

# CE 59700: Digital Photogrammetric Systems

Fall 2018

# Contact Information

- Instructor:
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  - Lectures (HAMP 2123):
    - Monday, Wednesday & Friday (8:30 a.m. – 9:20 a.m.)
  - Office Hours:
    - Monday & Wednesday (9:30 a.m. – 10:30 a.m.)
- Course webpage:
  - <http://purdue.edu/CE/DPRG>

# Course Objectives

- Gain familiarity with the basic principles of photogrammetric operations
- Emphasis:
  - Definition and possible applications,
  - Electromagnetic radiation,
  - Optical principles, film development, and digital cameras,
  - Vertical photography,
  - Image coordinate measurement and reduction,
  - Mathematical and geometric principles,
  - Theory and procedures of photogrammetric orientation,
  - Photogrammetric geo-referencing,
  - Digital image matching, and
  - Digital orthophoto generation.

# Course Notes and Textbooks

- Material presented in class, as well as supplemental notes, will be available through the course webpage.
  - Contains all the required material for the assignments and exams.
- Supplementary References (**optional**):
  - Mikhail, E., Bethel, J., McGlone, J., 2001. Introduction to Modern Photogrammetry. John Wiley & Sons, Inc.
  - McGlone, C, Mikhail, E., Bethel, J., 2012, Manual of Photogrammetry, Sixth Edition, American Society for Photogrammetry and Remote Sensing.
  - Wolf, P., Dewitt, B., 2000. Elements of Photogrammetry with Applications in GIS. McGraw-Hill.
  - Krauss, K., 1993. Photogrammetry, Volume 1: Fundamentals and Standard Processes. Dummler/Bonn.
  - Krauss, K., 1997. Photogrammetry, Volume 2: Advanced Methods and Applications. Dummler/Bonn.

# Grading Scheme

- Assignments: (25% of Total Grade)
  - Assignments will be due within roughly two weeks after they are handed out. Grades for late assignments will be reduced by 10% per day for each day overdue.
  - Some assignments will require computer programming (Matlab, C, or C++) and submissions must include a softcopy of the source code (well documented) and the program output.
- Mid-Term Exam: (25% of Total Grade)
- Final Exam: (50% of Total Grade)
  - Exams are closed book/notes
- Bonus points for class participation

# Syllabus (Course Content)

- **Chapter 1: Introduction**
  - Definition, concepts, and applications
- **Chapter 2: Electro-Magnetic Radiation**
  - Energy sources and radiation principles
- **Chapter 3: Basic Optics**
  - Principles of geometric optics and important optical conditions for photogrammetric applications
- **Chapter 4: Film Development & Digital Cameras**
  - Development of B/W and color films
  - Digital cameras (frame and line cameras)
- **Chapter 5: Vertical Photography**
  - Basic definitions, image scale, image to ground coordinate transformation, relief displacement

# Syllabus (Course Content)

- **Chapter 6:** Image Coordinate Measurements
  - Measurements and necessary reductions of image coordinates
- **Chapter 7:** The Mathematical Model
  - Rotation matrices, the collinearity equations (concept and derivation)
  - Projective transformation, DLT, and RFM
- **Chapter 8:** Theory of Orientation
  - Interior, relative, and absolute orientation
- **Chapter 9:** Photogrammetric Bundle Adjustment
  - Sequential reconstruction of the normal equation matrix and derivation of the unknown parameters
- **Chapter 10:** Photogrammetric Geo-Referencing
  - Integrated sensor orientation and direct geo-referencing

# Syllabus (Course Content)

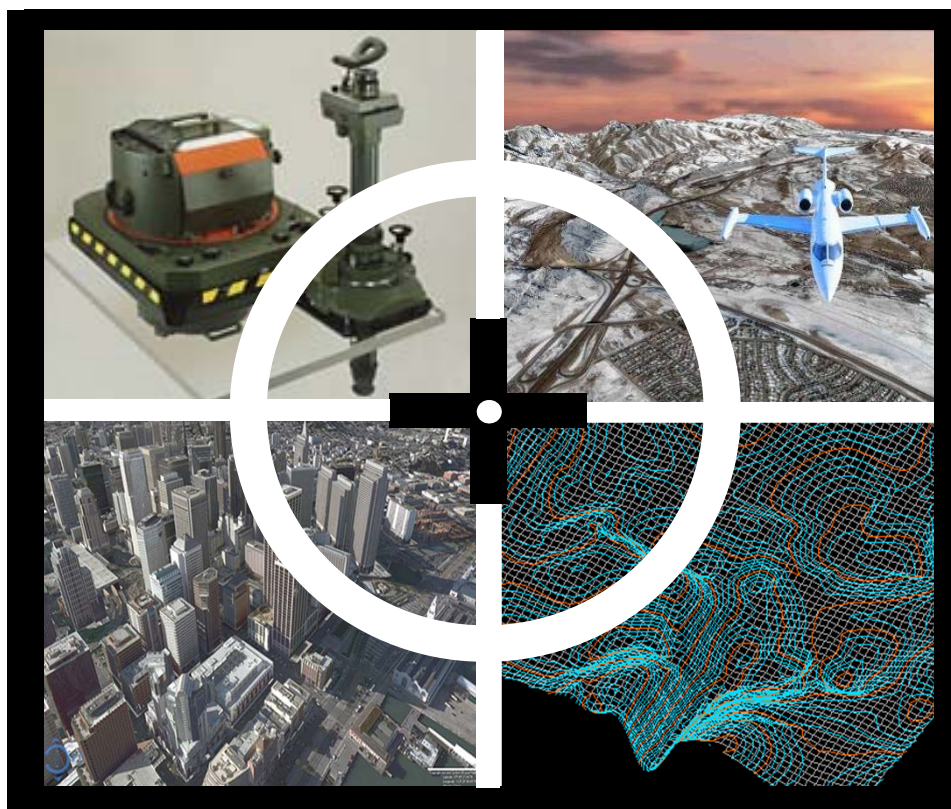
- **Chapter 11: Digital Image Matching**
  - Identification of conjugate points in overlapping images (cross correlation and least-squares matching)
- **Chapter 12: Digital Orthophoto Generation**
  - Polynomial rectification, differential rectification, and true orthophotos



# Ch 1: Introduction

- Definition & Objectives
- Applications:
  - Reconnaissance
  - Production of Topographic Maps
  - DEM Generation
  - Close Range Photogrammetry:
    - Precision survey of buildings and engineering objects
    - Documentation of historical buildings
    - Medical applications
    - Mapping of roads and nearby objects (mobile mapping systems)

# Ch 1: Introduction

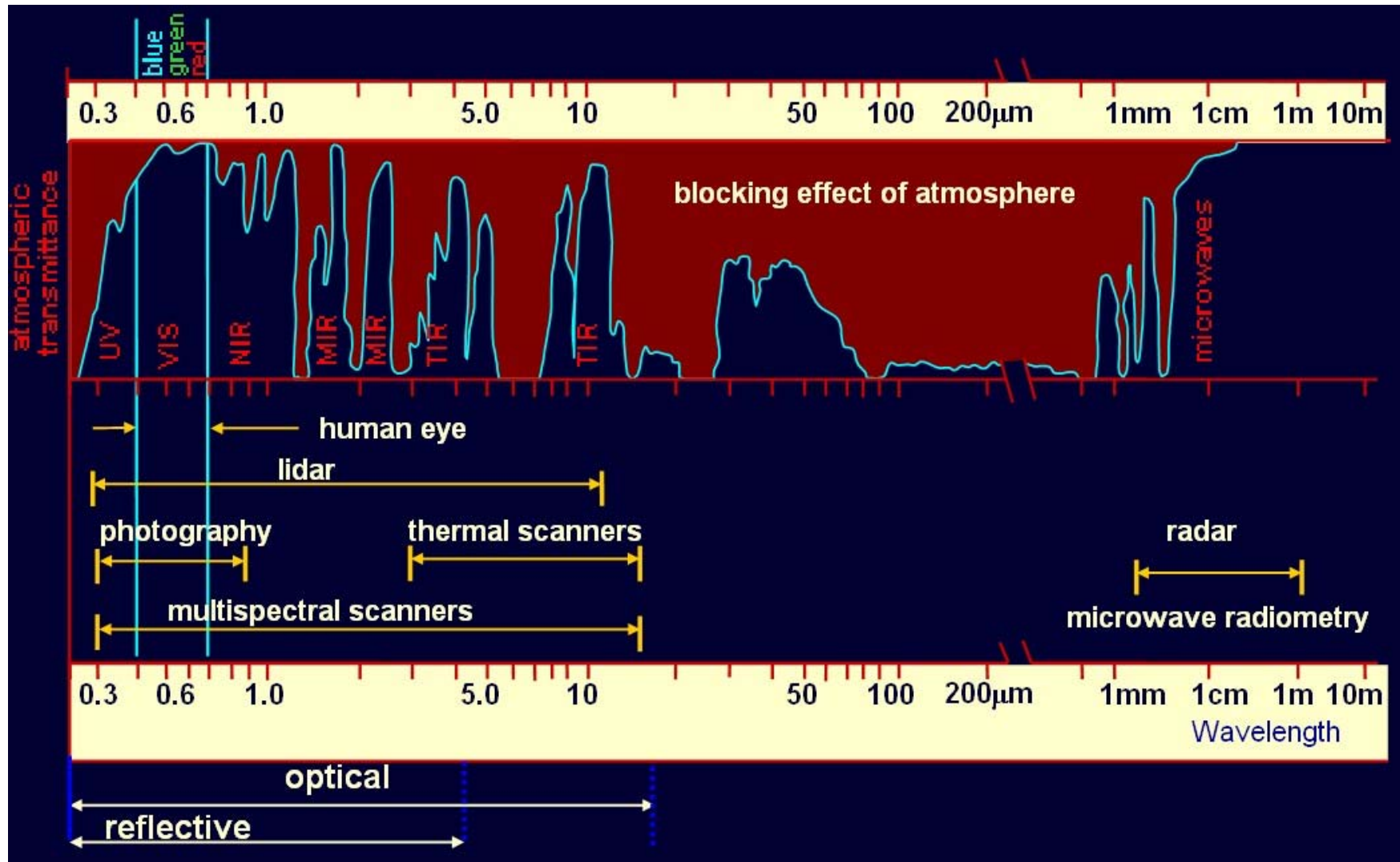


Art and science of tool development for automatic generation of spatial and descriptive information from multi-sensory data and/or systems

