UAV PHOTOGRAMMETRY

Victor Saikhom
Scientist/ Engineer 'SE'
North Eastern Space Applications Centre
Dept. of Space, Govt. of India
Umiam, Meghalaya – 793 103
www.nesac.gov.in
victor.saikhom@nesac.gov.in

The science of quantitative analysis of measurements from photographs

- **Photos** - light
- **Gramma** - to draw
- **Metron** - to measure

WHAT IS PHOTOGRAMMETRY?

Victor Saikhom
victor.saikhom@nesac.gov.in

- Measures the 3-D coordinates of points or features at one instant using one and/ or many cameras at the same time, or over a period of time using one camera

- It provides high accuracy results between 1 part in 500 to 1 part in 1,000,000 of the largest dimension of the object being measured

- The method can be applied to objects ranging from mm to kilometres in size

WHAT DOES IT DO?

Victor Saikhom
victor.saikhom@nesac.gov.in

- Very precise
- Time effective
- Cost effective
- Based on well established and tested algorithms.
- Less manual effort
- More geographic fidelity
- Achieve a reasonable accuracy without a great number of GCPs
- Create a three-dimensional stereo model and extract the elevation information

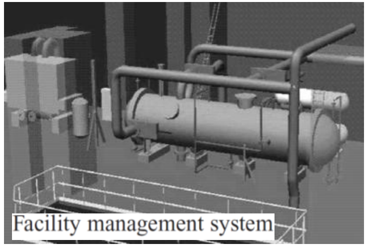
WHY PHOTOGRAMMETRY

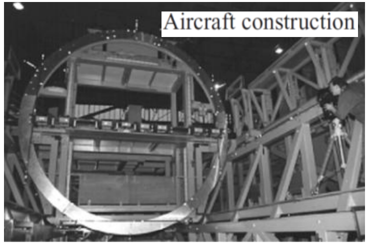
Victor Saikhom
victor.saikhom@nesac.gov.in

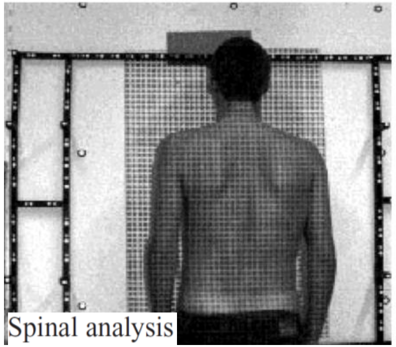
WHAT DOES PHOTOGRAMMETRY GET USED FOR?

- Mapping
- Architectural models of buildings or facades,
- Archaeology surveys
- Medical uses e.g. human body scans for back problem
- Missile/ plane tracking
- Antenna measurement
- Verification of the design of manufactured structures.
- Virtual reality
- Entertainment


Car building

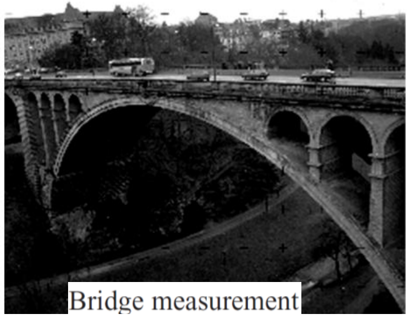

Facility management system


Aircraft construction


Spinal analysis


Accident recording


Building record


Bridge measurement

Victor Saikhom
victor.saikhom@nesac.gov.in

Advantages:

- Non-contact process
- 2D or 3D information options
- High density of measurement possible
- Measurements are made in the laboratory
- Photographs/ images are a permanent record
- Re-measurement is possible

Disadvantages:

- Photographic coverage is limited
- Dead ground precludes measurement
- Measurement and analysis delays
- Efficient only for large data sets

PHOTOGRAMMETRIC MEASUREMENT PROS AND CONS

Victor Saikhom
victor.saikhom@nesac.gov.in

Based on **method**

- Metric Photogrammetry
- Interpretation Photogrammetry

Based on **evolution**

- Analogue Photogrammetry
- Analytical photogrammetry
- Digital photogrammetry

Based on **platform**

- Terrestrial
- Aerial
- Satellite

TYPES OF PHOTOGRAMMETRY

Victor Saikhom
victor.saikhom@nesac.gov.in

An **Unmanned Aerial Vehicle** (UAV), commonly known as a **drone**, is an aircraft without a human pilot onboard.

The flight of UAVs may operate either under remote control by a human operator or autonomously by onboard computers.

Pajares, G. 2015. Overview and current status of remote sensing applications based on unmanned aerial vehicles (UAVs). Photogrammetric Engineering & Remote Sensing. 81, 281-329.

What is UAV

Victor Saikhom
victor.saikhom@nesac.gov.in

Multirotor/ Rotary Wings
Advantages: VTOL, Surveillance or Survey
Disadvantages: Short Endurance, Multiple points of failure

Fixed Wings
Advantages: Longer Endurance, Large area coverage
Disadvantages: May need launching device, Needs open area for take-off/ landing

Hybrid Model
VTOL, Medium Altitude Long Endurance (MALE), and High Altitude Long Endurance (HALE), Large area coverage

TYPES OF UAV PLATFORMS

Victor Saikhom
victor.saikhom@nesac.gov.in

❖Conventional Airborne Photogrammetry

- **Data acquisition**
  - Performed by specific purpose aircrafts
  - Need clearances against security and logistics
  - Suitable for large areas

- **Operating cost**
  - User requirements: Project specifications, mapping requirements
  - Sensor characteristics
  - Terrain type
  - Flying operations

Victor Saikhom
victor.saikhom@nesac.gov.in

❖ Technology advancements

- **Hardware development**
  - High resolution digital camera
  - Global positioning system
  - Inertial measurement system
  - Miniature and integrated hardware

- **Software development**
  - Computer vision algorithms
  - Large data handling and retrieval, cloud computing
  - Automated processing and fast work flow
  - Compatibility

Recent Developments

Victor Saikhom
victor.saikhom@nesac.gov.in

- ❑ Very high spatial resolution (up to 5-10cm/pix) & High temporal resolution
- ❑ 3D modeling
- ❑ Can fly at lower altitudes
  - ✓ Can be flown in foggy, cloudy weather
  - ✓ Higher ground resolution can be achieved
- ❑ Can reach inaccessible, high risk areas with minimum human intervention
  - ✓ Disaster sites – landslides, flash flood, accident sites, earthquake, volcanoes, building collapse, crop damage
  - ✓ Inaccessible sites - high rise monuments, heritage sites etc.
- ❑ Combine aerial and terrestrial photogrammetry
- ❑ Flexible cost

UAV ADVANTAGES

Victor Saikhom
victor.saikhom@nesac.gov.in

UAV payloads can either be sensors such as RGB cameras, Multispectral, Hyperspectral, LiDAR, or other specialised instruments, such as parcels, medical or rescue equipment etc.

