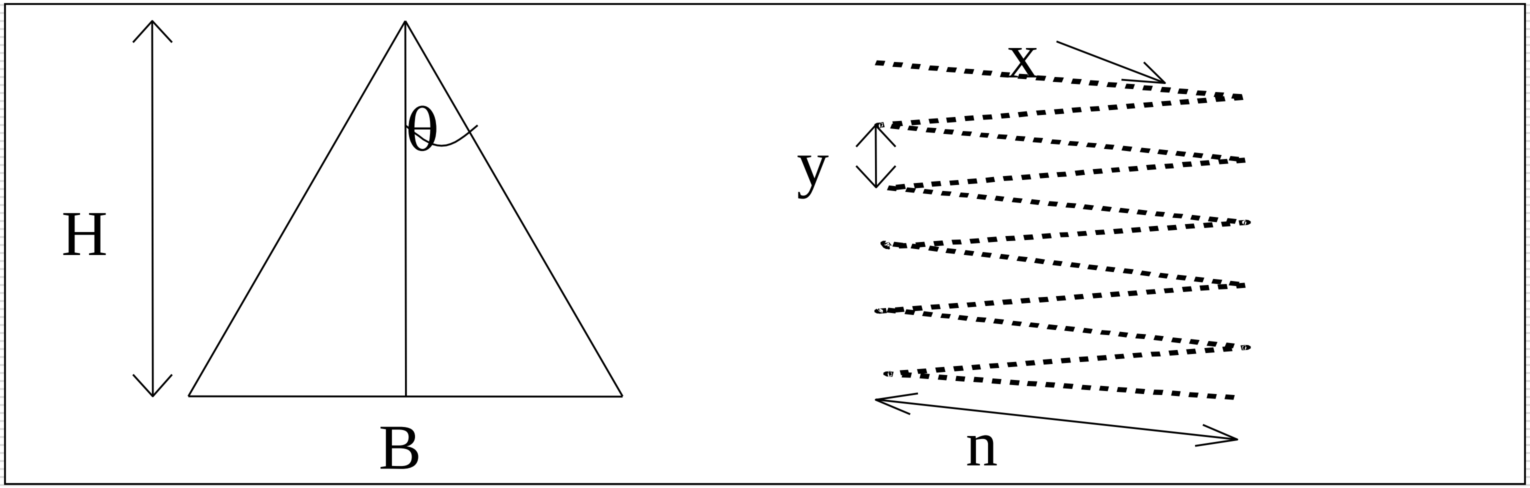
What controls flight planning



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 ‘θ’
- Single and multiple data returns

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

LiDAR Scanner: ALTM 3100EA

Scanning frequency

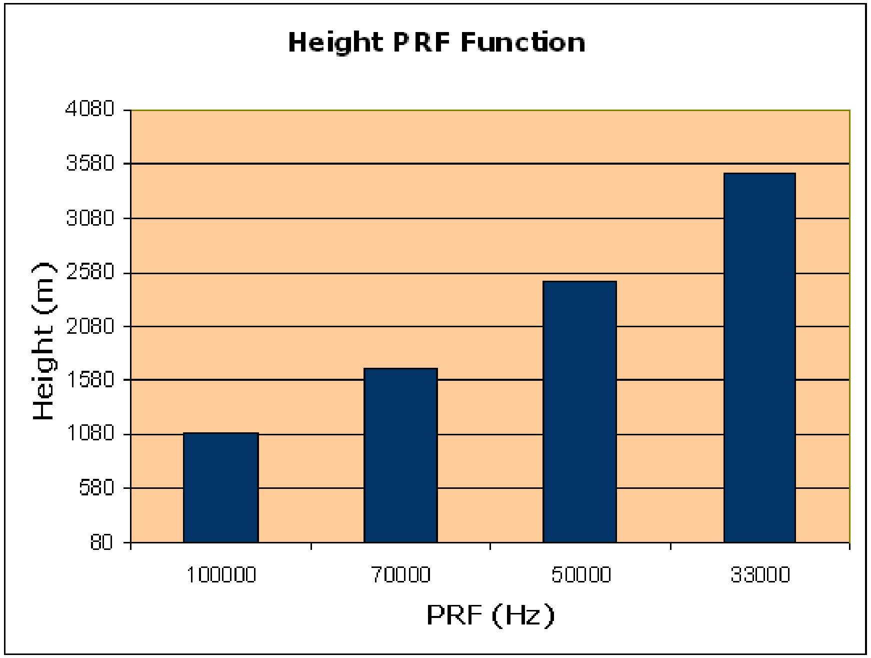
0 – 70 Hz (+1Hz)