# Ch 2: Electro-Magnetic Radiation

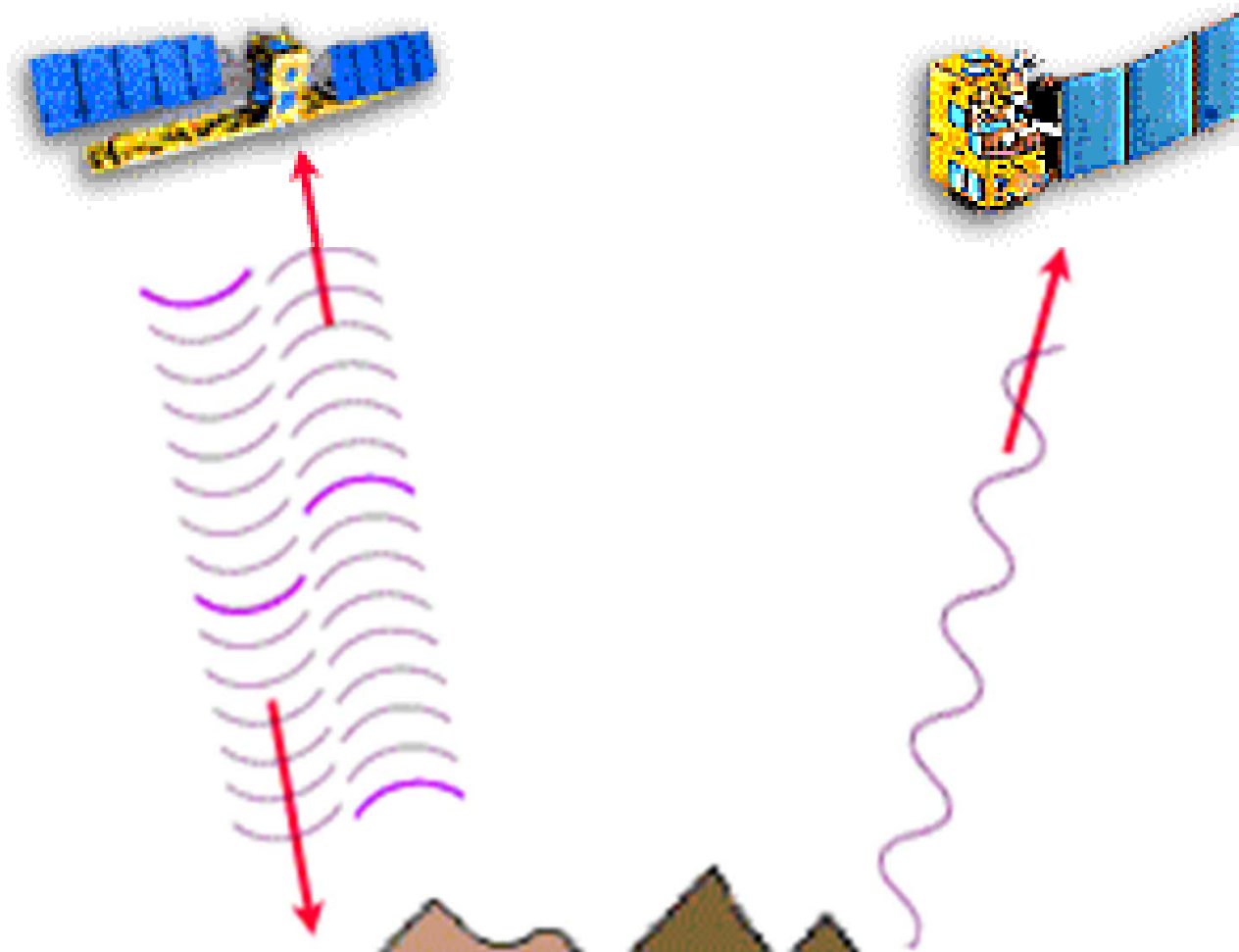
- Bands of the electro-magnetic radiation:
  - Radio waves
  - Microwaves
  - Infrared radiation
  - Visible light
  - Ultraviolet rays
  - X-rays
  - Gamma rays
- Properties of the electro-magnetic radiation
- Passive versus active remote sensing systems

# Ch 2: Electro-Magnetic Radiation



<http://foto.hut.fi/opetus/350/k04/luento6/luento6.html>

# Active Versus Passive Sensors



<http://www.neis.gov.cn/kjddYG/index.jhtml>

# Ch 3: Basic Optics

- Basic camera components
- Reflection and refraction
- Lenses: Definitions
- Lens equation, aberrations, and distortions
- Diffraction
- Resolving power of optical systems
  - Depth of focus and depth of field
  - Motion blur

# Ch 3: Basic Optics



<http://www.dpreview.com/reviews/sonydsf828/3>

# Ch 4: Film Development & Digital Cameras

- Photographic film components
- Processing of Black and White (B/W) film
  - Negative film & inverse film
- Nature of color
- Processing of color film
  - Negative film & inverse film
- Digital cameras
  - Frame cameras
  - Line cameras (push-broom, three-line, and panoramic scanners)



# Ch 4: Film Development & Digital Cameras



<http://www.dpreview.com/reviews/sonydscf828/3>

# Ch 4: Analog Cameras



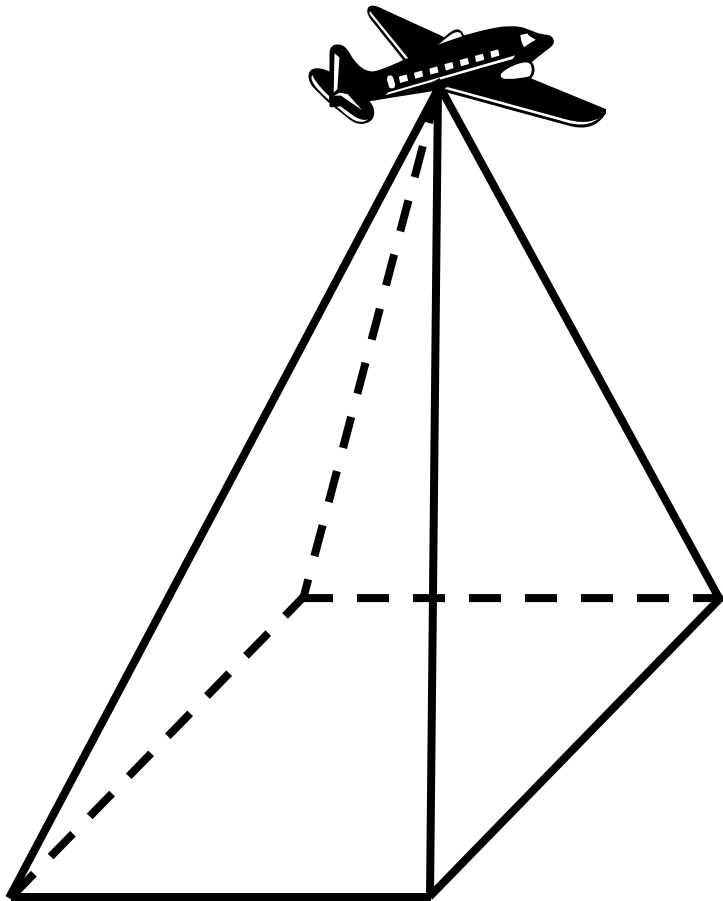
Negative Film



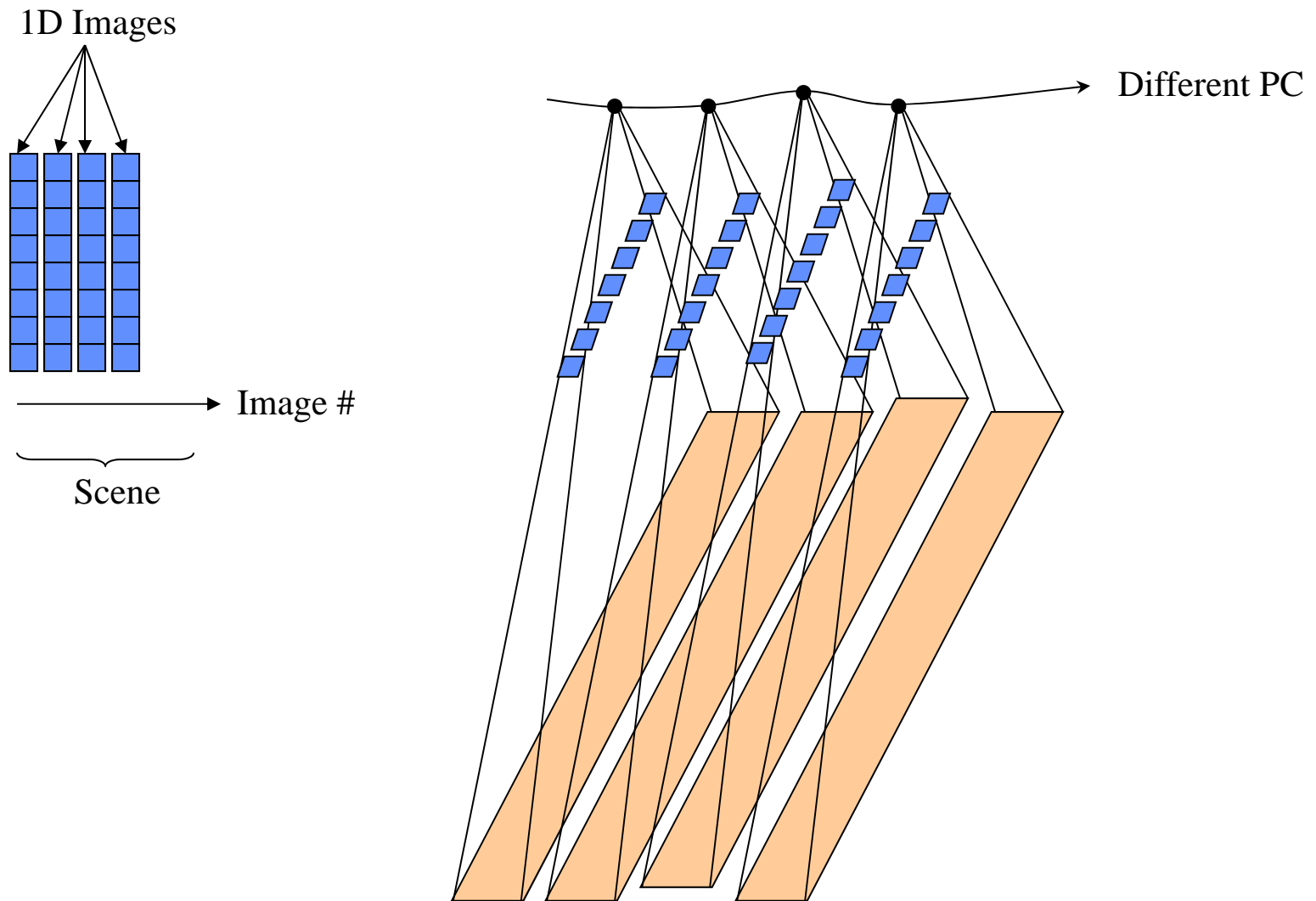
Positive Film

<http://www.beautiful-landscape.com/>

# Frame Camera: Scene Acquisition



# Line Camera: Scene Acquisition



# Ch 5: Vertical Photography

- Image versus map characteristics
- Vertical photography: definitions and characteristics
- Image scale
- Mathematical relationship between corresponding image and ground coordinates
- Relief displacements

