



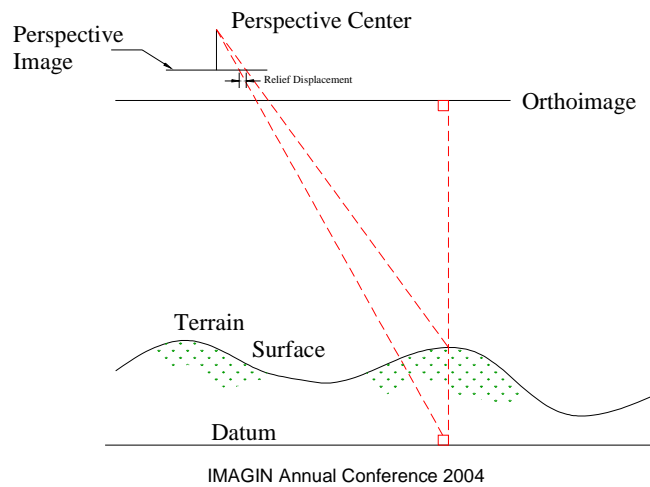
ORTHOPHOTOGRAPHY AS A GIS MAPPING PRODUCT

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PRINCIPLES OF ORTHOPHOTOGRAPHY

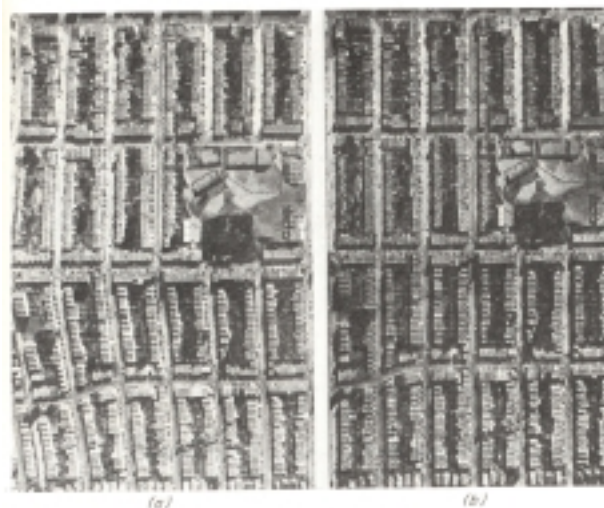
- Desire a picture where perspective aspect of picture is removed
 - Eliminate relief and tilt displacement
 - Process called differential rectification
 - Small segments of photograph rectified individually
 - Rectification – removal of tilt displacement

PERSPECTIVE VS ORTHOGRAPHIC PROJECTION



PRINCIPLES OF ORTHOPHOTOGRAPHY

- Aerial photo (a)
 - Streets displaced outward crossing over a hill
- Orthophoto (b)



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PRINCIPLES OF ORTHOPHOTOGRAPHY

- One of earliest instruments
 - Gallus-Ferber Photorestituteur
 - Not economical



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DATA SOURCES FOR DIGITAL ORTHOPHOTO

- Unrectified raster image
 - Scanned aerial photo
 - Image collected with digital sensor
- Digital elevation model (DEM) or digital terrain model (DTM) over area
 - Used to compensate for effects of relief
- Ground control
 - Provides absolute orientation if image and provides means to georeference each pixel in the image
- Sensor calibration data
 - Compensate for distortions within sensor- interior orientation

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DIGITAL ORTHOPHOTOGRAPHY

- Differential rectification performed on pixels
- Problems in urban and other areas with sharp vertical relief
 - Impossible to obtain truly orthographic projections
 - Areas hidden from image



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BUILDING LEAN

- Use 80% endlap and sidelap
 - Only about 1 ½" of photo used in orthophoto
- Use longer focal length camera
 - E.g. Merrick & Co. used 12" focal length camera over central Chicago
 - To maintain scale with 6" photography, fly at higher altitude
 - Acquired spot or pinpoint photography over buildings
 - All these items added to cost of project