Scan angle

0 - 25° (± 1°)

PRF

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



Relations

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

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

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

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

Current Practices

- 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

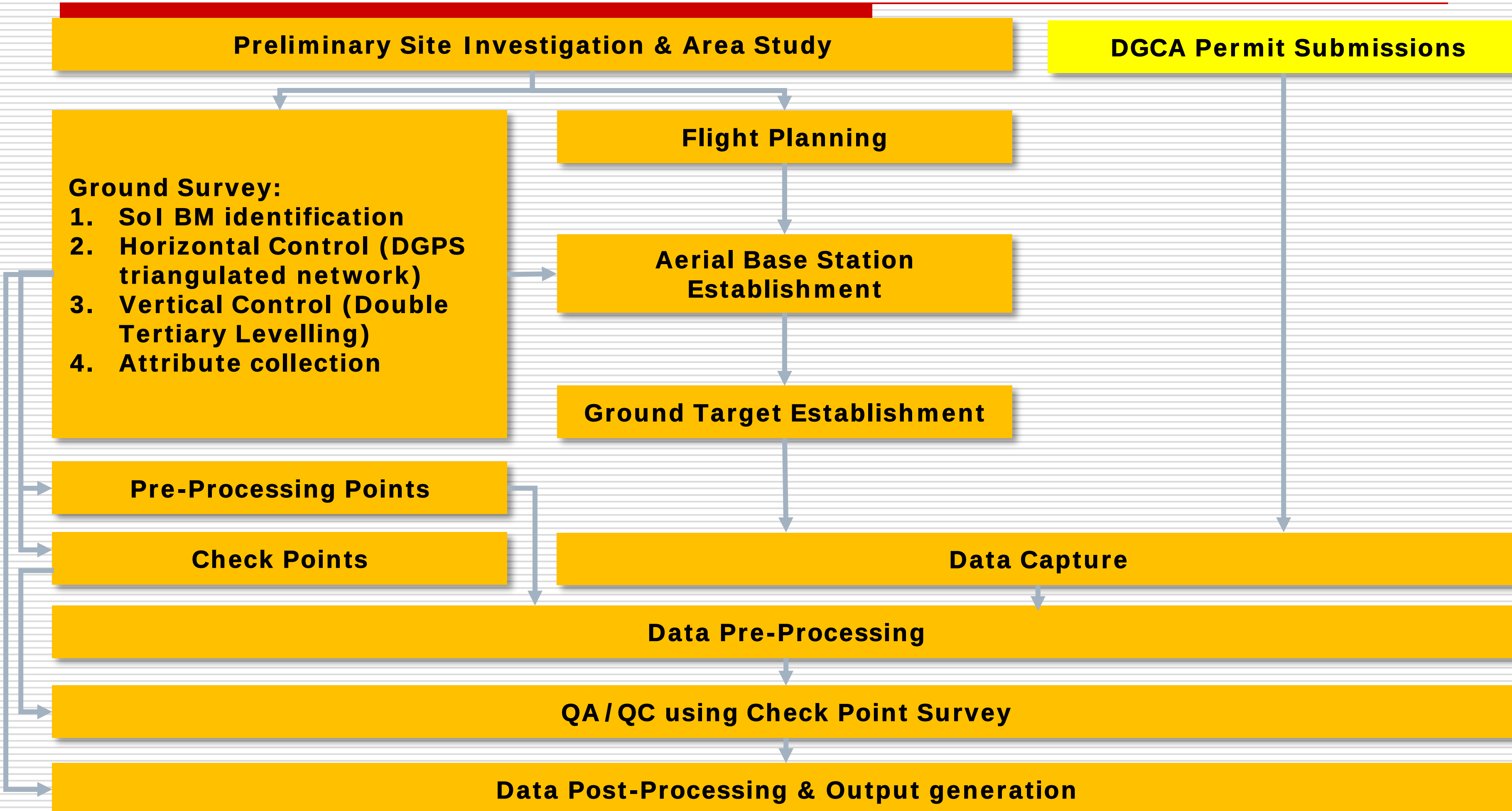
- Genetic algorithm based approach
- Objective Function-minimize total time of flight