# Ch 5: Vertical Photography



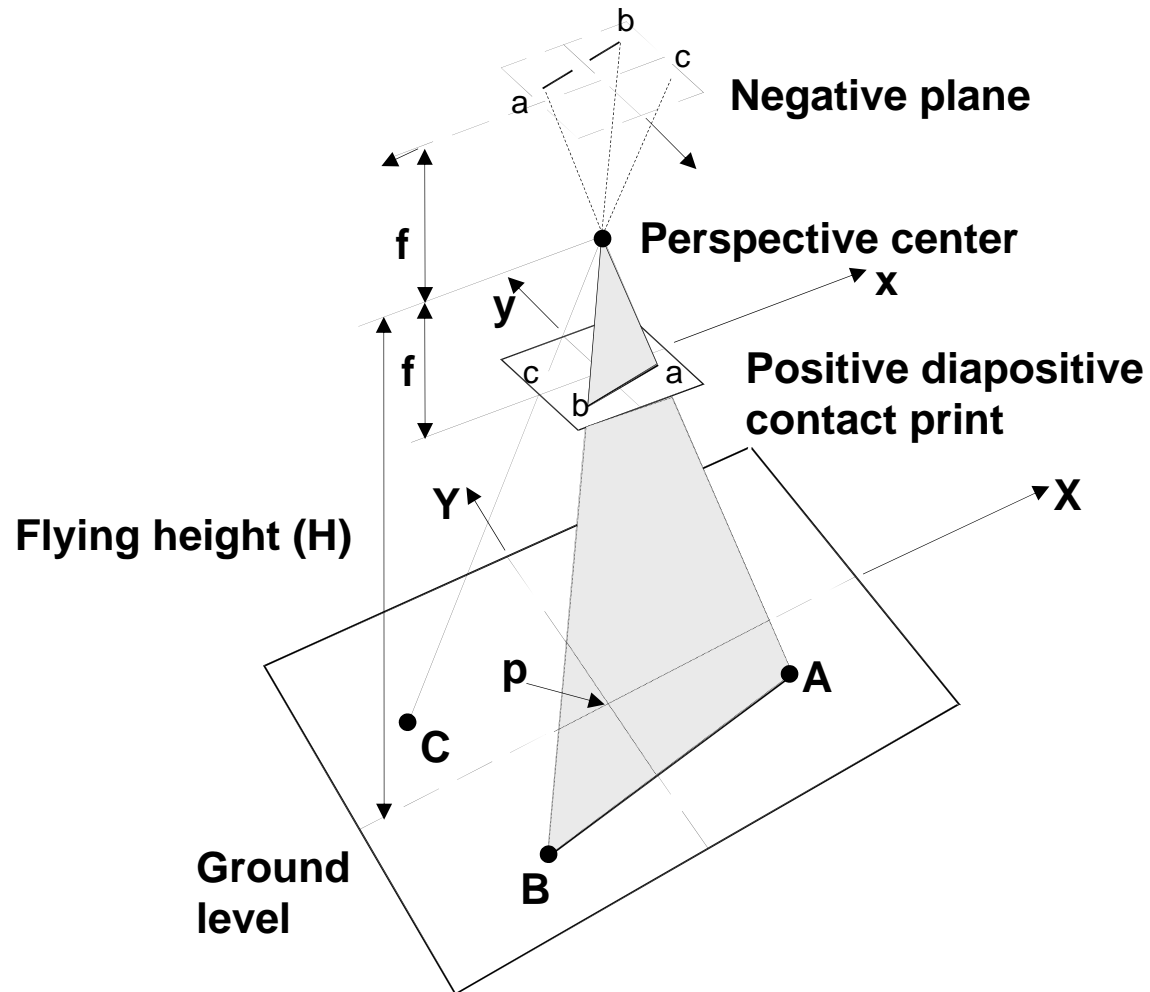
Vertical photographs



Oblique photographs

<http://civisit.com/blog/?p=52>

# Ground Coordinates from Image Coordinates

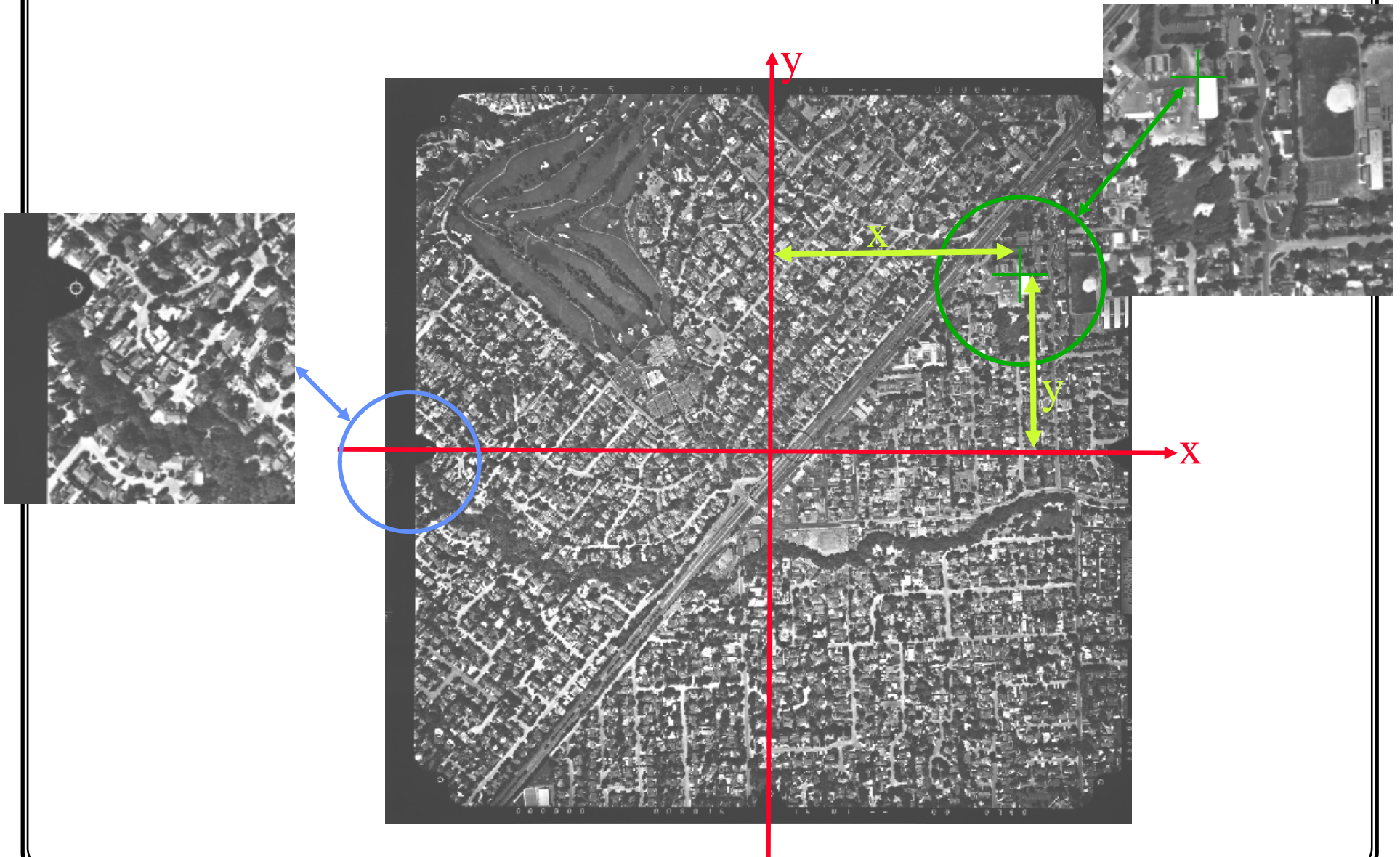


# Ch 6: Image Coordinate Measurements

- Image coordinate measurements in analog, analytical, and digital environments
- Comparators: mono and stereo-comparators
- Comparator to image coordinate transformations
- Reduction/refinement of image coordinate measurements:
  - Radial and de-centering lens distortions
  - Atmospheric refraction
  - Earth curvature