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RELATIONSHIP BETWEEN MAP SCALES AND RESOLUTIONS

Photogrammetric Mapping Scales and Digital Orthophoto Resolutions						
Negative Scale	1" = 250'	1" = 300'	1" = 417'	1" = 833'	1" = 666'	1" = 2,640'
Representative Fraction	1:3,000	1:3,600	1:5,000	1:10,000	1:20,000	1:31,680
Flying Height Above Mean Terrain	1,500'	1,800'	2,500'	5,000'	10,000'	15,840'
Ground Coverage	1,575' x 1,575'	1,890' x 1,890'	2,621' x 2,621'	5,280' x 5,280'	2 miles x 2 miles	3 miles x 3 miles
Coverage in PLS Sections	1/4 1/4 Section (40 acres)		1/4 Section	1 Section	2 x 2 Sections	3 x 3 Sections
Map Scale	1" = 40'	1" = 50'	1" = 100'	1" = 200'	1" = 400'	1" = 500'
Contour Interval	1'	1'	1'	2'	4'	10'
15 µm Pixel Size (Ground)	1.8"	2.1"	3.0"	5.9"	11.8"	18.7"
30 µm Pixel Size (Ground)	3.5"	4.3"	5.9"	11.8"	23.6"	37.4"
15 µm TIF Image Size	98.0 mb	144.0 mb	144.0 mb	144.0 mb	144.0 mb	120.0 mb
30 µm TIF Image Size	24.0 mb	36.0 mb	36.0 mb	36.0 mb	36.0 mb	30.0 mb

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IMAGE QUALITY

- Depends on:
 - Camera quality
 - Photo to orthophoto map scale magnification
 - Orthophoto diapositive density range (bits in scanner scan pixel)
 - Sample scan rate
 - Micrometer or dots per inch (dpi)
 - Rectification procedures
 - Pixel ground resolution – pixel size on ground
 - Radiometric image smoothing/electronic auto-dodging
 - Selection of control points
 - DEM data density

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ACCURACY

- Function of:
 - Magnification
 - Geometric accuracy of scanner
 - Quality of DEM
 - Control
 - Focal length of the taking camera

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MAGNIFICATION

- Affects image quality
- Recommended range 8-9 times enlargement
 - 10 times degrades image quality – distance between silver crystals on film noticeable
 - Below 5 times – no noticeable quality improvement
 - 5-9 times is optimal range
 - For final orthophoto scale 1" = 100', photo scale should no be less than 1" = 900'
 - Guides valid for optimum terrain

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RADIOMETRIC RESOLUTION

- Ability to discern small tonal changes
- Content Standard recommends 8-bit binary data for B/W and 24-bit, 3-byte data for color
 - 8-bits gives 256 gray levels (0-255)
- Radiometric corrections that may be applied:
 - Contrast stretching, analog dodging, noise filtering, destriping, edge matching

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TONE MATCHING

- Diapositive or negative scanning
 - Tone matching between photos complex
 - Changing light conditions from flight line to flight line and from frame to frame
 - Within single frame – hot spots --- dark to light trends
 - Most software use 8-bit imagery
 - Aerial negative film – wider dynamic range
 - Need to compress range of possible values into gray shaded constraints imposed by 8 bits
 - 1) Ortho diapositive produced to specific and restricted density range on electronic auto dodge contact printer
 - 2) Air negatives scanned with wider density range (10-12 bits) then software restricts final output by truncating values or running logarithmic function

SCANNER RESOLUTION

- Scanner and scan process have inherent errors
- High precision scanners used
 - Calibrated to ensure performance meets minimum specifications for mapping
- Most softcopy instruments capable of adding scanner calibration to program to correct for scanner distortions

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SCANNER RESOLUTION

- Important relationship: size of scan pixel to scale of photography and desired output orthophoto scale
 - One suggestion: 240 dpi for each magnification range
 - Ex: if desired photo to final orthophoto magnification is 5 times
 - Scan photo is $5 \times 240 = 1200$ dpi as minimum
 - Using 9 times magnification yields 2160 dpi or roughly 12 micrometers