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

Project execution Steps

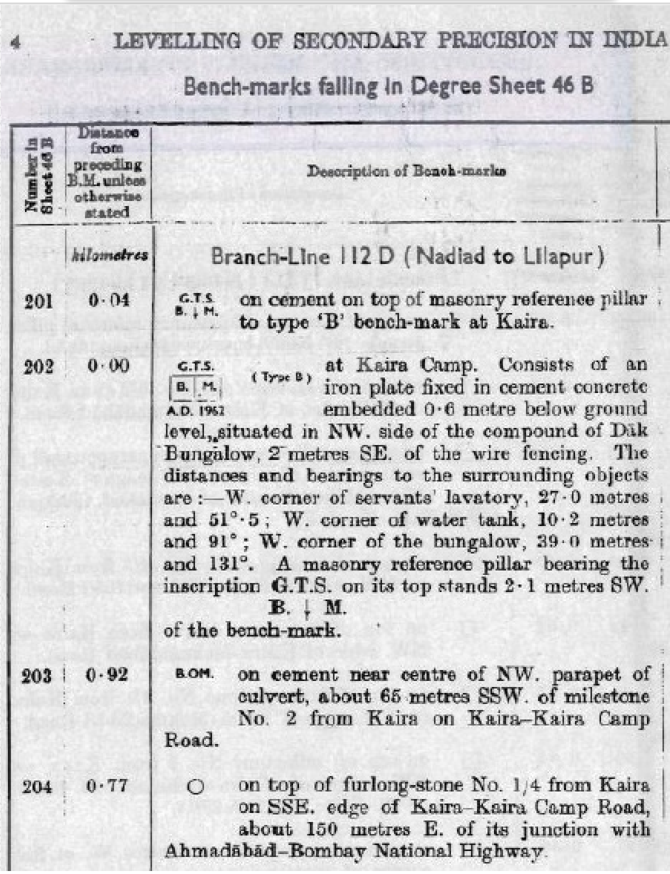
Steps in field to collect LiDAR data

Methodology



SoI Bench Mark need to be identified

Sample BM Description



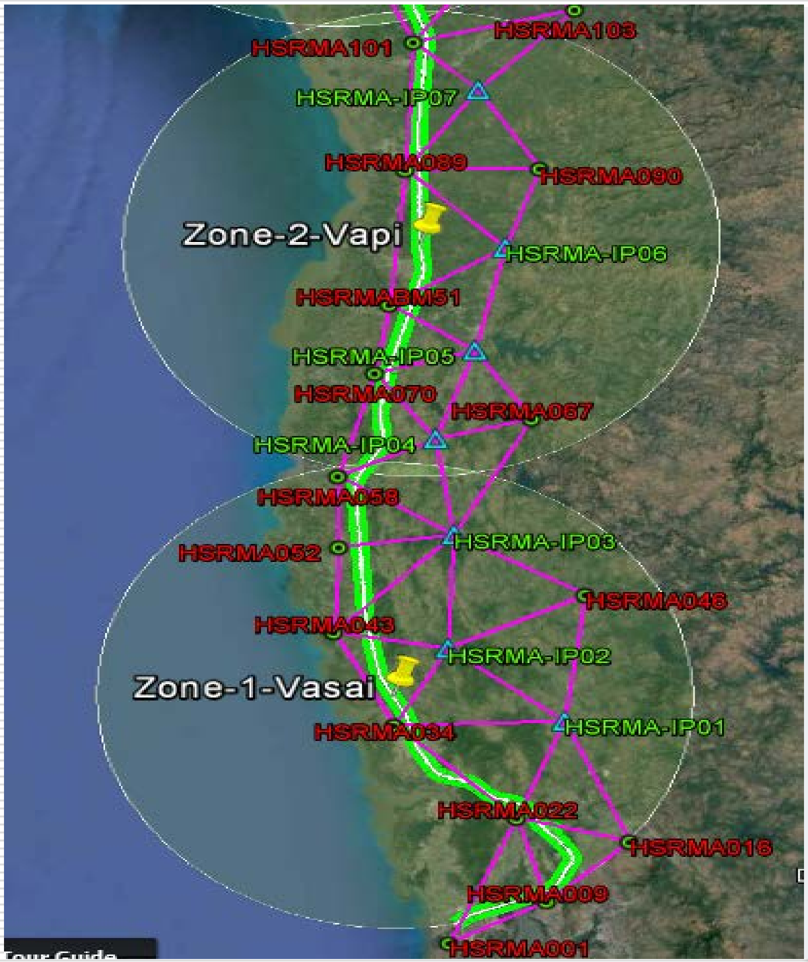
4 LEVELLING OF SECONDARY PRECISION IN INDIA