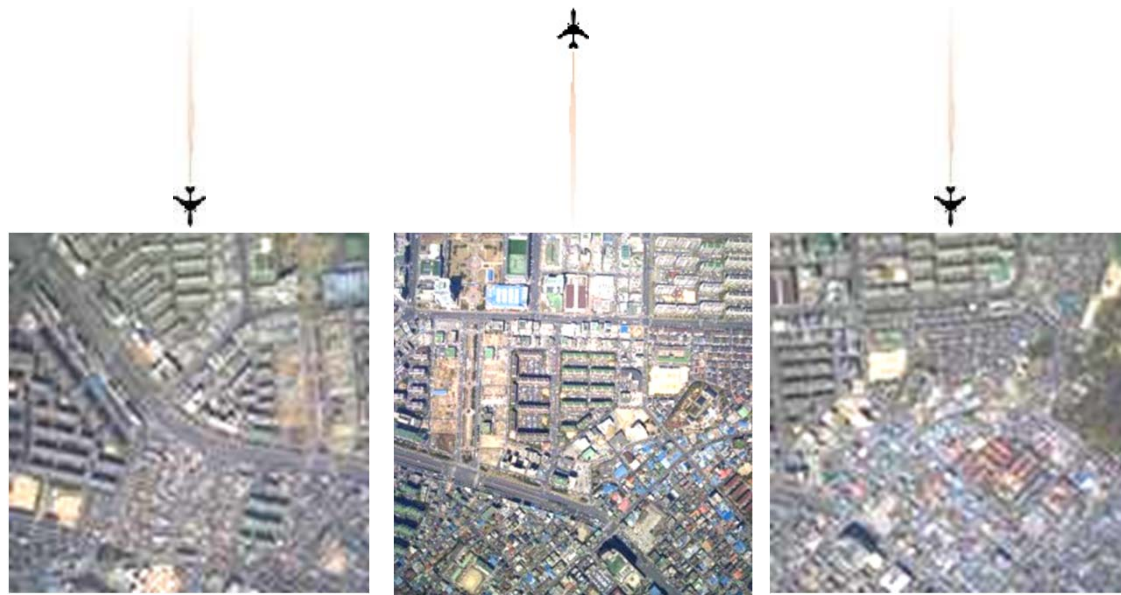
# Ch 6: Image Coordinate Measurements



# Ch7: Mathematical Model

- Objectives: Derive the general mathematical relationship between corresponding image and object space coordinates
- Projection alternatives
- Rotation matrices (2-D and 3-D)
  - Derivations and characteristics
- Collinearity equations
  - Concept and derivation
- Projective transformation, DLT, and RFM
- Least-squares adjustment in photogrammetry

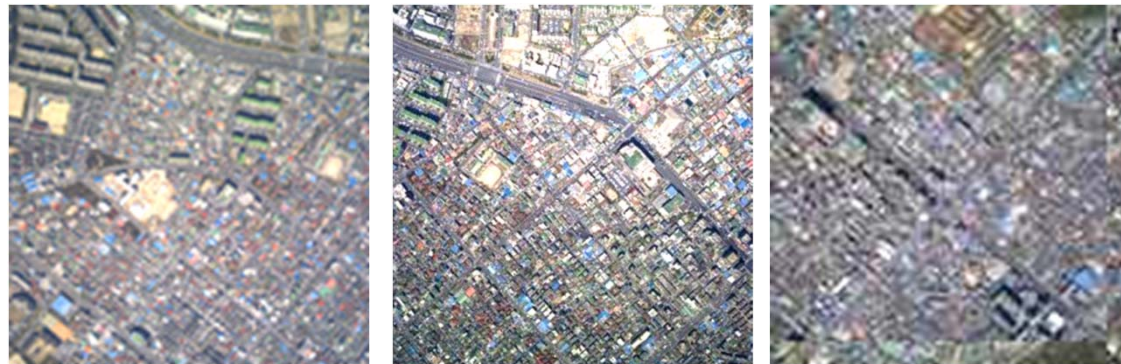
# Ch7: Mathematical Model



7575

8092

8686

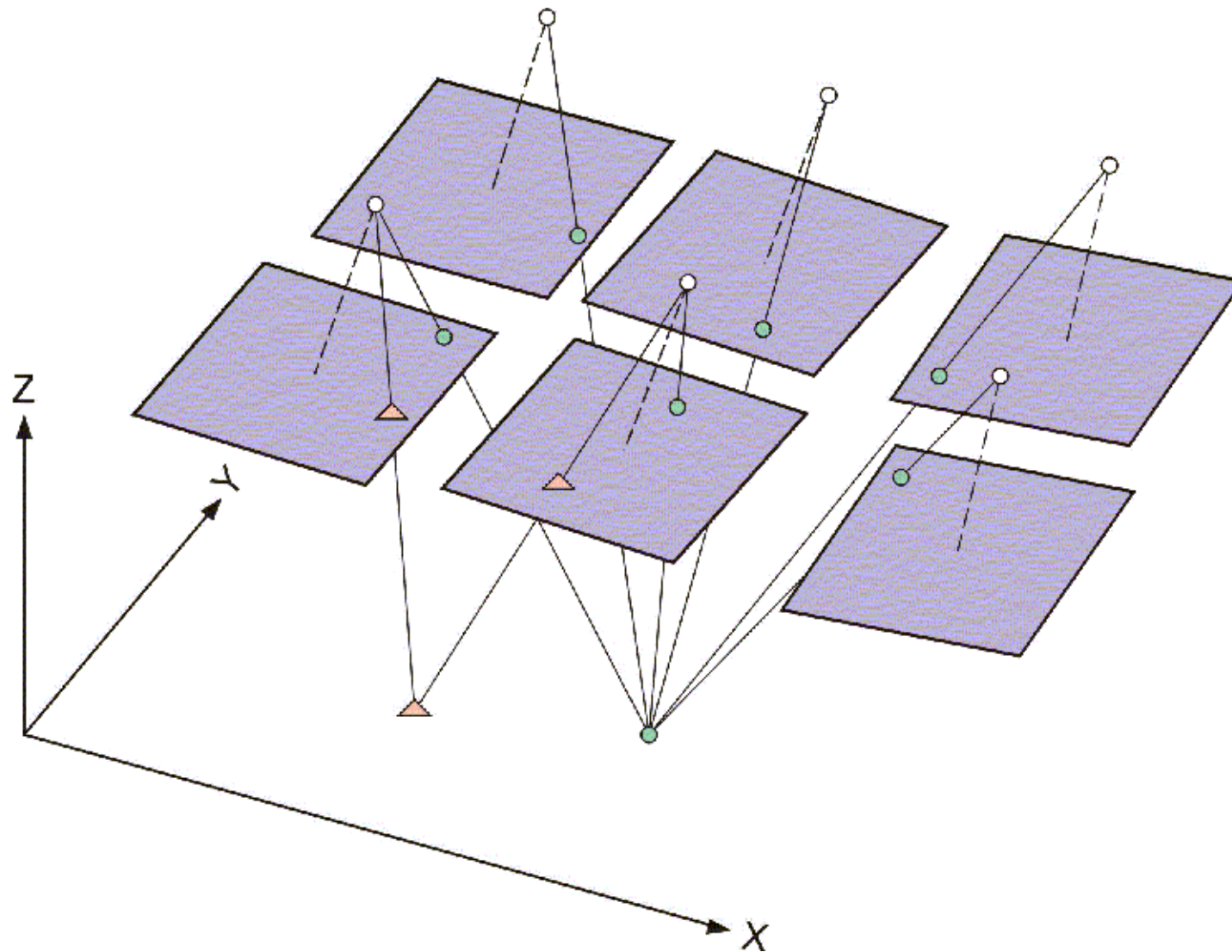


7582

8086

8692

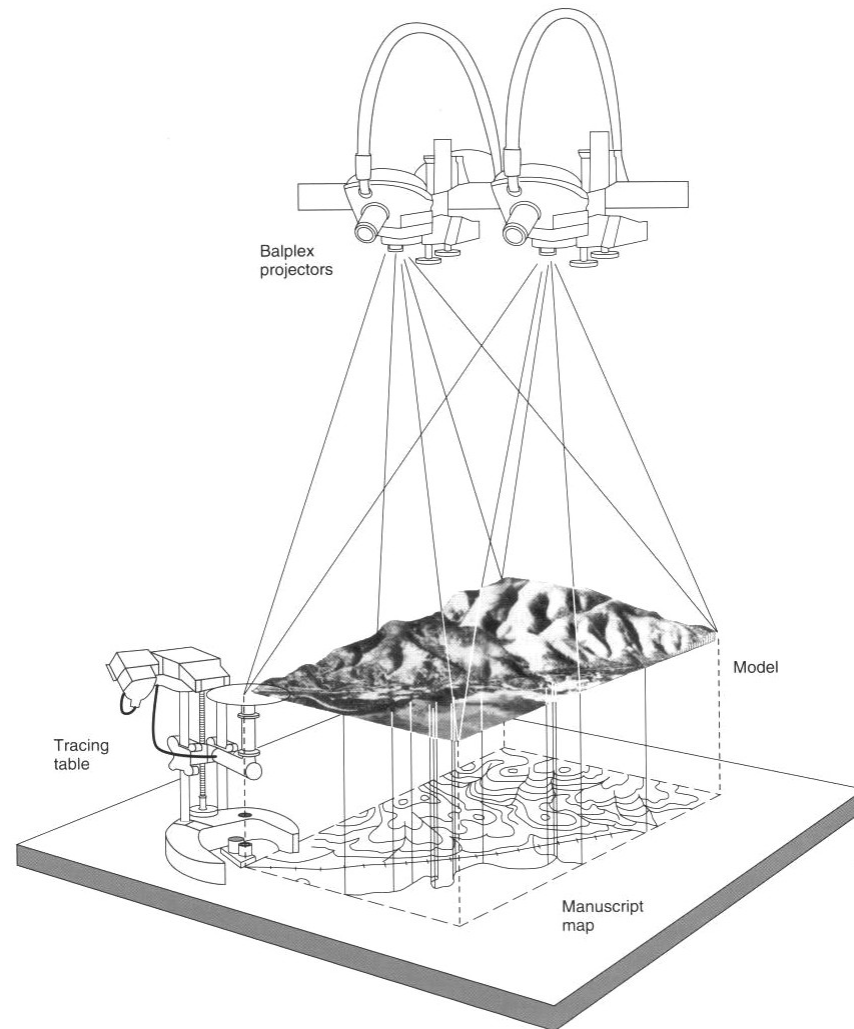
# Ch7: Mathematical Model



# Ch 8: Theory of Orientation

- Objective: Transform centrally projected images into a three-dimensional model which we can use to plot an orthogonal map
- Interior orientation
- Exterior orientation:
  - Relative orientation
    - X versus y-parallax
  - Absolute orientation
- Aerial Triangulation: Strip and block triangulation