Zenmuse Camera (RGB)

Parrot Sequoia multispectral sensor

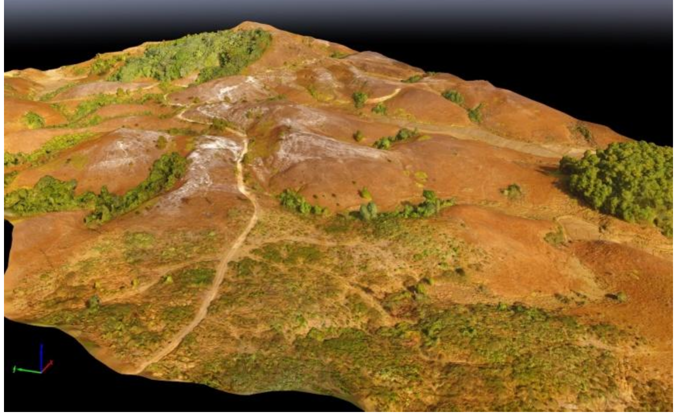
Specim Hyperspectral sensor

Routescene LidarPod

UAV Payloads

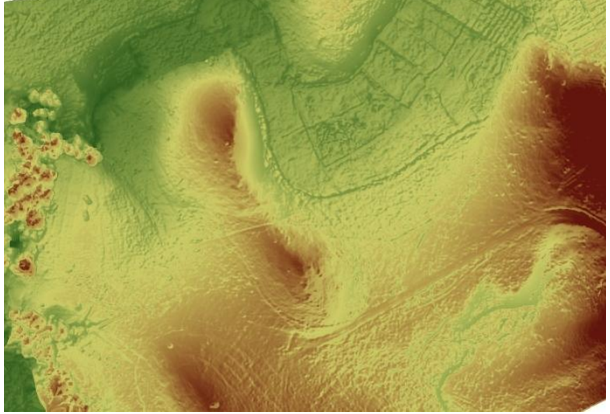
Victor Saikhom
victor.saikhom@nesac.gov.in

UAV Data Deliverables



Textured 3D Point Cloud

- Composed of points in 3D space
- Useful for 3D measurements, Volumetric Calculations



Digital Surface Model

Provide elevation data

Orthomosaic Image

A photo map that has been geometrically corrected to uniform scale.

- Make 2D Measurements (distance, area)
- GIS Integration

Victor Saikhom
victor.saikhom@nesac.gov.in

3D Fly Through

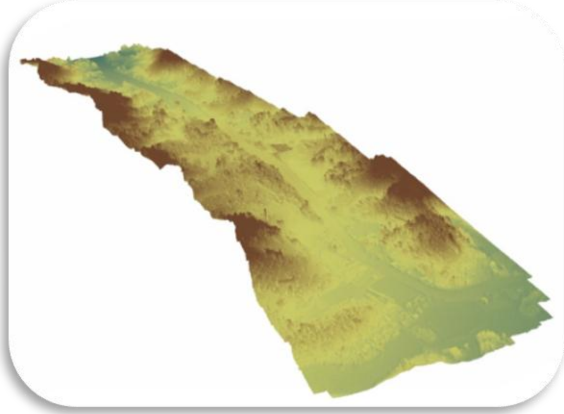
Real Time Video Streaming

Series of still photographs

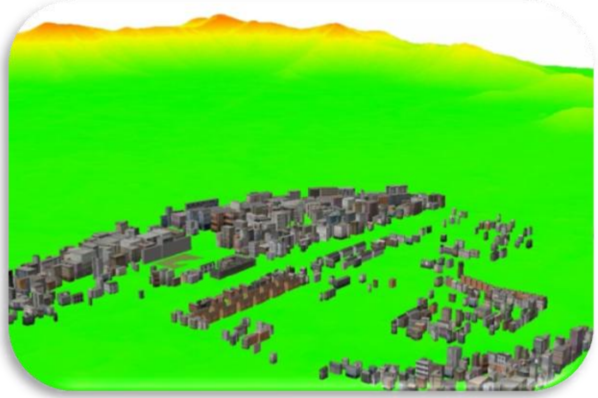
UAV Data Deliverables

Victor Saikhom
victor.saikhom@nesac.gov.in

2D Maps



Terrain



GIS

UAV APPLICATIONS
LAND SURVEYING

Victor Saikhom
victor.saikhom@nesac.gov.in

Crop Monitoring

Chemical Application

Land Management

Diseases
Insects
Weed
Crop Progress
Crop Stress

Fertilizer Application
Pesticide Application

Drainage Issues
Replanting Decisions
Yield Estimations
Soil Moisture

UAV Applications
Agriculture

Victor Saikhom
victor.saikhom@nesac.gov.in

Forest

River Bank

Wildlife

Forest Fire
Deforestation

Bank Erosion

Animal Counting

UAV APPLICATIONS
ENVIRONMENTAL STUDIES

Victor Saikhom
victor.saikhom@nesac.gov.in

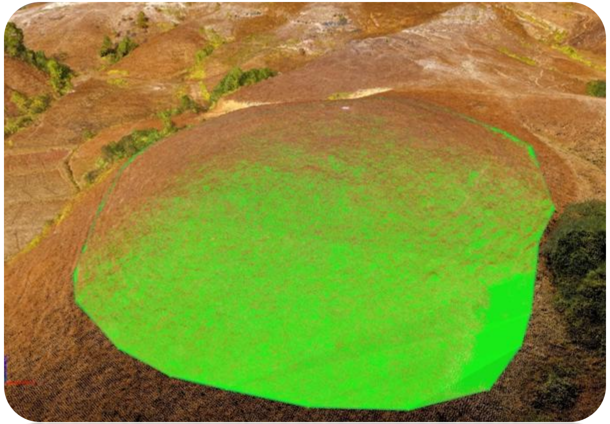
Infrastructure Inspection

Bridges
Cell Phone Towers
Power lines
Solar Panels

Feasibility Surveys

Transportation Routes

Mining



Volume Calculation

UAV APPLICATIONS
CIVIL ENGINEERING

Victor Saikhom
victor.saikhom@nesac.gov.in

Disaster Mapping	Hazard Monitoring	Emergency Delivery
Emergency response coordination Search and Rescue Post disaster assessment	Volcanos Glaciers Floods	Medicine

UAV Applications
Humanitarian Efforts

Victor Saikhom
victor.saikhom@nesac.gov.in

Limitations

- Limited payload capacity
- Limited flight endurance
- Less area coverage
- Relatively costly
- Suitable for small study area
- Cannot operate during rain
- Airspace Regulations

UAV Limitations

Victor Saikhom
victor.saikhom@nesac.gov.in

Effective:
01^{st} December, 2018

Applicable for All civilian organizations:
Central Govt./ State Govt./ PSUs/ Private industries/ Academia etc.

Except: Indian Army, Indian Air force, Indian Navy, Police, Central Reserve forces.