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. 1961 (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. B.↓M. on its top stands 2·1 metres SW. 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



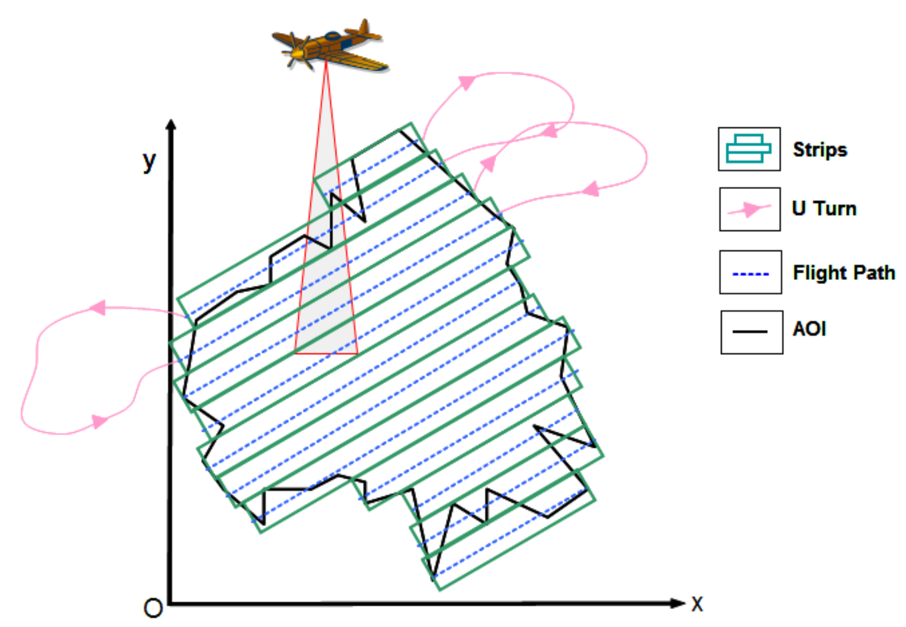
- Control network needs to be established starting from SoI GCPs
- Important to check the stability and suitability of SoI BMs
- Levelling network to be established connecting SoI BMs to project controls