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SCANNER RESOLUTION

- Smaller pixel size may give better resolution but not necessarily higher accuracy
 - Accuracy function of survey control, flying height, focal length, pixel size, etc.
- Approximately 15 μm resolution required to maintain photographic resolution of aerial film
 - 20-30 μm scan rates common in industry

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PIXEL SIZE – GROUND UNITS

- Most important factor – magnification ratio
- Generally better to resample to coarser pixel than finer
 - Do not scan at 1' and resample to 0.5'
- Rule of thumb – resample by multiplication factor of 1.2 or greater
 - Scan at 1', finished orthophoto should be at least a 1.2' pixel

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PIXEL SIZE – GROUND UNITS

- Orthophoto rectification should be resampled using cubic convolution resampling process
- Sub-sampling should only be applied within limits defined by the Nyquist theorem
 - Limits resampling to maximum of 2x
 - Limit avoids undesirable aliasing

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ACCURACY OF ORTHOPHOTO

- Relative accuracy – directly related to photo scale
- Absolute accuracy – related to quality of ground control as well as photo scale
- Primary factors for absolute accuracy:
 - Survey control
 - DEM accuracy

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ACCURACY OF ORTHOPHOTO

- Controlling image to be scanned
 - For large-scale orthophotos – control should be surveyed ground targets
 - More commonly, aerotriangulation control used
 - Effects of deriving control from maps or other inaccurate methods
 - Significant errors introduced
 - Accuracy of orthophoto accordingly degraded

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ACCURACY OF DEM

- DEM important component
- Appropriateness of DEM related to
 - Scale specification to which the orthophoto is being created
 - Roughness of terrain
 - Focal length of aerial camera
 - Magnification
- Creation of DEM – possibly most expensive
- Density of DEM depends on
 - Roughness of terrain (coarser sampling for flatter terrain)
 - Accuracy required (for large-scale – include break lines)
 - scale

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ERRORS IN DIGITAL ORTHOPHOTOS

- Formula expressed as:

$$e_{\text{Ortho}} = e_{\text{DEM}} \times \tan A$$

- where
 - e_{Ortho} = error in digital orthophoto,
 - e_{DEM} = error in the digital elevation model, and
 - A = viewing angle in degrees outward from the center of the photo

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ORTHOPHOTO DEFECTS

- Image Completeness
 - If area not adequately covered by DEM, image will be inaccurate and digital orthophoto will not be complete
- Image Stretch (Blurring)
 - Typical causes
 - Anomalies/spikes in DEM
 - Excessive relief – especially near edge of photo
 - Result – small amount of information stretched to fill out area required by shift from perspective to orthogonal projection

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ORTHOPHOTO DEFECTS



- Image Distortions
 - (a) Distortions along bridge deck due to reliance on regular grid of elevations
 - (b) Break lines used to give more faithful rendition of terrain

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ORTHOPHOTO DEFECTS

- Double Image
 - When adjacent orthophotos compared and the same features are shown on both – should not occur
 - Caused by
 - Improper orientation of control
 - Inaccurate DEM where elevations are higher than reality
- Missing Image
 - Identified by missing sections of linear sections
 - Same cause as double image except DEM is under representing real ground elevations