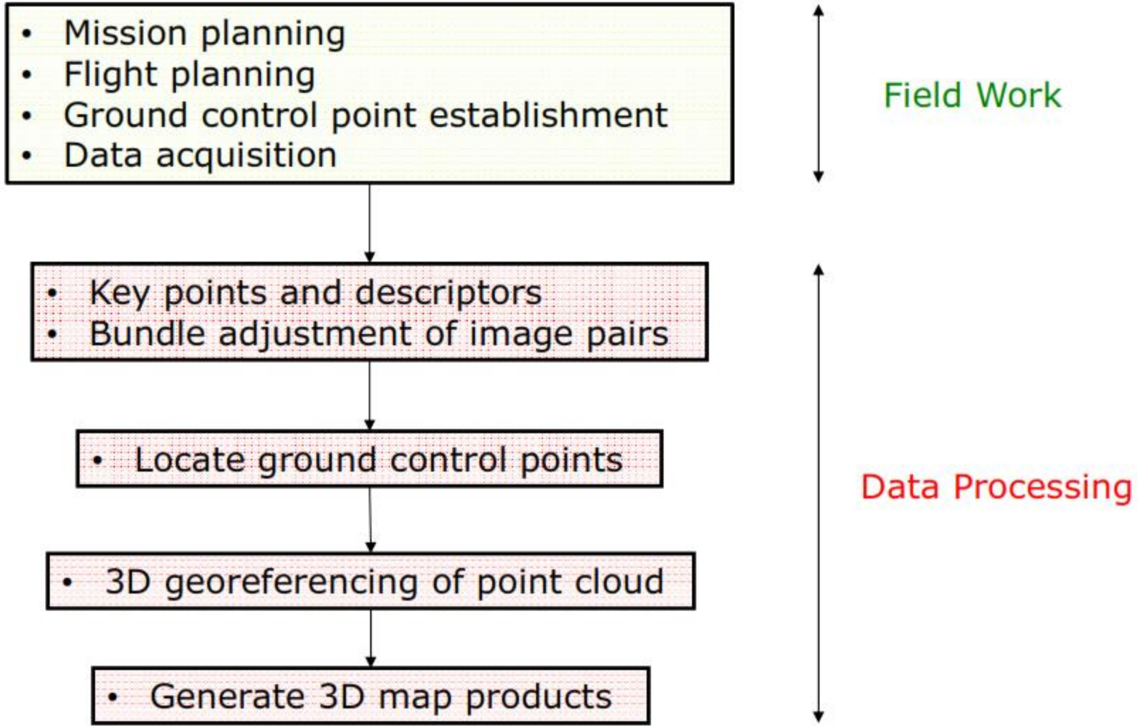
Application Process:
Online: Digital Sky Platform

Classification Name	Size
Nano	Less than 250gm
Micro	250gm to 2kg
Mini	2kg to 25kg
Small	25kg to 150kg
Large	Greater than 150kg

DGCA regulations for UAV
Category of UAV

Victor Saikhom
victor.saikhom@nesac.gov.in

Work Flow



Victor Saikhom
victor.saikhom@nesac.gov.in

Mission Planning and Flight Planning

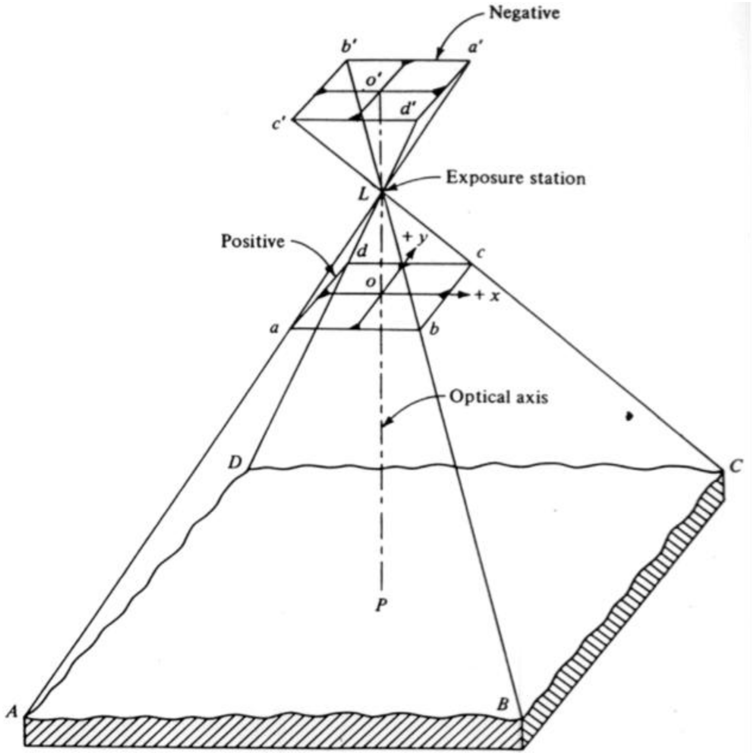
Victor Saikhom
victor.saikhom@nesac.gov.in

Courtesy: Pix4D

3 types of imagery (photography)

- **True vertical photography**: ±0º from nadir
- **Tilted or near-vertical photography** > 0º but less than ±3º
- **Oblique photography**: Between ±35º and ±55º off nadir

Victor Saikhom
victor.saikhom@nesac.gov.in



Geometry of Aerial Photographs

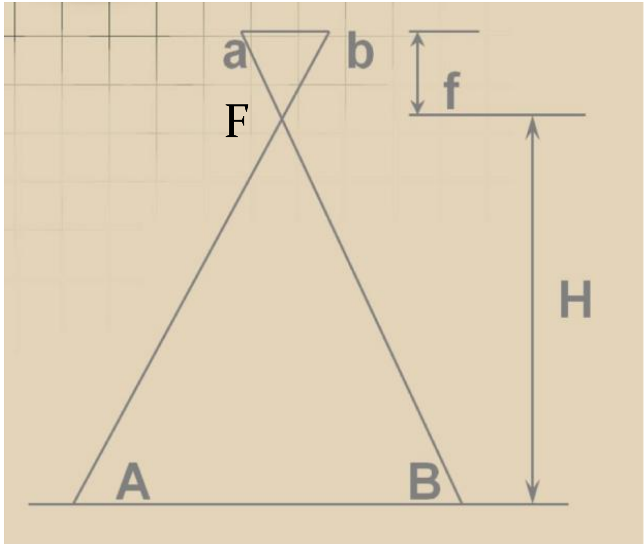
Victor Saikhom
victor.saikhom@nesac.gov.in

Scale of Vertical Image

The scale of an image is the ratio of the distance on the image to the corresponding distance on the ground.

scale = (distance 'ab')/(distance 'AB')

scale = (lens focal length (f))/(Flying height (H))



Scale is expressed either in a unitless ratio such as 1/12,000 (or 1:12,000) or in pronounced units ratio such as 1 in. = 1,000 ft (or 1"=1,000')

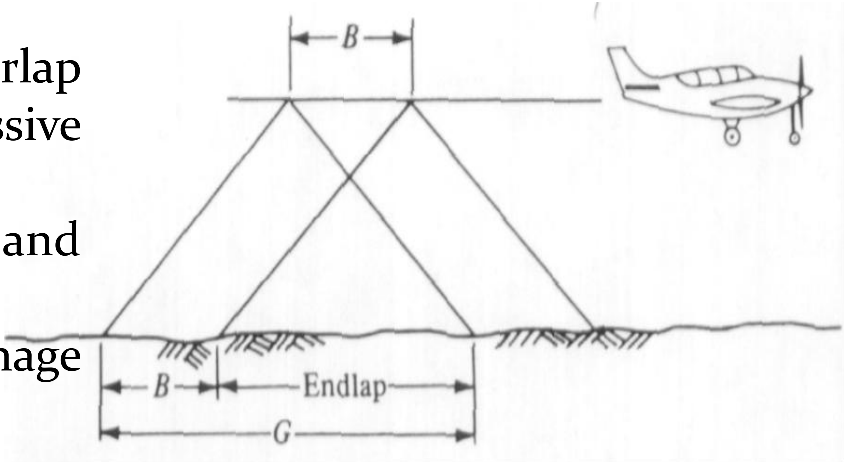
Victor Saikhom
victor.saikhom@nesac.gov.in

Imagery Overlap

Imagery acquired for photogrammetric processing is flown with two types of overlap: Forward Lap and Side Lap.