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

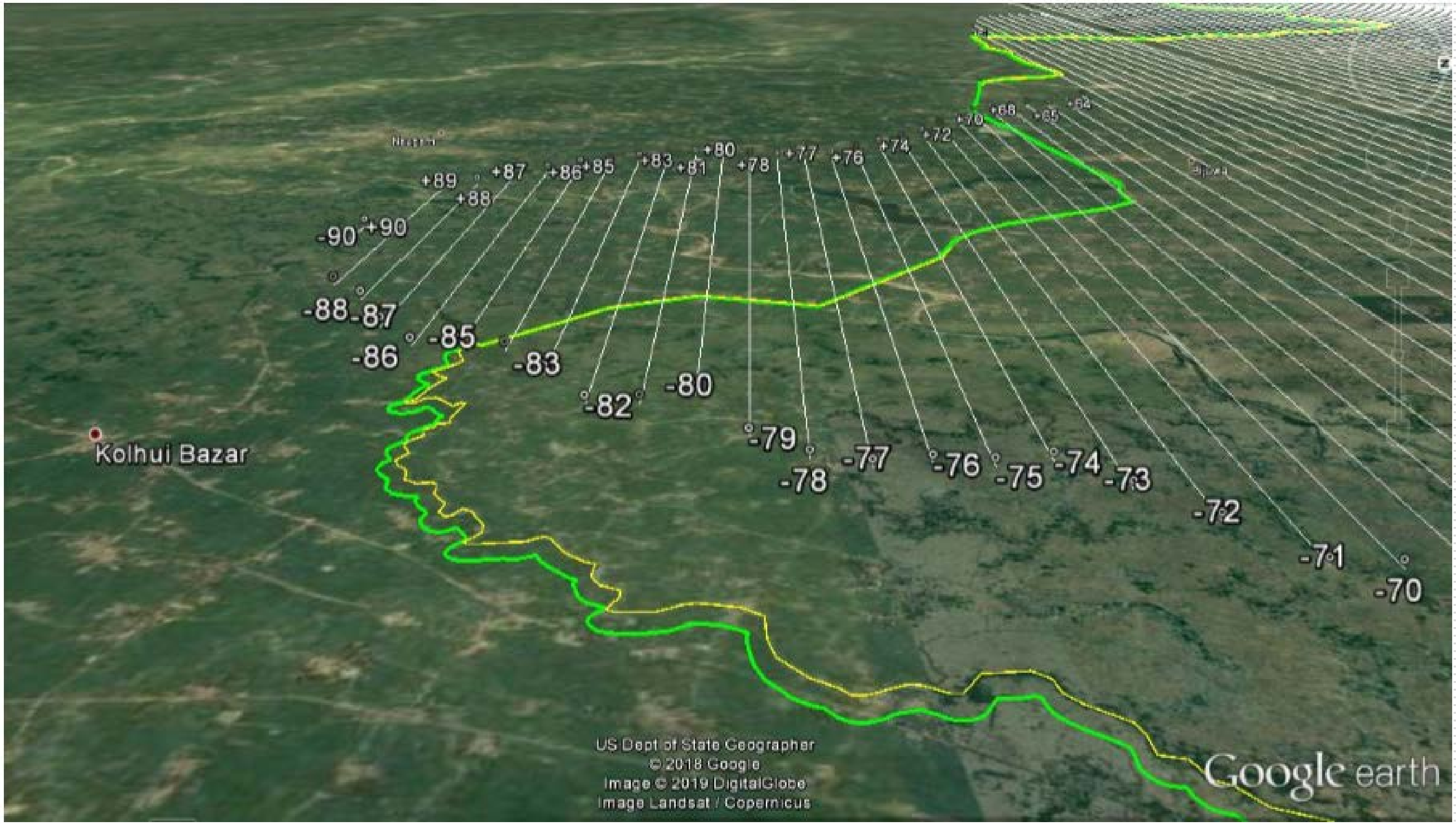
Flight Planning

- 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

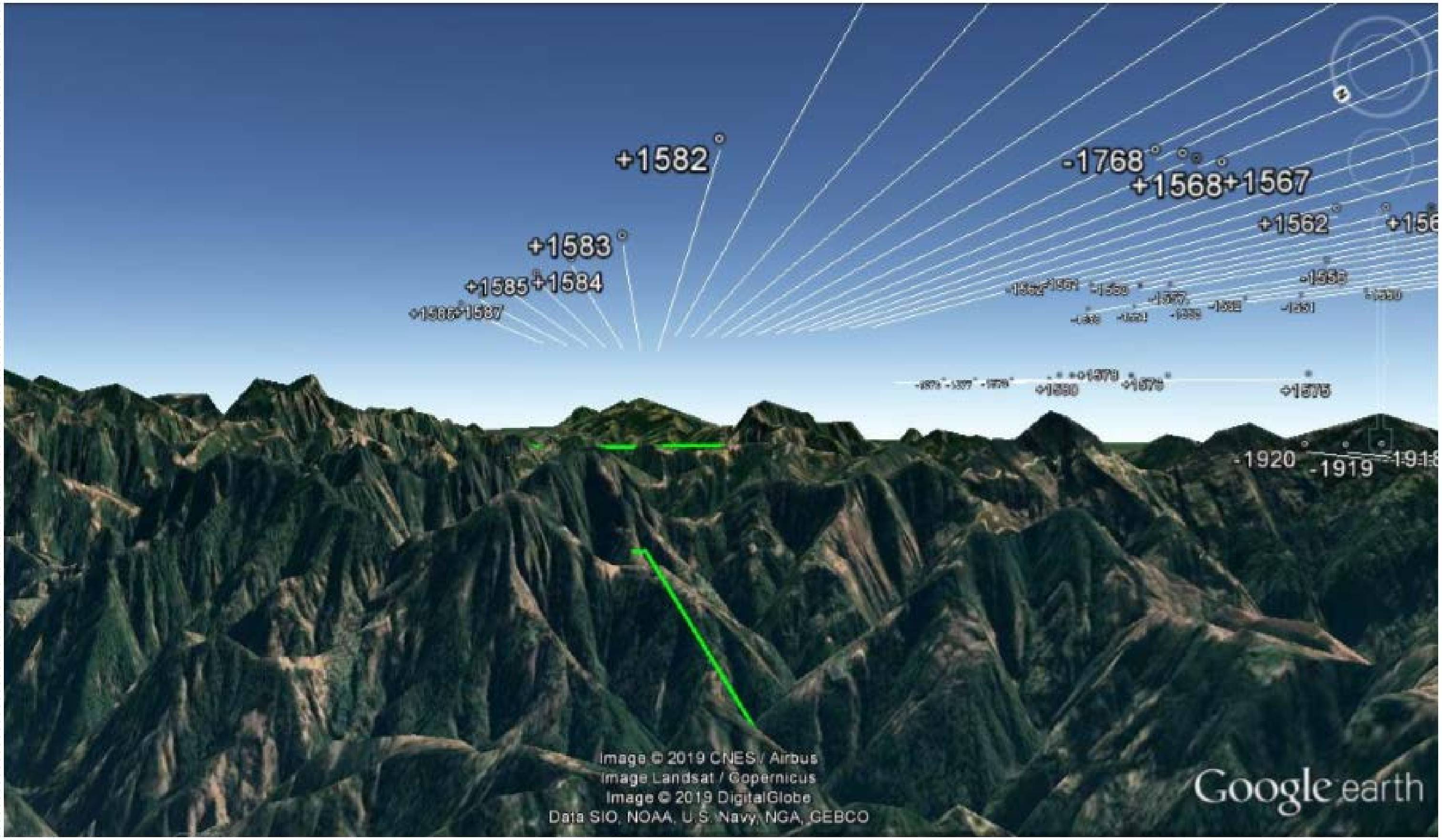


❖ Desirable
- Minimum cost