# Ch 8: Theory of Orientation



# Ch 9: Bundle Block Adjustment

- Objective: Mathematical manipulation of the observation equations to speed up the
  - Formation of the normal equation matrix, and
  - Derivation of the unknown parameters
- Special cases:
  - Single photo resection,
  - Spatial intersection,
  - Relative orientation, and
  - Stereo-pair orientation

# Ch 9: Bundle Block Adjustment

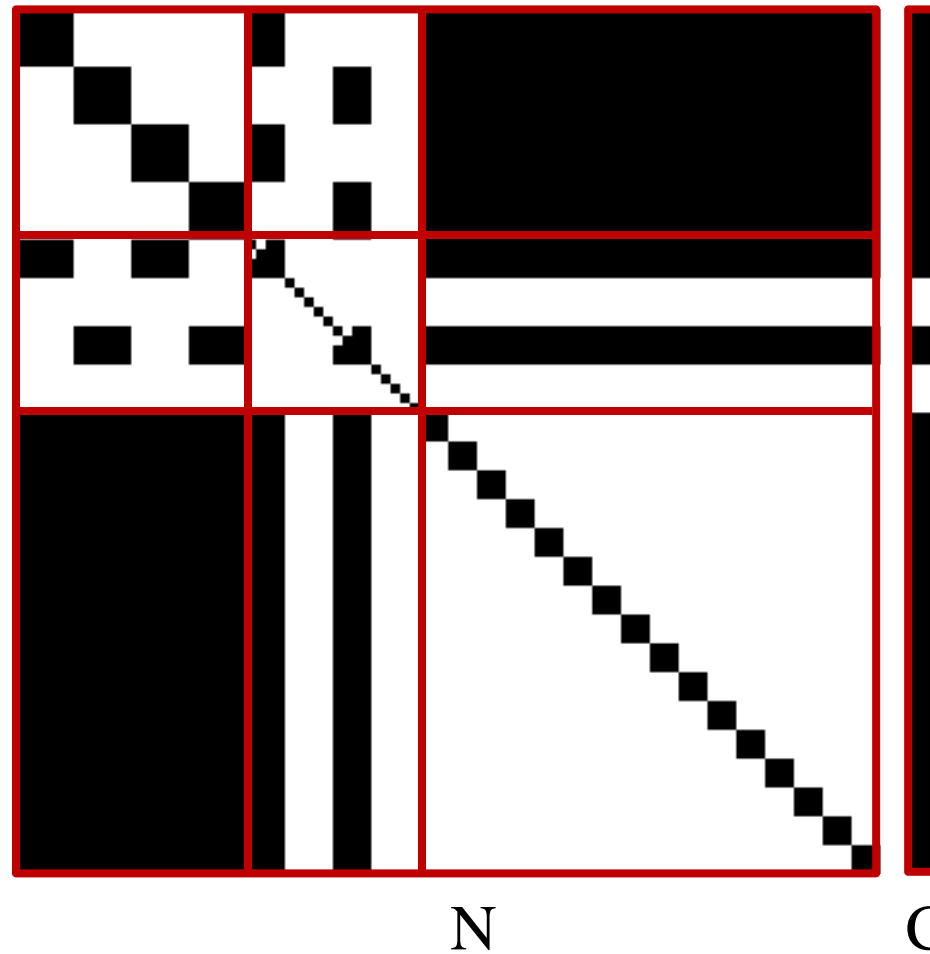


- 2 cameras
- 4 images
- 16 points

- All the points appear in all the images.
- Two images were captured by each camera.



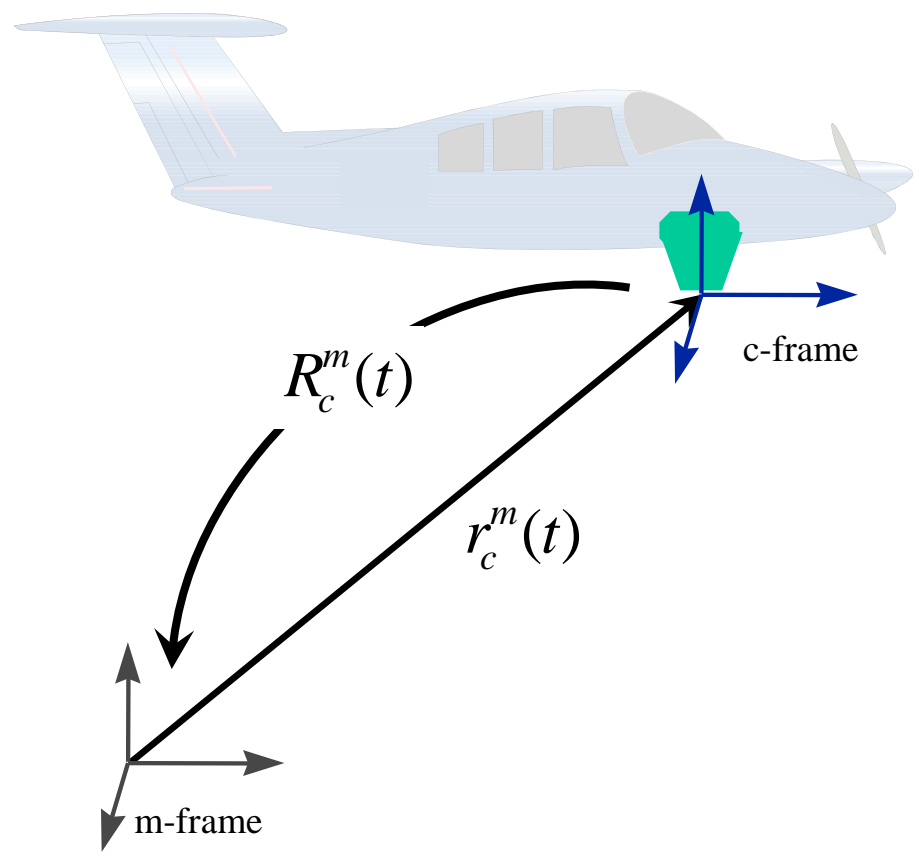
# Ch 9: Bundle Block Adjustment



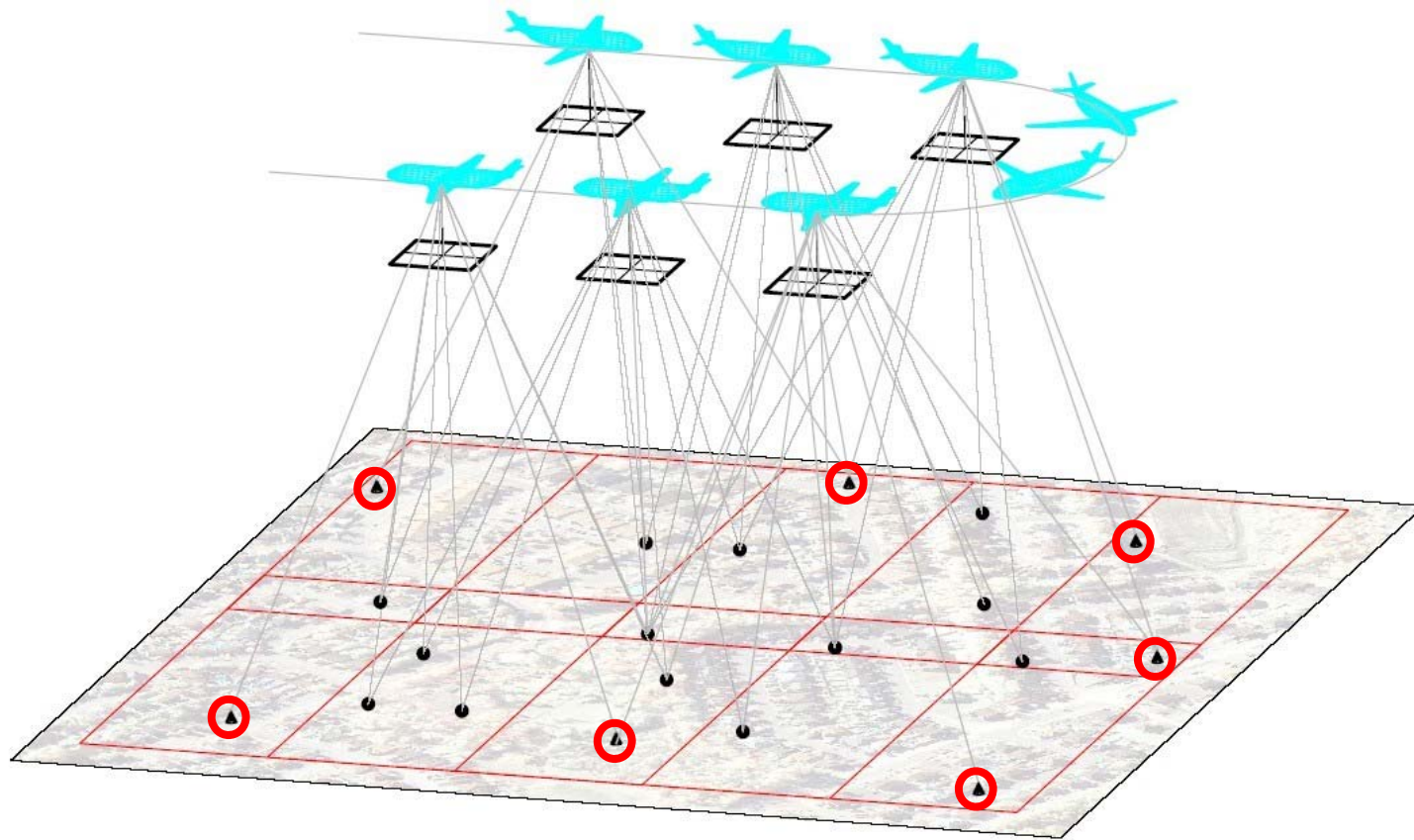
# Ch 10: Photogrammetric Geo-Referencing

- Objective: Define the position and orientation of the different images at the moment of exposure
  - Exterior Orientation Parameters (EOP)
- Geo-referencing alternatives:
  - Indirect geo-referencing,
  - Integrated Sensor Orientation (ISO), and
  - Direct geo-referencing