Forward Lap

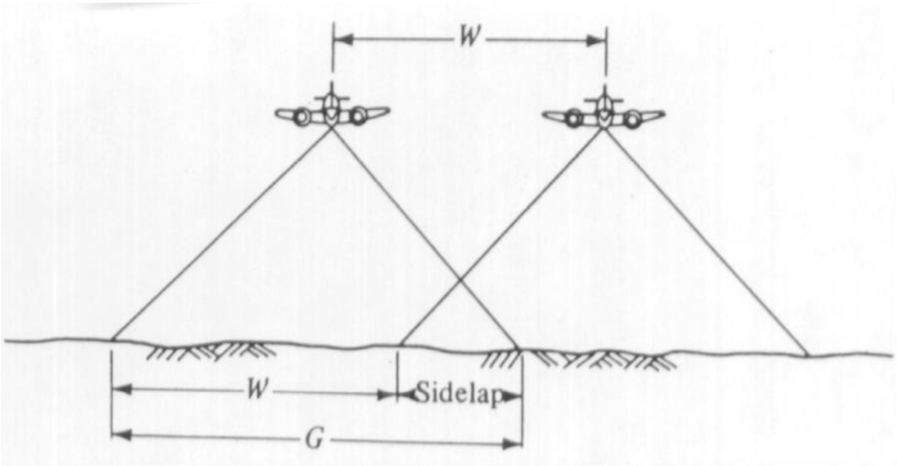
- ✓ describes the amount of image overlap intentionally introduced between successive photos along a flight line
- ✓ used to form stereo-pairs for stereo viewing and processing.
- ✓ measured as a percentage of the total image coverage.



Victor Saikhom
victor.saikhom@nesac.gov.in

Side Lap

- ✓ describe the amount of overlap between images from adjacent flight lines
- ✓ needed to make sure that there are no gaps in the coverage.
- ✓ measured as a percentage of the total image coverage.

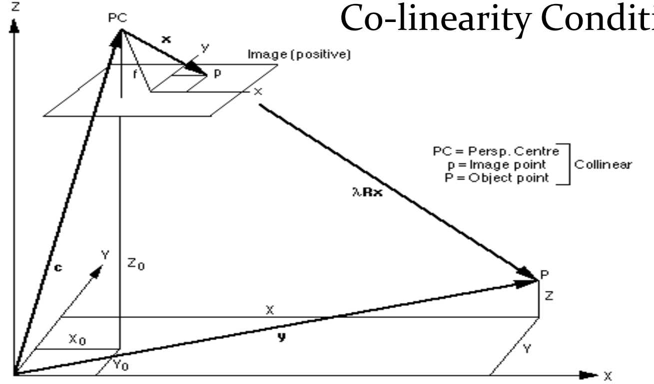


GEOMETRY OF AERIAL PHOTOGRAPHS

Victor Saikhom
victor.saikhom@nesac.gov.in

- Simultaneous space resection and space intersection of image rays recorded by an aerial mapping camera
- Conjugate image rays projected from two or more overlapping photographs intersect at the common ground points to define the three-dimensional space (3-D) coordinates of each point
- Achieved in Two steps
  - Interior Orientation
  - Exterior Orientation
    - ✓ Relative Orientation
    - ✓ Absolute Orientation