- Collect data as desired

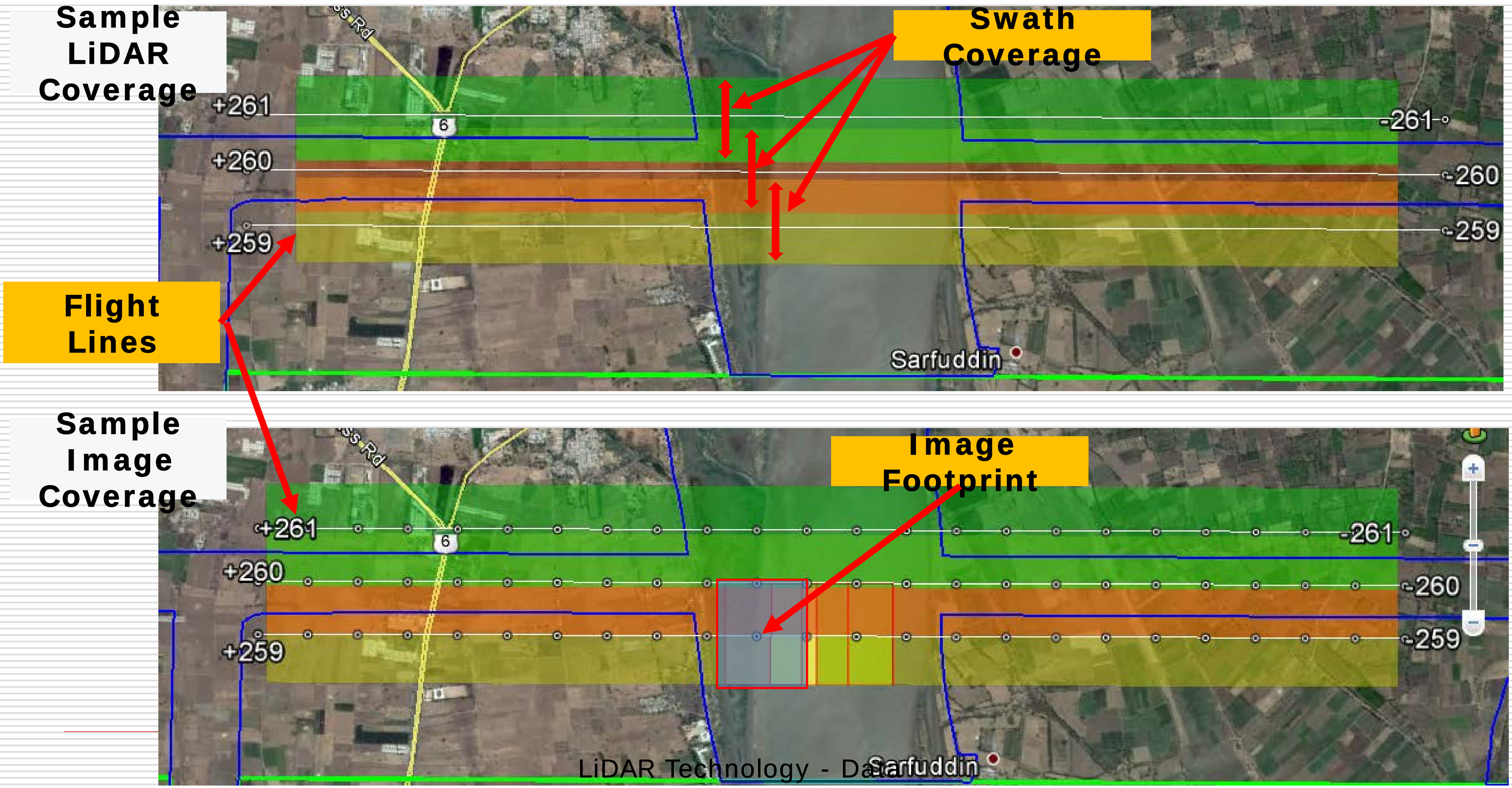
Example of Flight Plan Done



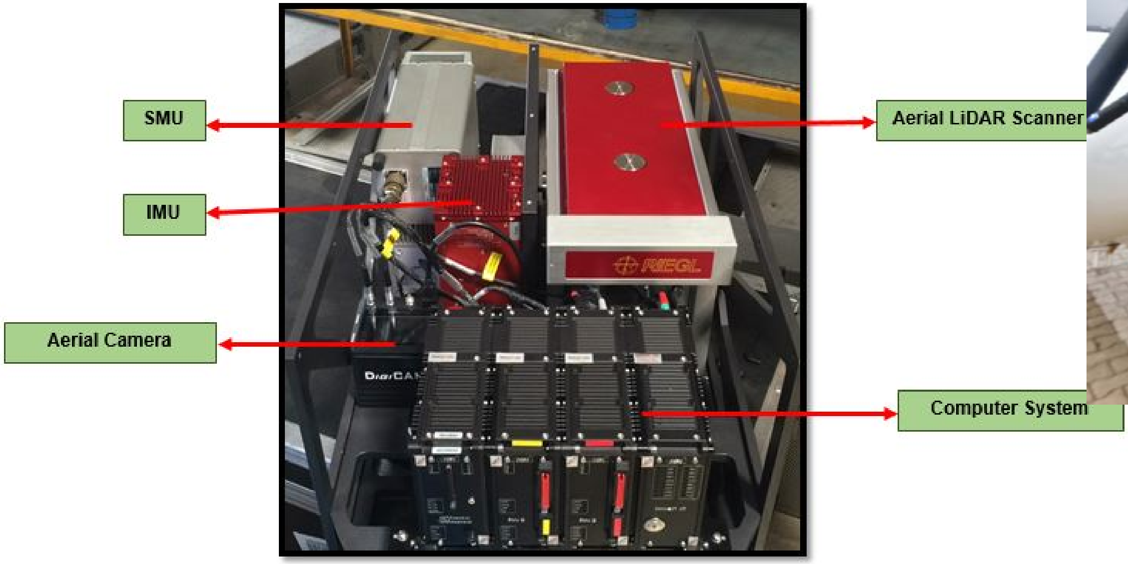
Example of Flight Plan Done

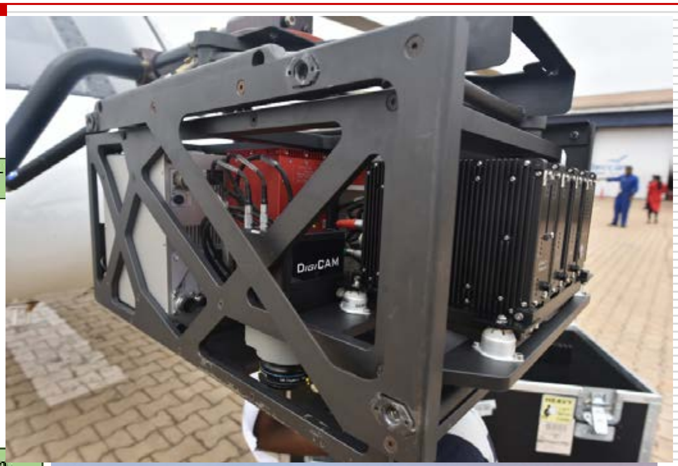