# Ch 10: Photogrammetric Geo-Referencing



# Indirect Geo-Referencing



- ▲ Ground Control Points
- Tie Points

# Indirect Geo-Referencing



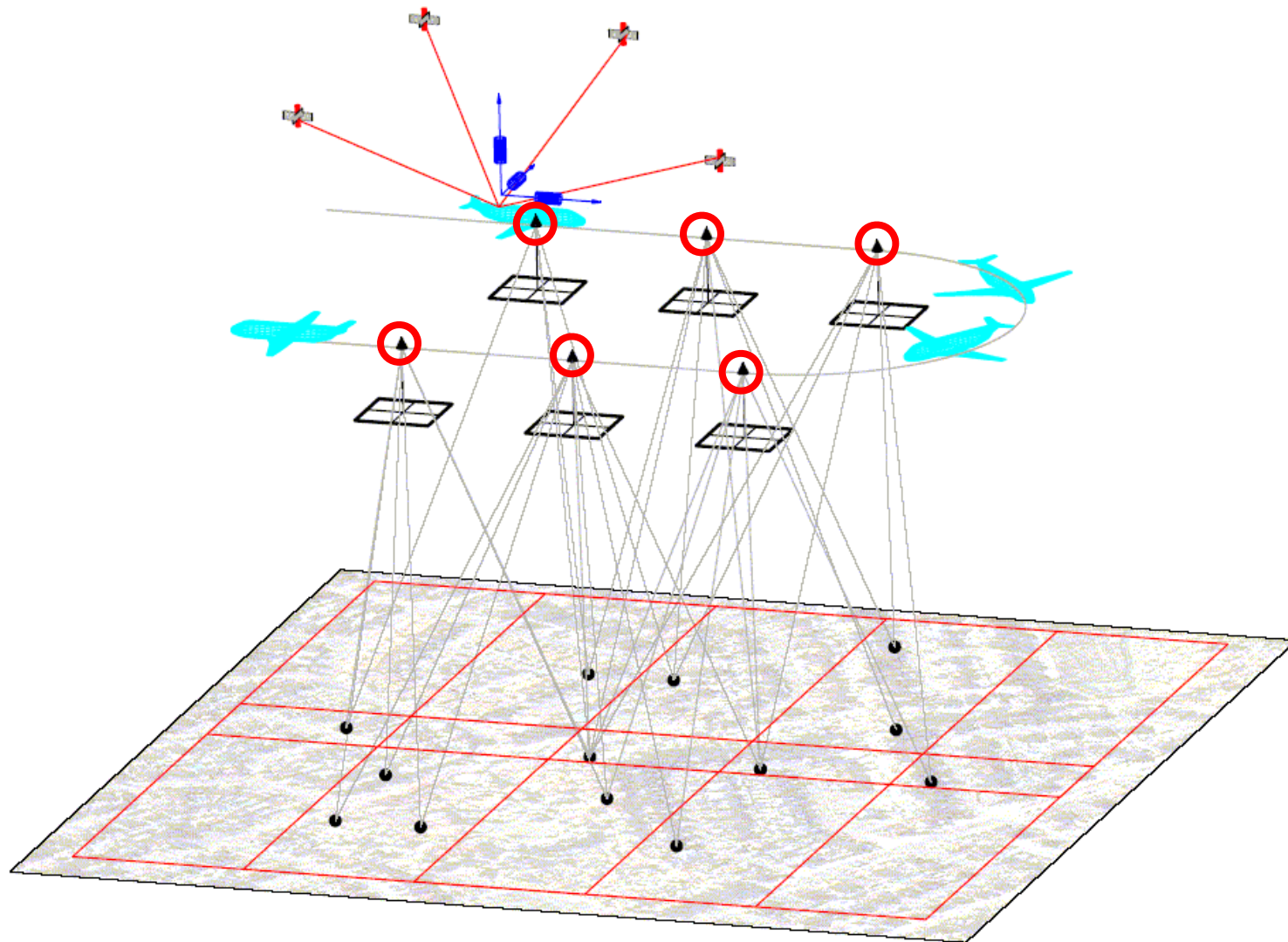
Signalized Targets

# Indirect Geo-Referencing

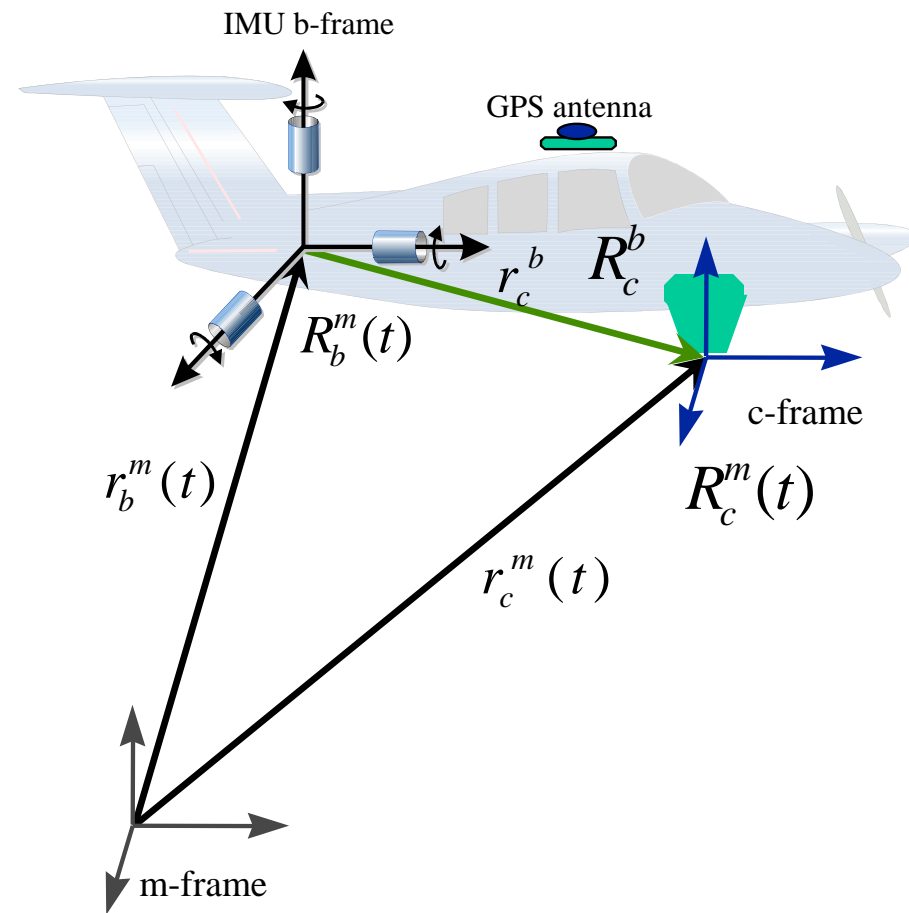


Natural Targets

# Direct Geo-Referencing



# Direct Geo-Referencing





# Direct Geo-Referencing: Airborne System



GPS Antenna

INS

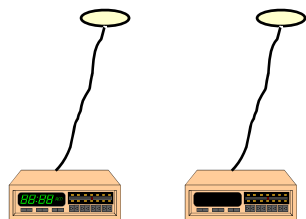
PC



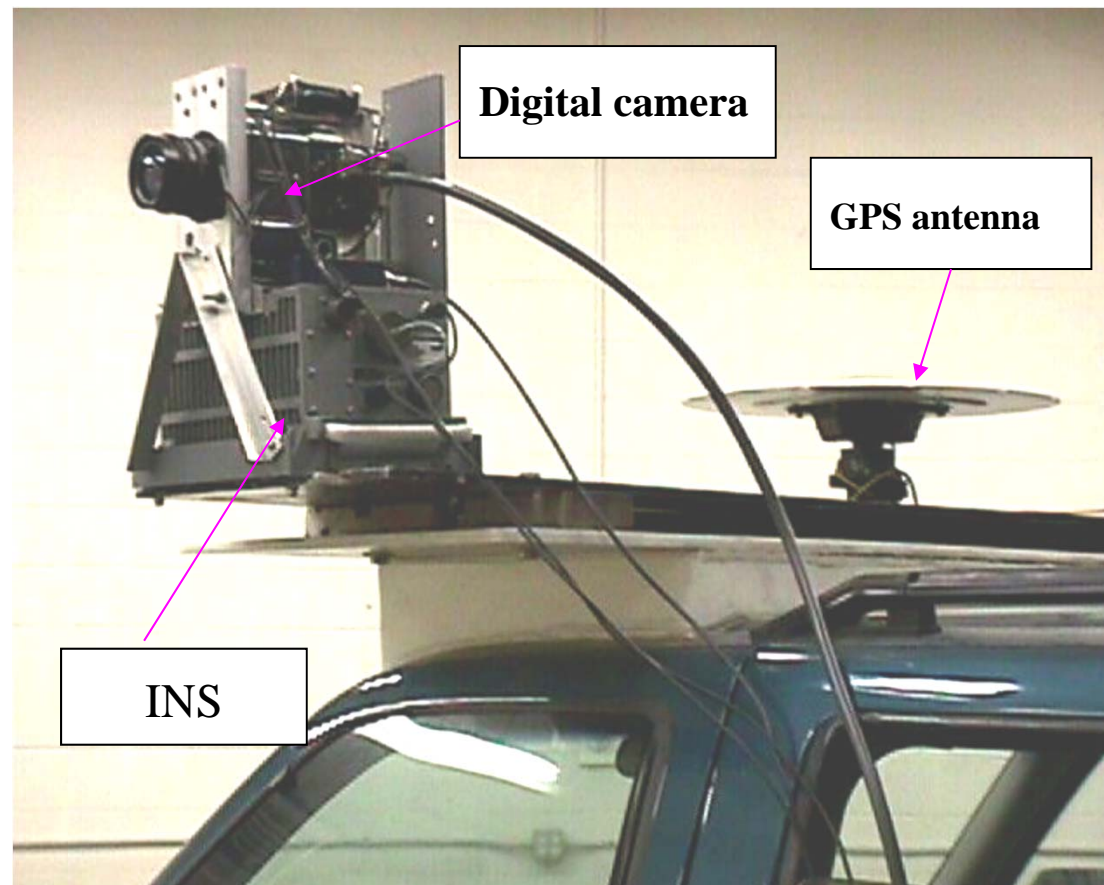
Two Base Stations

Camera

GPS Receiver