Co-linearity Condition

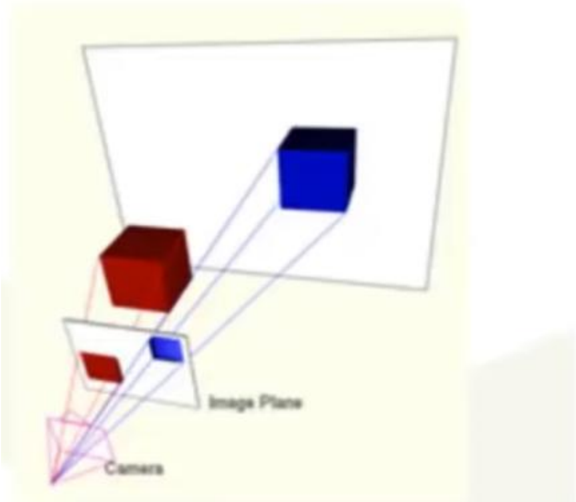


AEROTRIANGULATION

Victor Saikhom
victor.saikhom@nesac.gov.in

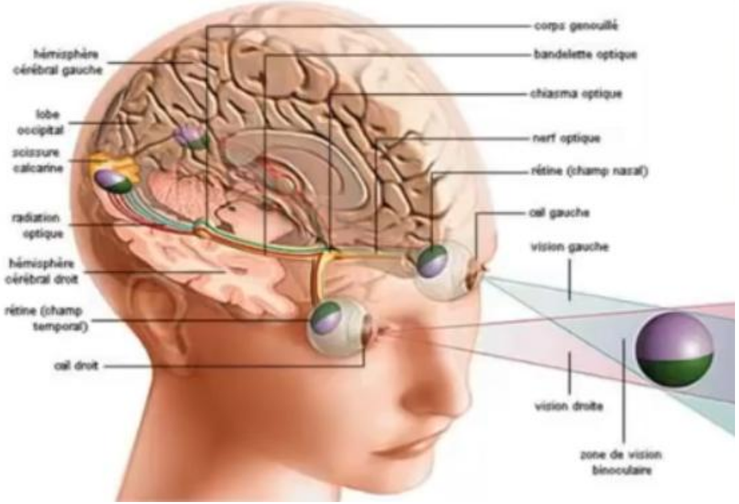
From 3D to 2D

One camera
Far appears smaller
than near on image



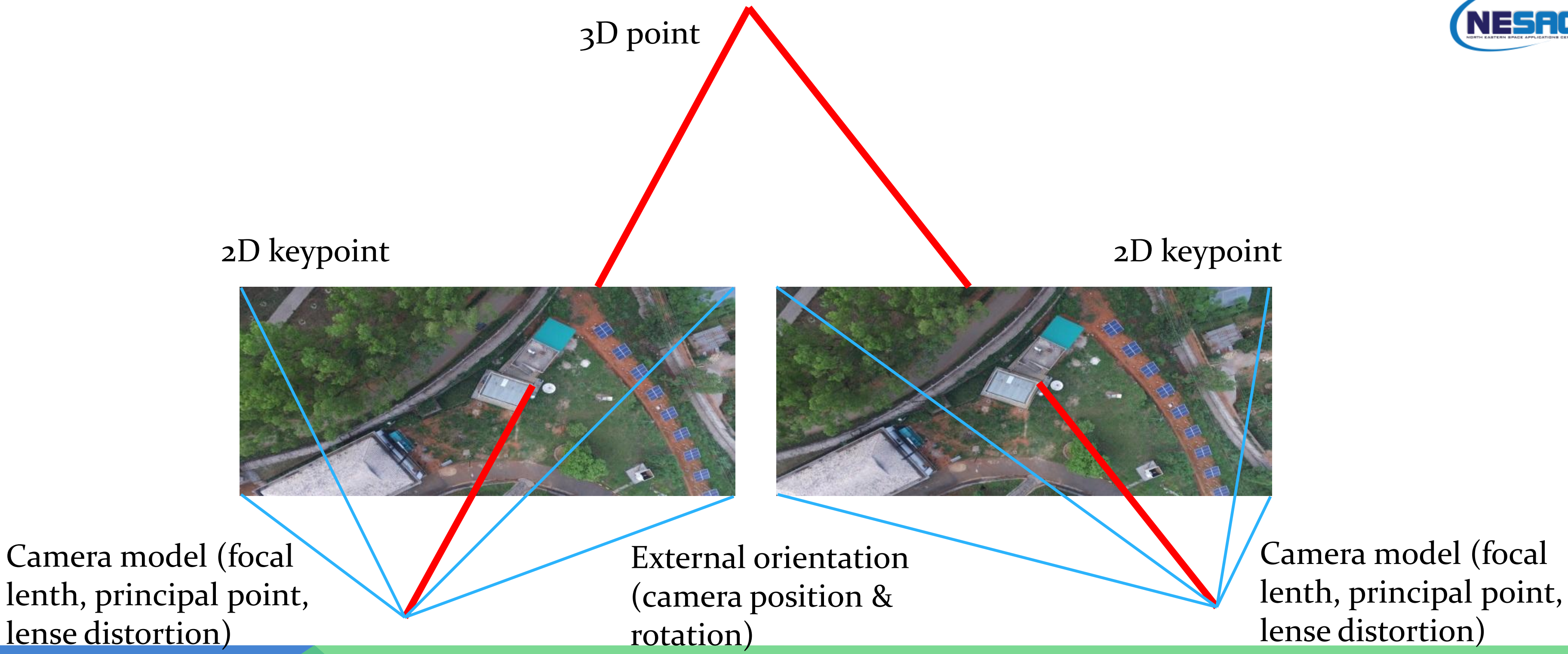
From 2D to 3D

Two images
Triangulate to get
sense of depth



From 2D to 3D: Stereoscopy

Victor Saikhom
victor.saikhom@nesac.gov.in



From 2D to 3D: Stereoscopy

Victor Saikhom
victor.saikhom@nesac.gov.in

A dataset of insufficient quality will lead to poor results or may even lead to processing failure.

A good dataset is required in order to automatically produce results with high quality and accuracy.

Steps involved are:

1. Designing the Images Acquisition Plan
2. Configuring the Camera Settings
3. Georeferencing the Images
4. Getting GCPs on the field or through other sources

Victor Saikhom
victor.saikhom@nesac.gov.in

- ✓ Type of project (aerial, terrestrial, mixed).
- ✓ Type of terrain / object.
- ✓ Type of camera.
- ✓ Purpose of the project.
- ✓ Image rate that the images are taken.
- ✓ Distance (flight height) at which the images are taken and with which angle to take the images.
- ✓ Path(s) to follow to take the images, etc.

Designing the Images Acquisition Plan

Victor Saikhom
victor.saikhom@nesac.gov.in

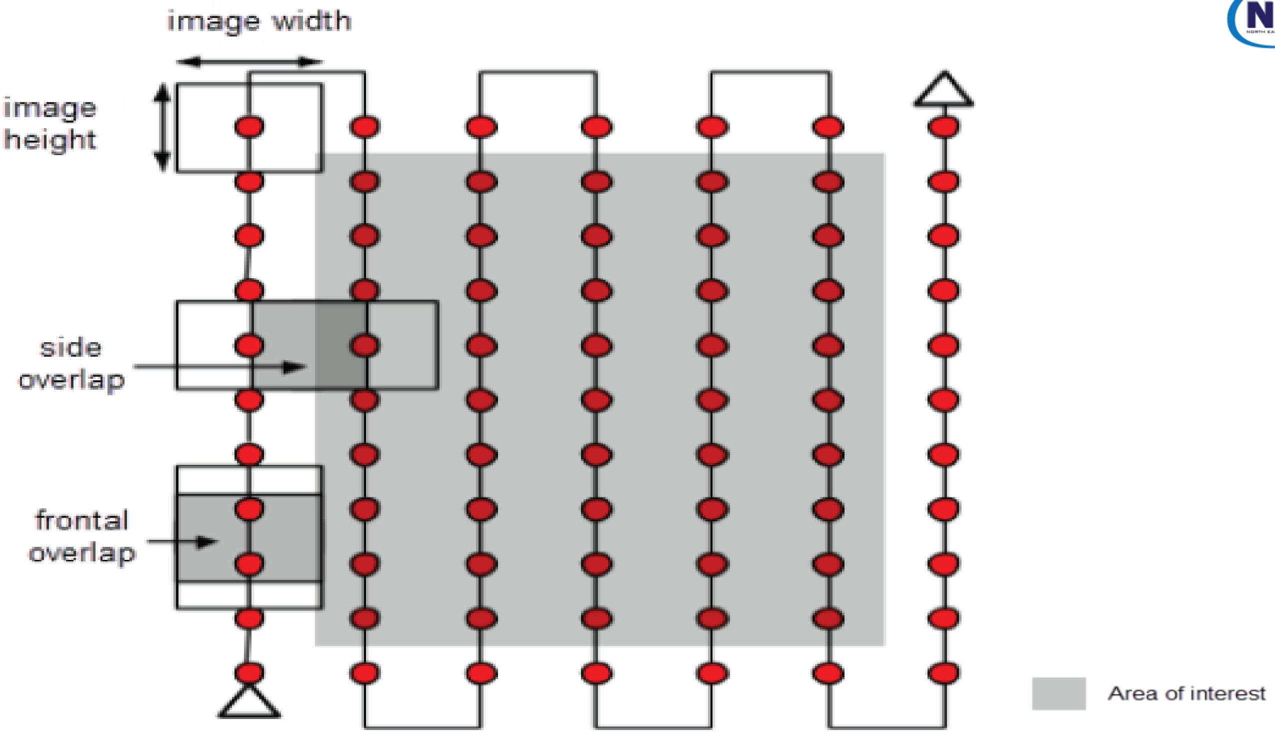
The design of the image acquisition plan consists of 3 steps:

I. Selecting the Image Acquisition Plan Type
II. Computing the Flight Height for a given GSD
III. Computing the Image Rate for a given Frontal Overlap

Designing the Images Acquisition Plan

Victor Saikhom
victor.saikhom@nesac.gov.in

General case:



Designing the Images Acquisition Plan

I. Selecting the Image Acquisition Plan Type

Victor Saikhom
victor.saikhom@nesac.gov.in

Forest and dense vegetation case:

Trees and dense vegetation often have a very different appearance between overlapping images due to their complex geometry (thousands of branches and leaves). Therefore, it is difficult to extract common characteristic points (keypoints) between the images. In order to achieve good results, it is recommended to use a grid image acquisition plan.