Flight Path planning – Sample Flight Plan



Aerial Survey System





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

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 $\Delta\vartheta$ [19]	$\Delta\vartheta \geq 0.012°$ @ laser power level ≥ 50% $\Delta\vartheta \geq 0.006°$ @ 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

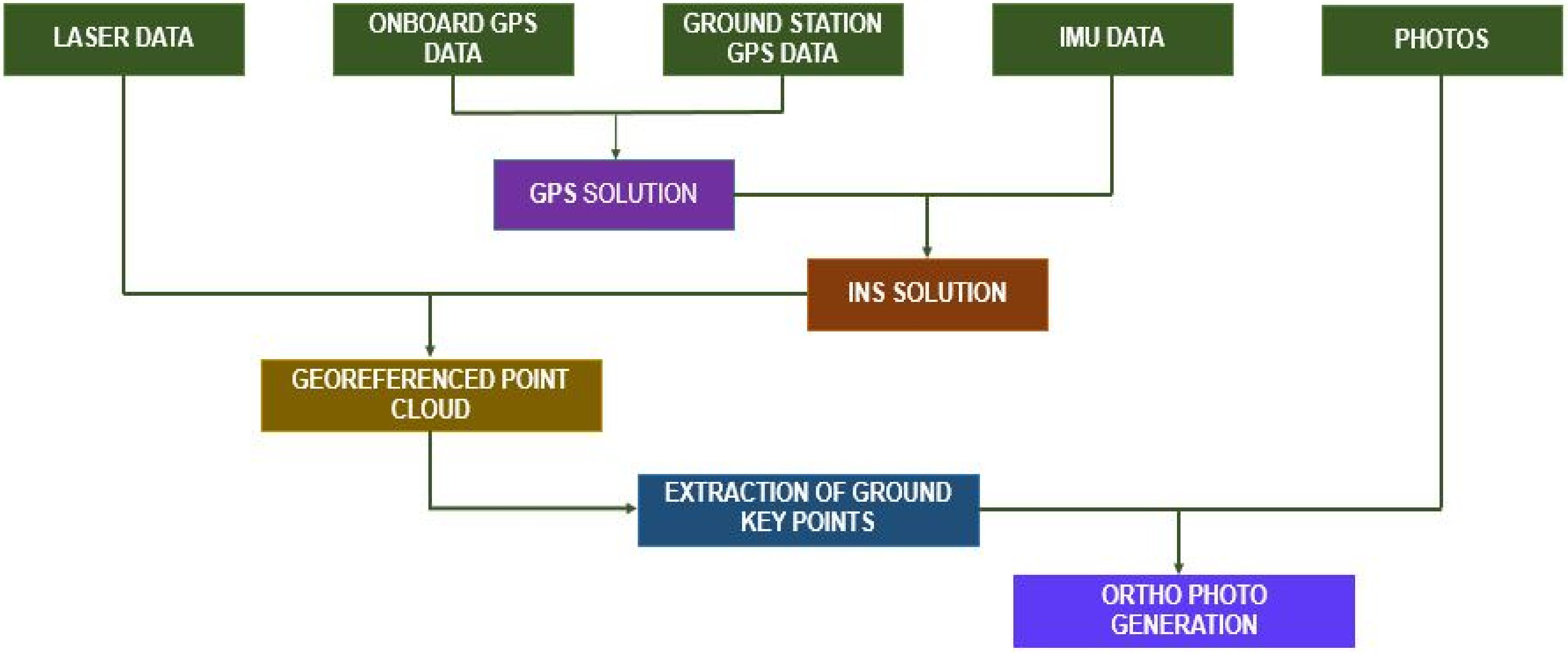
Phase One Industrial

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

Data Pre-Processing



Thanks