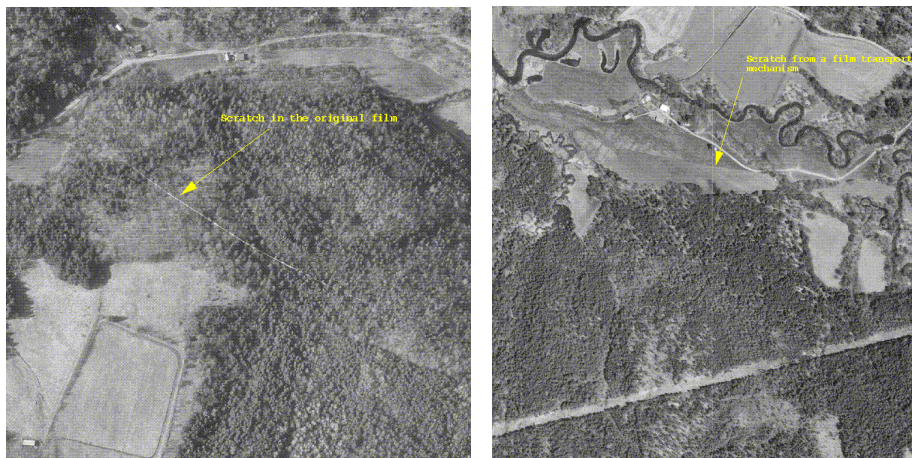
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ORTHOPHOTO DEFECTS

- Inaccurate Planimetry
 - Planimetric positions of pixels in error
 - Look at control
- Image Replication
 - Problems in tone in digital imagery – varies depending on different computing environments

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ORTHOPHOTO DEFECTS SCRATCHES



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ORTHOPHOTO DEFECTS

- Discrepancies found by overlaying digital file over orthophoto



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ORTHOPHOTO DEFECTS

- Alignment problems between two digital images
 - More noticeable with linear features



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ORTHOPHOTO DEFECTS

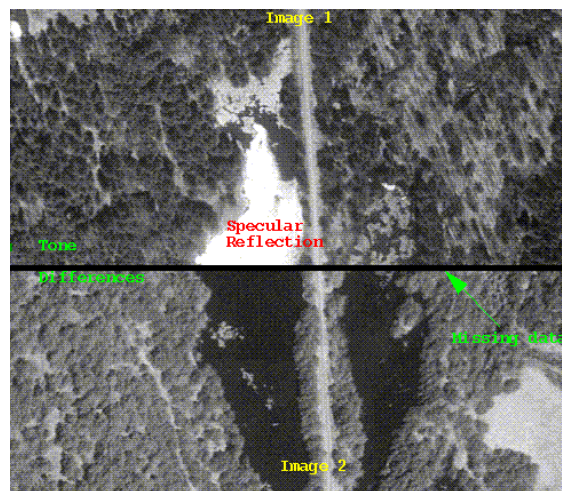
- Effects of relief displacement – caused part of tank to be cut out
- Optical artifact



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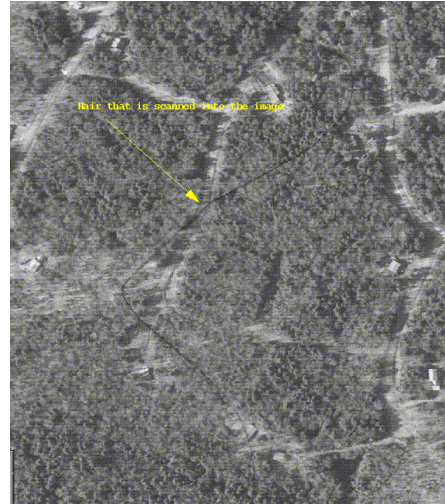
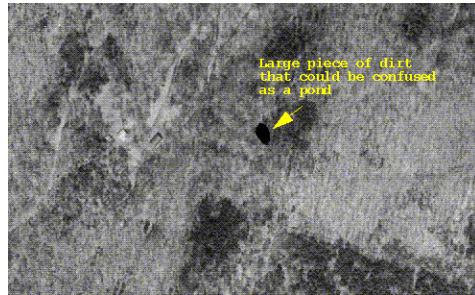
ORTHOPHOTO DEFECTS

- Example of tone differences, specular reflector and missing data (black line) due to operator error



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ORTHOPHOTO DEFECTS DIRT AND HAIR EFFECTS



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ORTHOPHOTO DEFECTS

- Shadow and time of day



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