- ✓ Increase the overlap between images to at least 85% frontal overlap and at least 70% side overlap.
- ✓ Increase the flight height

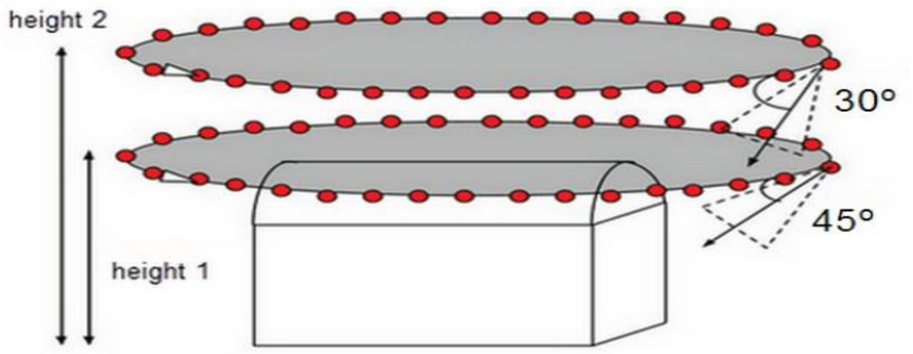
Victor Saikhom
victor.saikhom@nesac.gov.in

Building reconstruction :

Reconstructing 3D buildings requires a specific image acquisition plan.

- ✓ Fly around the building a first time with a 45° camera angle.

- ✓ Fly a second and third time around the building increasing the flight height and decreasing the camera angle with each round.



DESIGNING THE IMAGES ACQUISITION PLAN

I. SELECTING THE IMAGE ACQUISITION PLAN TYPE

Victor Saikhom
victor.saikhom@nesac.gov.in

Special cases:

Cases that is difficult to map such as terrains with snow, sand, lakes, etc.

Snow and sand

Snow and sand have little visual content due to large uniform areas. Therefore:

- ✓ Use a **high overlap**.
- ✓ Set the exposure settings accordingly to get as much **contrast** as possible in each image.

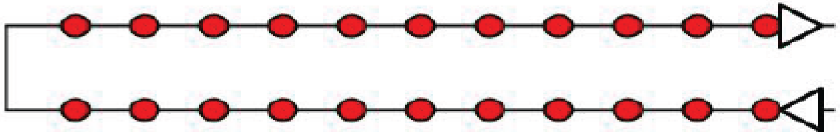
Water

Water surfaces have almost no visual content due to large uniform areas. Sun reflection on the water and waves cannot be used for visual matching.

Victor Saikhom
victor.saikhom@nesac.gov.in

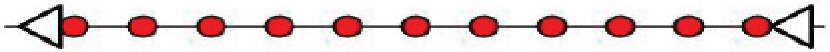
Corridor mapping:

Mapping corridors such as railways, roads or rivers requires at least 2 flight lines.



If a dual track image acquisition plan is not possible, a single track image acquisition plan can be used if:

- ✓ Overlap is high enough.
- ✓ Ground control points (GCPs) are defined along the flight line in zig zag.

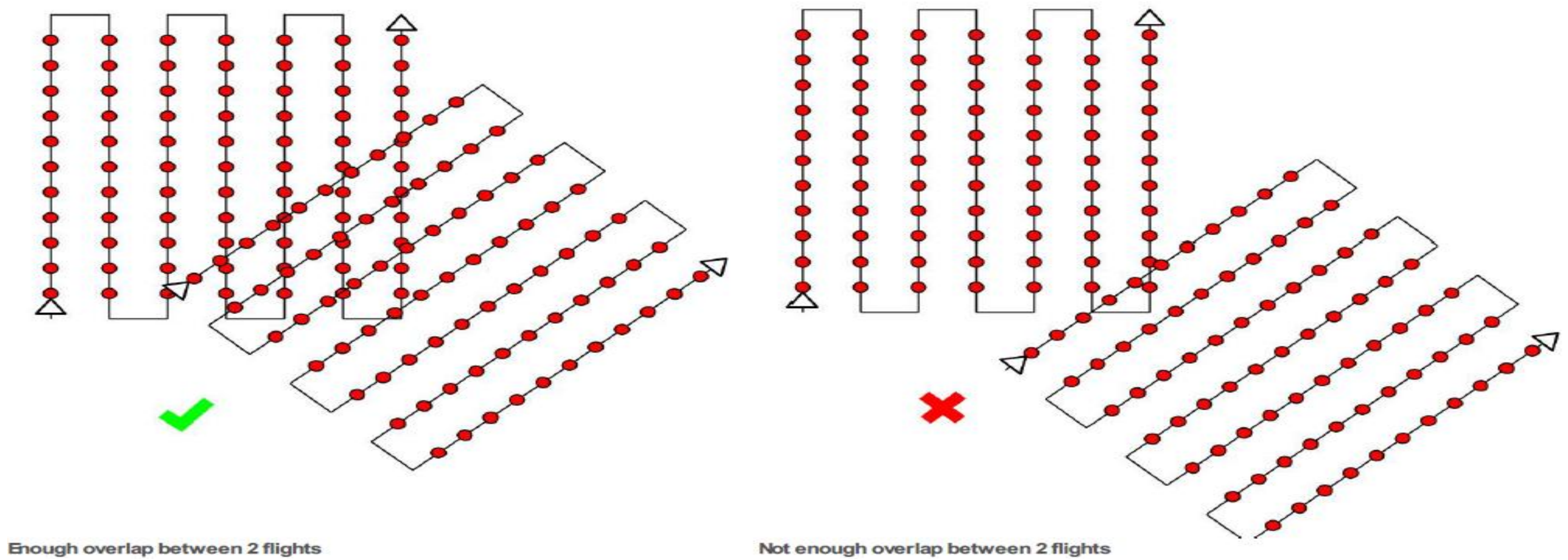


Designing the Images Acquisition Plan

I. Selecting the Image Acquisition Plan Type

Victor Saikhom
victor.saikhom@nesac.gov.in

Multiple flights:

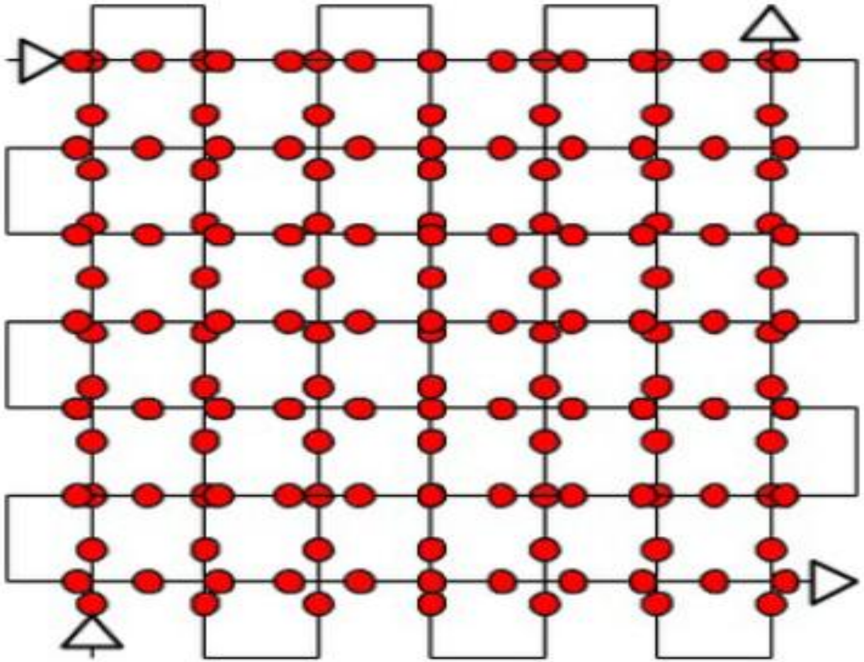


DESIGNING THE IMAGES ACQUISITION PLAN

I. SELECTING THE IMAGE ACQUISITION PLAN TYPE

Victor Saikhom
victor.saikhom@nesac.gov.in

City reconstruction (visible facades):