# Direct Geo-Referencing: Land-Based System



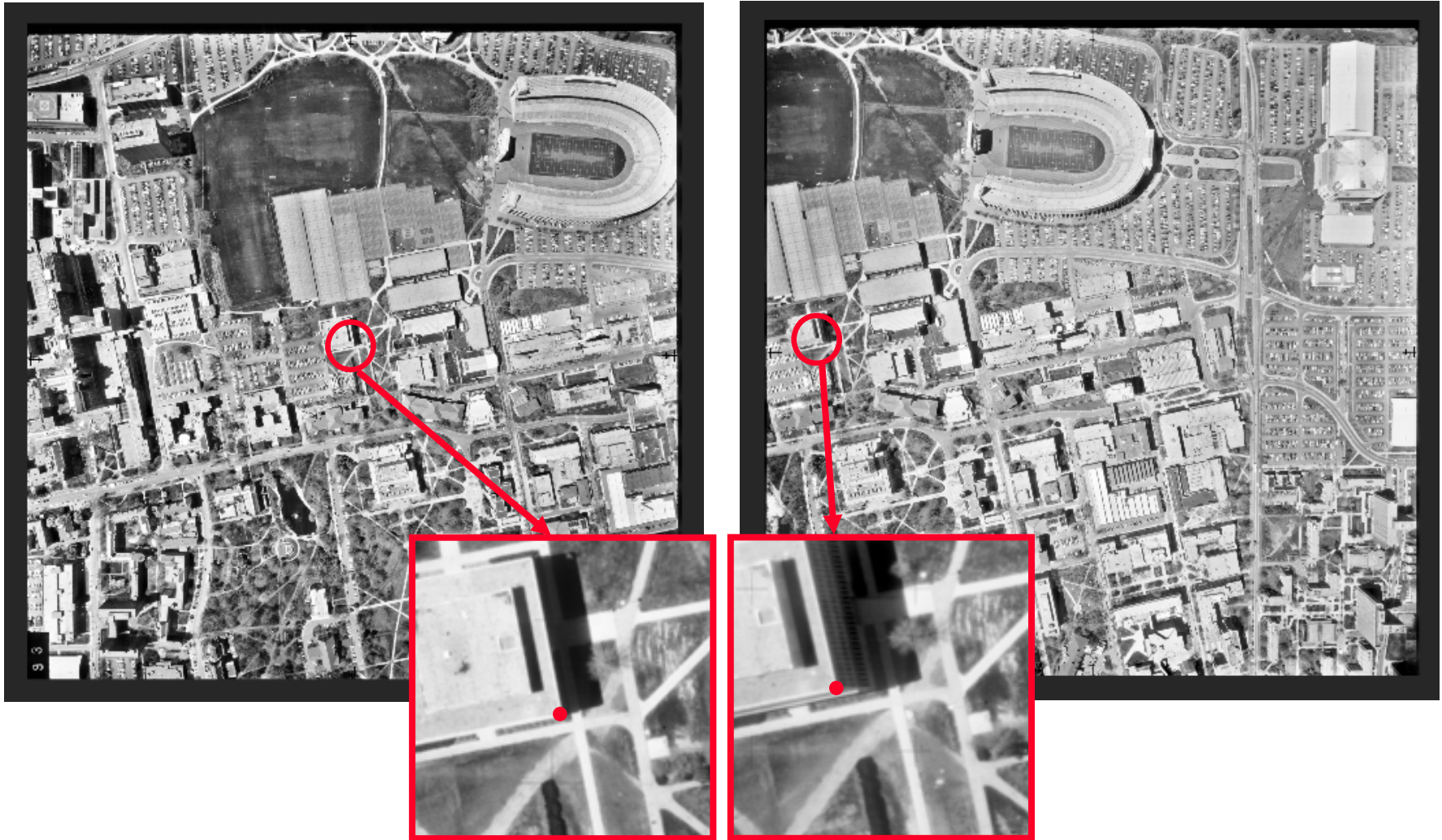
# Direct Geo-Referencing: Land-Based System



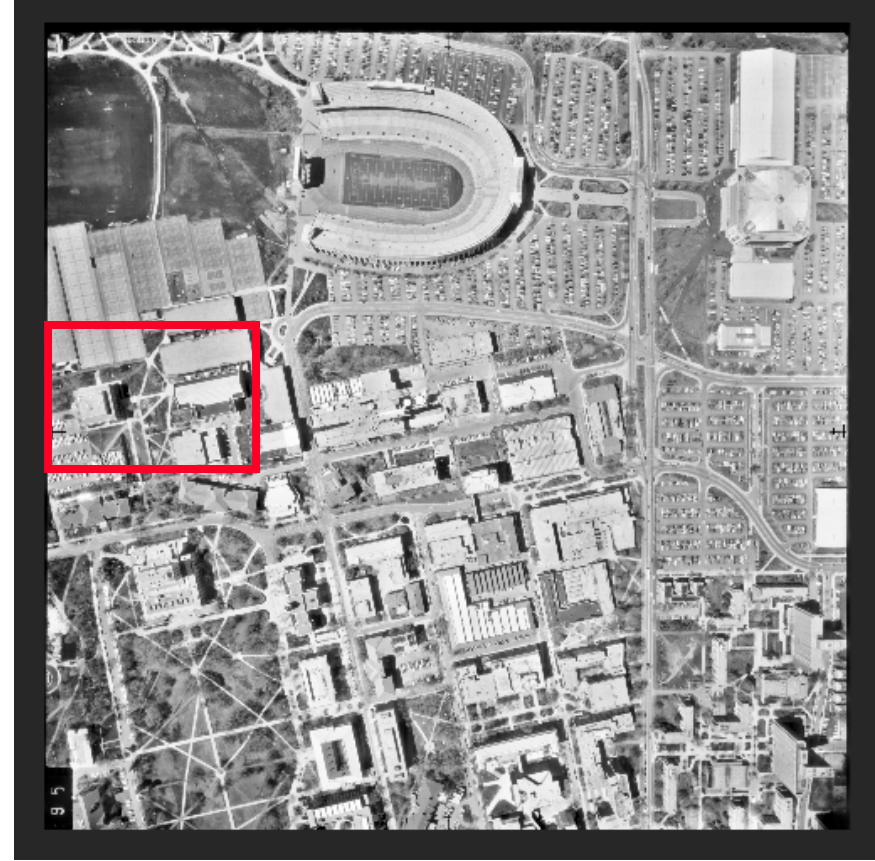
# Ch 11: Digital Image Matching

- Objective: Automated identification of conjugate points in overlapping images
- Terminology
- Issues affecting the complexity of the matching problem
- Area-based matching:
  - Cross correlation, and
  - Least-squares matching
- Image resampling according to epipolar geometry

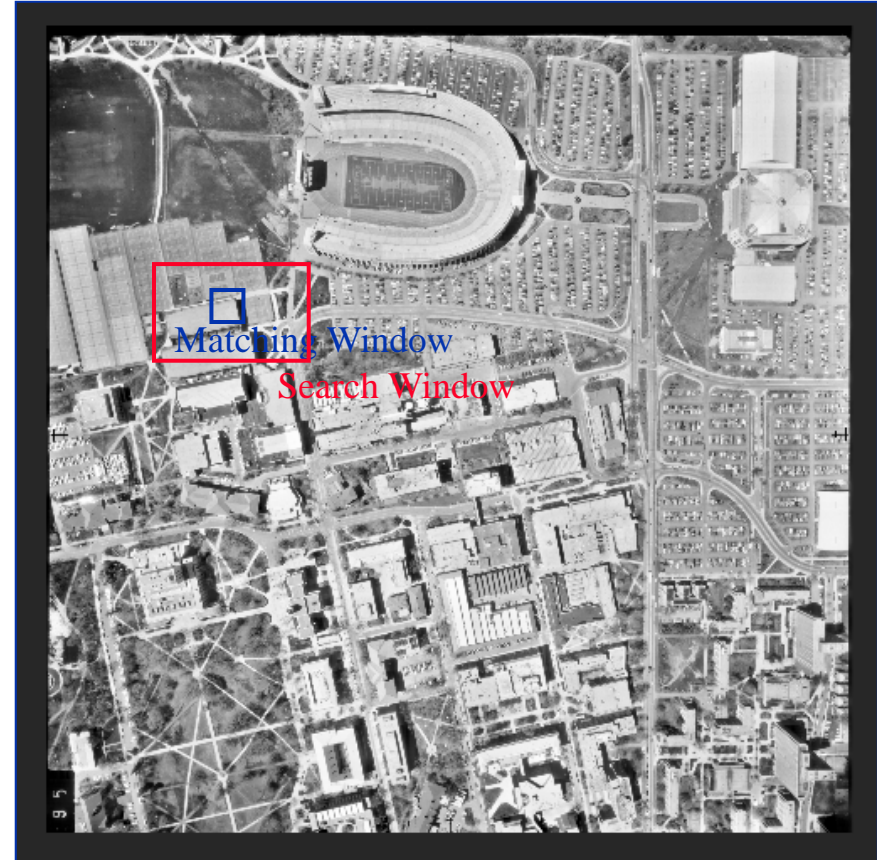
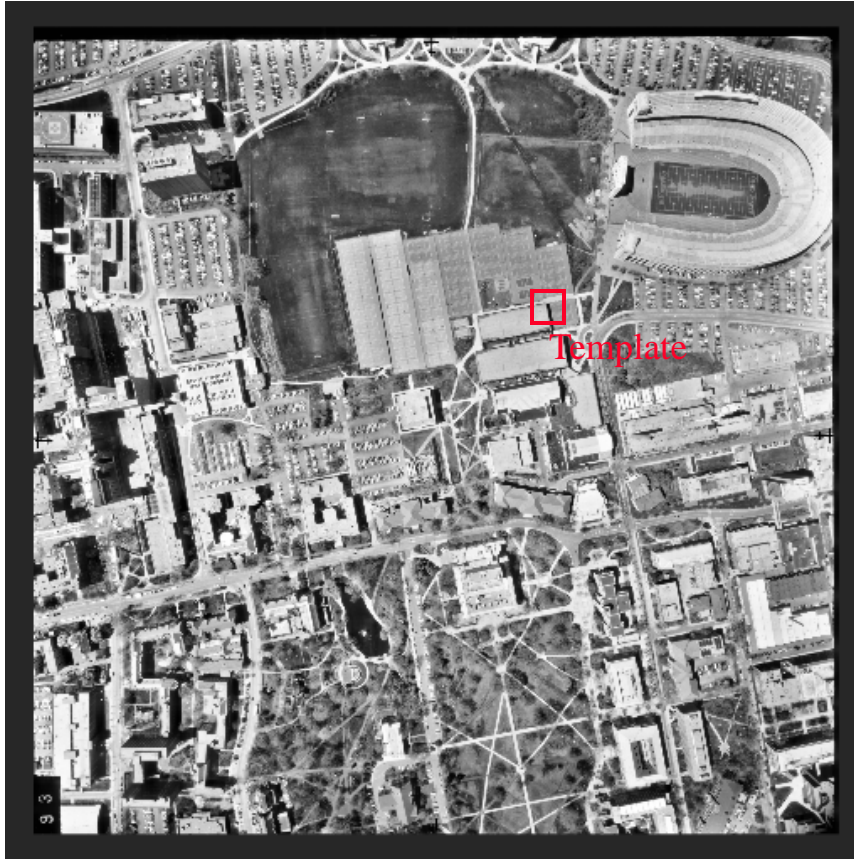
# Image Matching