angle between 10º and 45º and not pointing to the nadir

Designing the Images Acquisition Plan

I. Selecting the Image Acquisition Plan Type

Victor Saikhom
victor.saikhom@nesac.gov.in

Mixed reconstruction:

- ✓ It is possible to combine interior/exterior and/or aerial/terrestrial and /or nadir/oblique. Any combination is possible.
- ✓ The images should have enough overlap in each dataset and between datasets.
- ✓ For such cases it is strongly recommended to use GCPs or Manual Tie Points to properly adjust the different sets of images.

Victor Saikhom
victor.saikhom@nesac.gov.in

II. Computing the **Flight Height for a given GSD**

Using the fact that

$$H / FR = DW / SW,$$

the flight height H is given by:

$$H = (DW * FR) / SW \quad \text{--}(1)$$

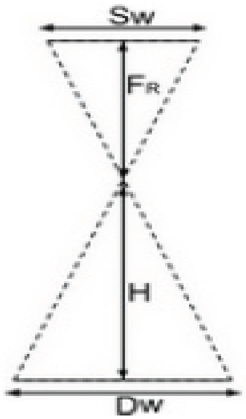
The distance covered on the ground by one image in the width direction (footprint width) is given:

$$DW = (imW * GSD) / 100 \quad \text{-------------------------------------}(2)$$

Combining equation (1) and (2), the flight height is given by:

$$\mathbf{H\ [m] = (imW * GSD * FR) / (SW * 100)} \quad \text{------------------------}(3)$$

***Note**: The result is given in [m], considering that the GSD is in [cm/pixel].*



Sw = real sensor width [mm]
FR = real focal length [mm]
H = flight height [m]
Dw = distance covered on the ground by one image in the width direction (footprint width) [m]
imW = image width [pixel]
GSD = desired GSD [cm/pixel]

DESIGNING THE IMAGES ACQUISITION PLAN

II. COMPUTING THE FLIGHT HEIGHT FOR A GIVEN GSD

Victor Saikhom
victor.saikhom@nesac.gov.in

III. Computing the **Image Rate for a given Frontal Overlap**

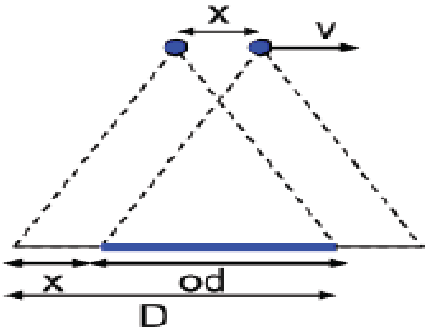
The image shooting rate to achieve a given frontal overlap depends on the speed of the UAV, the GSD and the pixel resolution of the camera.

From Figure, we obtain the following equations:

*od = overlap * D* ------------------------------(1)

x = D - od --(2)

t = x / v --(3)



D = distance covered on the ground by one image in the flight direction [m]

overlap = percentage of desired frontal overlap between two images

od = overlap between two images in the flight direction [m]

x = distance between two camera positions in the flight direction [m]

v = flight speed [m/s]

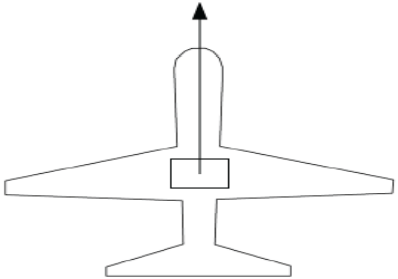
t = elapsed time between two images (image rate) [s]

DESIGNING THE IMAGES ACQUISITION PLAN

III. COMPUTING THE IMAGE RATE FOR A GIVEN FRONTAL OVERLAP

Victor Saikhom
victor.saikhom@nesac.gov.in

- ✓ Camera oriented with the sensor width (long dimension) perpendicular to the flight direction



$$D = Dh = (imH * GSD) / 100 \text{ ------------------------}(4)$$

Where:

Dh = distance covered on the ground by one image in the height direction (footprint height) [m]
imH = image height [pixel]
GSD = desired GSD [cm/pixel]

Combining Equations (1) and (4) into Equation (2):

$$x = Dh - overlap * Dh$$
$$x = Dh * (1 - overlap)$$
$$x = ((imH * GSD) / 100) * (1 - overlap) \text{ --------------------------------}(5)$$

Note: x is given in [m], considering that the GSD is in [cm/pixel].

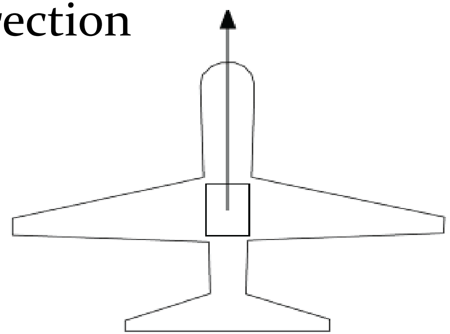
Combining the equations (3) and (5):

$$t = x / v = ((imH * GSD) / 100) * (1 - overlap) / v \text{ --------------------}(6)$$

Designing the Images Acquisition Plan
III. Computing the Image Rate for a given Frontal Overlap

Victor Saikhom
victor.saikhom@nesac.gov.in

- ✓ Camera oriented with the sensor width (long dimension) parallel to the flight direction



$$D = DW = (imW * GSD) / 100 \text{ -------------------}(7)$$

Where:

DW = distance covered on the ground by one image in the width direction (footprint width) [m]
imW = image width [pixel]
GSD = desired GSD [cm/pixel]

Combining equations (1) and (7) into the equation (2):

$$x = DW - overlap * DW$$
$$x = DW * (1 - overlap)$$
$$x = ((imW * GSD) / 100) * (1 - overlap) \text{ ----------------------------}(8)$$

Note: The result is given in [m], considering that the GSD is in [cm/pixel].

Combining equations (3) and (8):

$$t = x / v = ((imW * GSD) / 100) * (1 - overlap) / v \text{ ----------------}(9)$$

DESIGNING THE IMAGES ACQUISITION PLAN

III. COMPUTING THE IMAGE RATE FOR A GIVEN FRONTAL OVERLAP

Victor Saikhom
victor.saikhom@nesac.gov.in

Camera body and lens

- ✓ Perspective and fisheye lens supported.
- ✓ The zoom should be stable.
- ✓ Fixed focal length is recommended.
- ✓ Video frames are not recommended due to low pixel resolution.