# Image Matching



# Image Matching



# Original Images

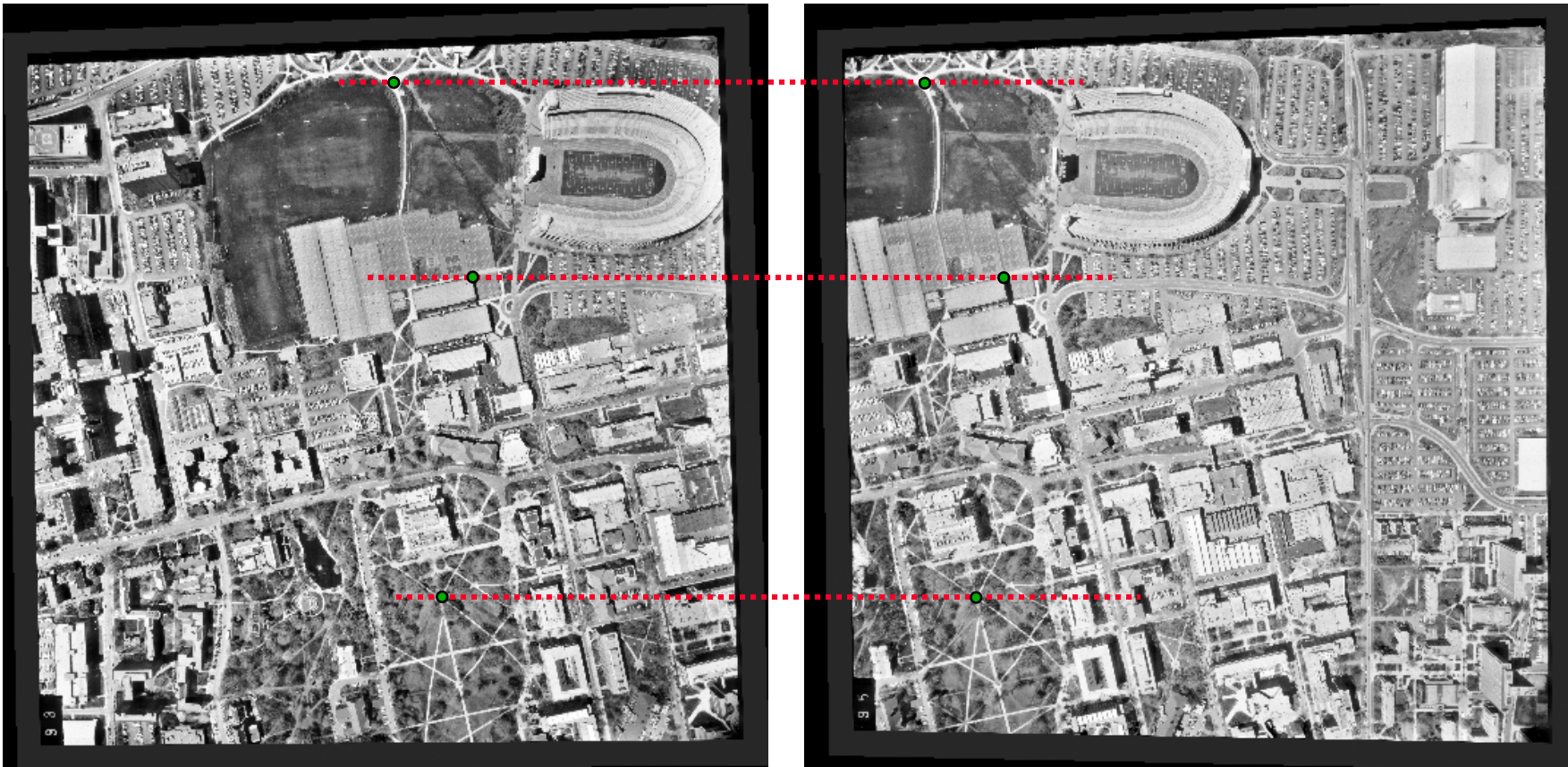
- Conjugate points do not have the same y-coordinates.





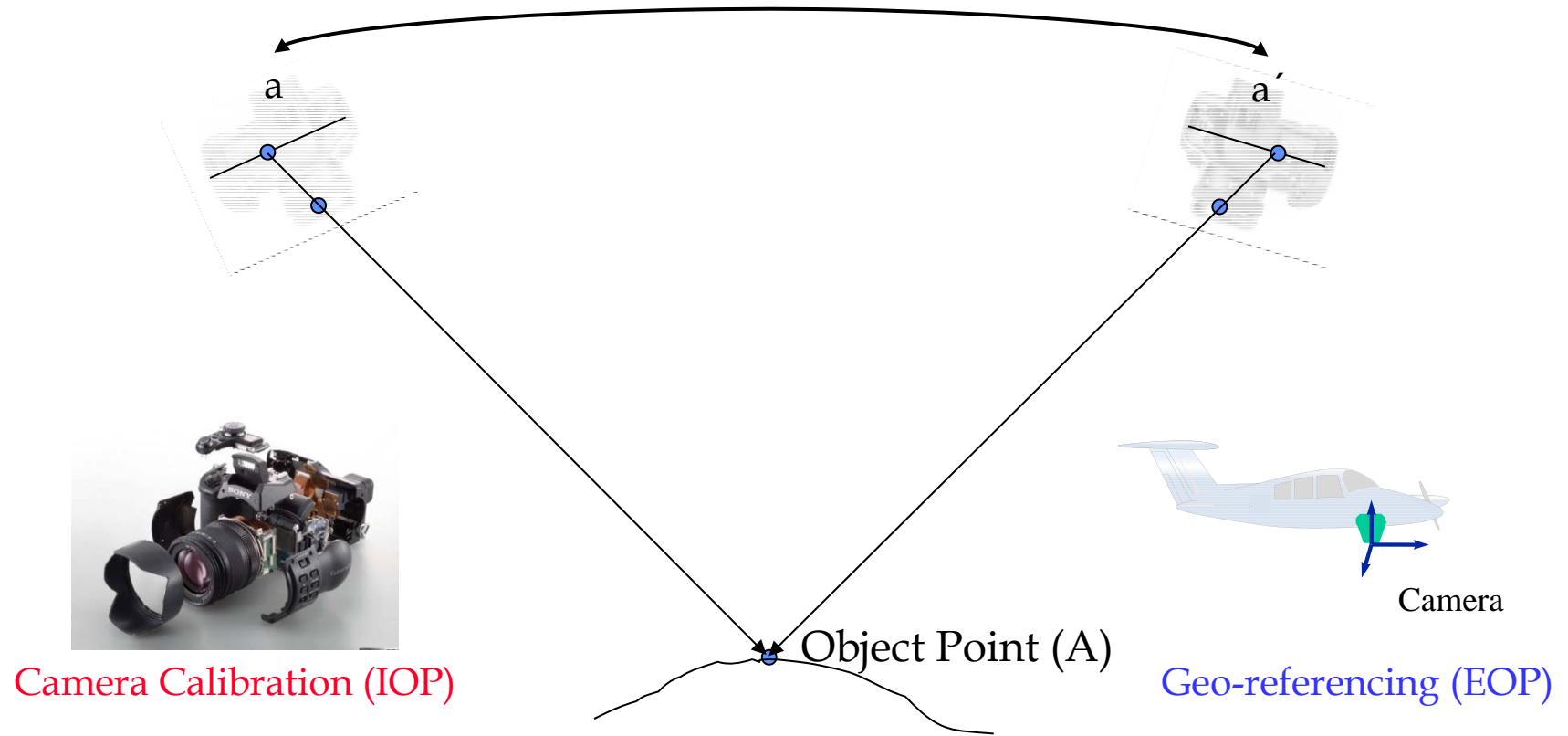
# Normalized Images

- Conjugate points have the same y-coordinates.



# 3D Reconstruction

Conjugate Points



- The interior orientation parameters of the involved cameras have to be known.
- The position and the orientation of the camera stations have to be known.

# Ch 12: Digital Orthophoto Generation

- Objective: Manipulate a perspective image to remove the sensor tilt and terrain relief effects
- Image resampling: Interpolation of intensity values
- Image transformation: Direct and indirect transformation
- Image Rectification:
  - Polynomial rectification,
  - Differential rectification, and
  - True orthophoto generation

# Perspective Image



# True Orthophoto



# CE 59700: Roadmap

- Chapter 1: Introduction
- Chapters 2 – 4: Data acquisition
- Chapters 5 – 12: Data manipulation
  - Chapter 5: Vertical imagery
  - Chapter 6: Image coordinate measurements and refinements
  - Chapters 7 - 10: Mathematical model, bundle block adjustment, integrated sensor orientation, and direct geo-referencing
  - Chapter 11: Digital image matching
  - Chapter 12: Production of map-like images (orthophotos)