Camera settings

- ✓ Stabilization settings should be **off**.
- ✓ Shutter/aperture/ISO should be on **automatic**.
- ✓ If images are blurry or noisy, **manually** set shutter/aperture/ISO.
- ✓ Select Manual Focus on **Infinity**.

CONFIGURING THE CAMERA SETTINGS

Victor Saikhom
victor.saikhom@nesac.gov.in

UAV data/ image processing can be done with --

- ❖ Images without geolocation
- ❖ Images with known position using a camera with built-in GPS tagging
- ❖ Images with known position using an external GPS logger

GEOREFERENCING THE IMAGES

Victor Saikhom
victor.saikhom@nesac.gov.in

Using GCPs is HIGHLY RECOMMENDED.

When using GCPs the following points need to be taken into consideration:

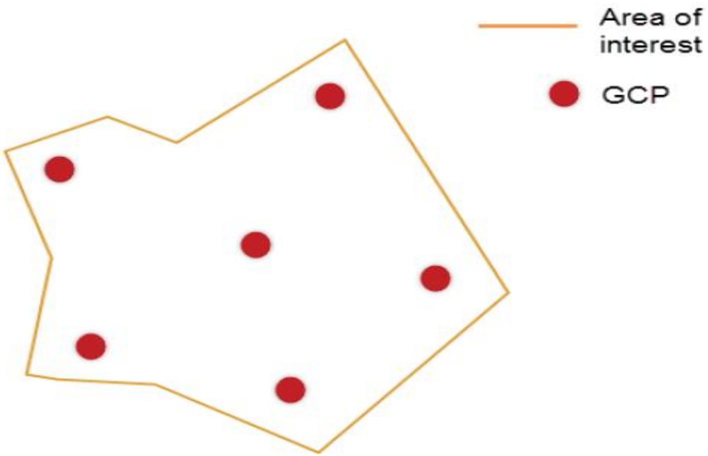
- ✓ Number and distribution of GCPs
- ✓ GCP acquisition

GROUND CONTROL POINTS

Victor Saikhom
victor.saikhom@nesac.gov.in

Number and distribution of GCPs

- A minimum number of 3 GCPs is required. Each one should be clicked in at least 2 images.
- A minimum number of 5 GCPs is recommended. 5 to 10 GCPs are usually enough, even for large projects. More GCPs do not contribute significantly to increase the accuracy.
- In cases that the topography of the area is complex, then more GCPs will, indeed, lead to better (more accurate) reconstruction.



GROUND CONTROL POINTS

Victor Saikhom
victor.saikhom@nesac.gov.in

HOW ACCURATE IS YOUR DRONE SURVEY?

SURVEY ACCURACY VS. PIXEL SIZE

RELATIVE AND ABSOLUTE ACCURACY

WHAT INFLUENCES DRONE SURVEY ACCURACY?

WHAT ACCURACY CAN BE ACHIEVED IN DRONE PHOTOGRAMMETRY?

HOW DO YOU KNOW IF YOUR DRONE SURVEY IS ACCURATE OR NOT?

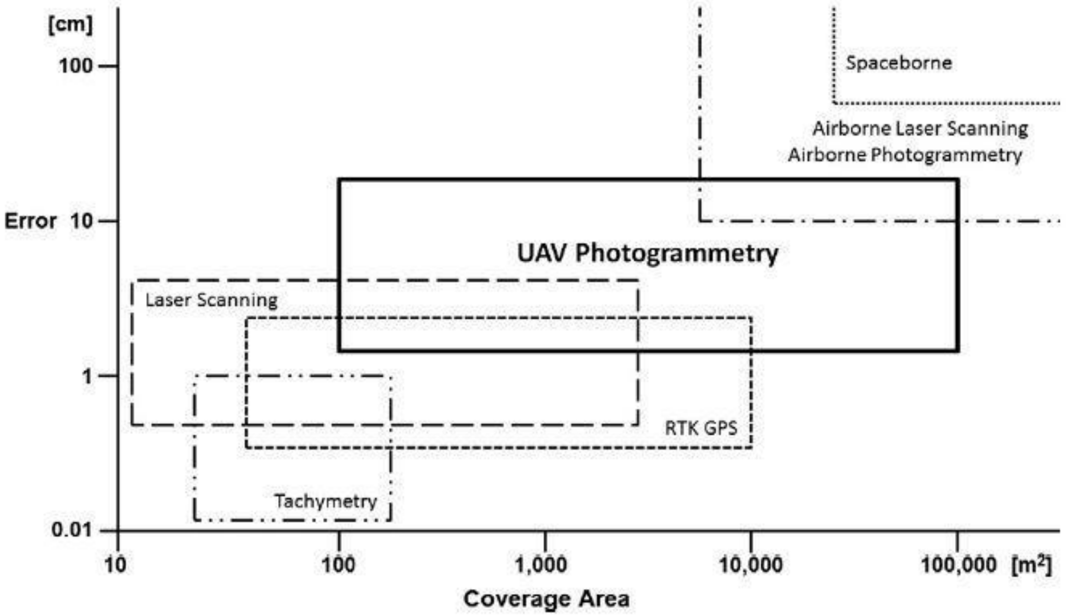
WHY AND WHEN DO YOU NEED ACCURATE DRONE SURVEY DATA?

ACCURACY

Victor Saikhom
victor.saikhom@nesac.gov.in

SUMMARY

- UAV photogrammetry can provide reliable horizontal accuracy
- Vertical accuracy require denser ground control network to be reliable
- UAV photogrammetry is extremely time and cost efficient
- UAV photogrammetry can fill in the gaps of existing technology



Victor Saikhom
victor.saikhom@nesac.gov.in

- Windows 7, 8 or 10, 64 bits.
- CPU quad-core or hexa-core Intel i7/Xeon.
- GeForce GPU compatible with OpenGL 3.2 and 2 GB RAM.
- Hard disk: SSD.
- Small projects (under 100 images at 14 MP): 8 GB RAM, 15 GB SSD Free Space.
- Medium projects (between 100 and 500 images at 14 MP): 16GB RAM, 30 GB SSD Free Space.
- Large projects (over 500 images at 14 MP): 32 GB RAM, 60 GB SSD Free Space.
- Very Large projects (over 2000 images at 14 MP): 32 GB RAM, 120 GB SSD Free Space.

Recommended Systems requirement for running UAV Software

Victor Saikhom
victor.saikhom@nesac.gov.in

Some of the paid software

- Pix4D Mapper
- Agisoft PhotoScan
- Hexagon Imagine UAV
- ESRI Drone2Map for ArcGIS.
- Opsis Photomod
- Skyline Photomesh
- TBC: Trimble Business Center| Trimble Geospatial
- …

Some of the Open Source Tools

- VisualSfM
- Meshlab
- OpenDroneMap
- Python osm-bundler
- SfMToolkits
- …

UAV SOFTWARES

Victor Saikhom
victor.saikhom@nesac.gov.in

Thank You

Victor Saikhom
victor.saikhom@nesac.gov.in