Photogrammetry in Age of UAS

NYSAPLS Annual Conference 2021

Joseph V.R. Paiva, PS, PE, PhD

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Objectives

- Some basic principles
- How UAS photogrammetry works
- Ensuring quality
- Mapping products
- Independent determination of map accuracy

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Traditional Photogrammetry

- Tedious
- Expensive
- Time consuming
- The “Gold Standard”

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Many Needs Not Addressable

- Focused areas
- Quick turnaround
- Limitations due to weather and season
- Accuracy not appropriate

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Enter the Drone

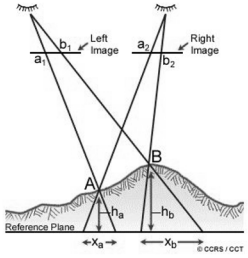
- UAS relatively inexpensive to acquire, equip, fly and process imagery
- Fast, even for the processing
- Relatively automated
- BUT, you can't use it properly without a trained brain!

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Stereoscopic Parallax

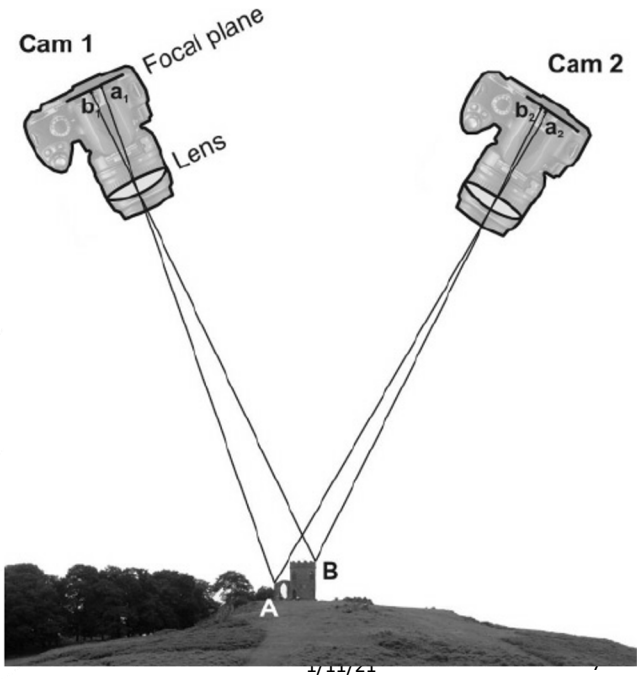
- The displacement of an object caused by a change in the point of observation is called parallax.
- Stereoscopic parallax is caused by taking photographs of the same object but from different points of observation.



Graphic from http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/stereosc/chap4/

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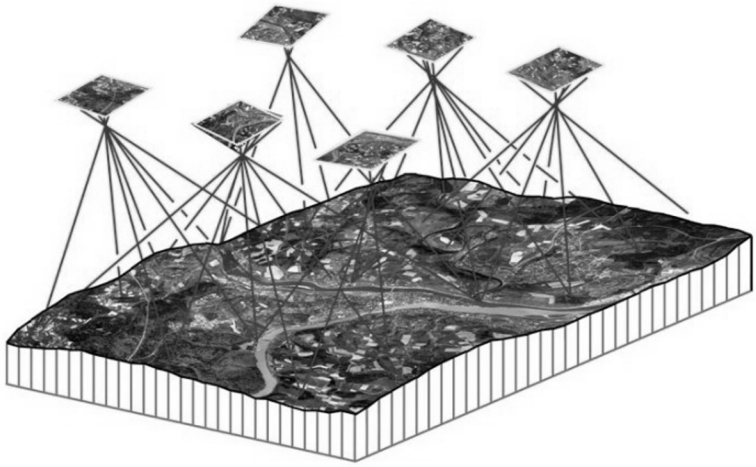
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Mission Planning

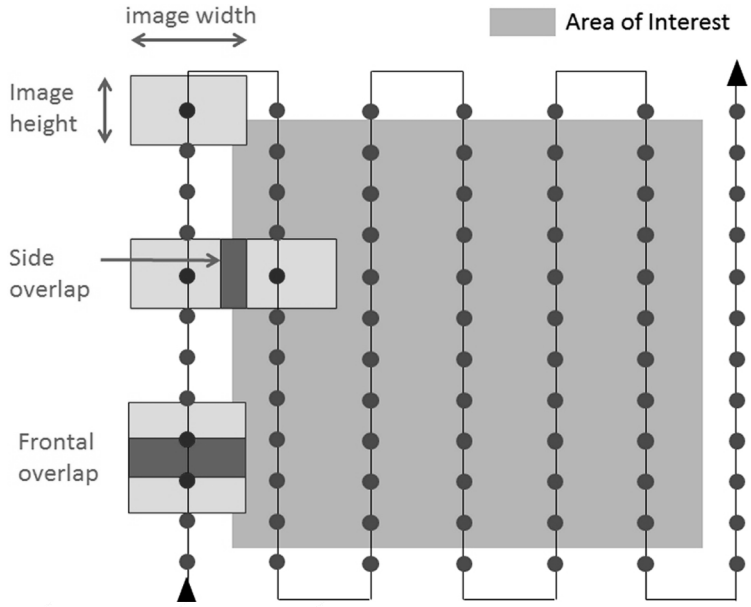
- Serious aspect to successful drone photogrammetry
- Consider terrain, weather, capabilities of your aircraft, capabilities of your sensors (cameras), settings on camera, power and capabilities of your image processing system

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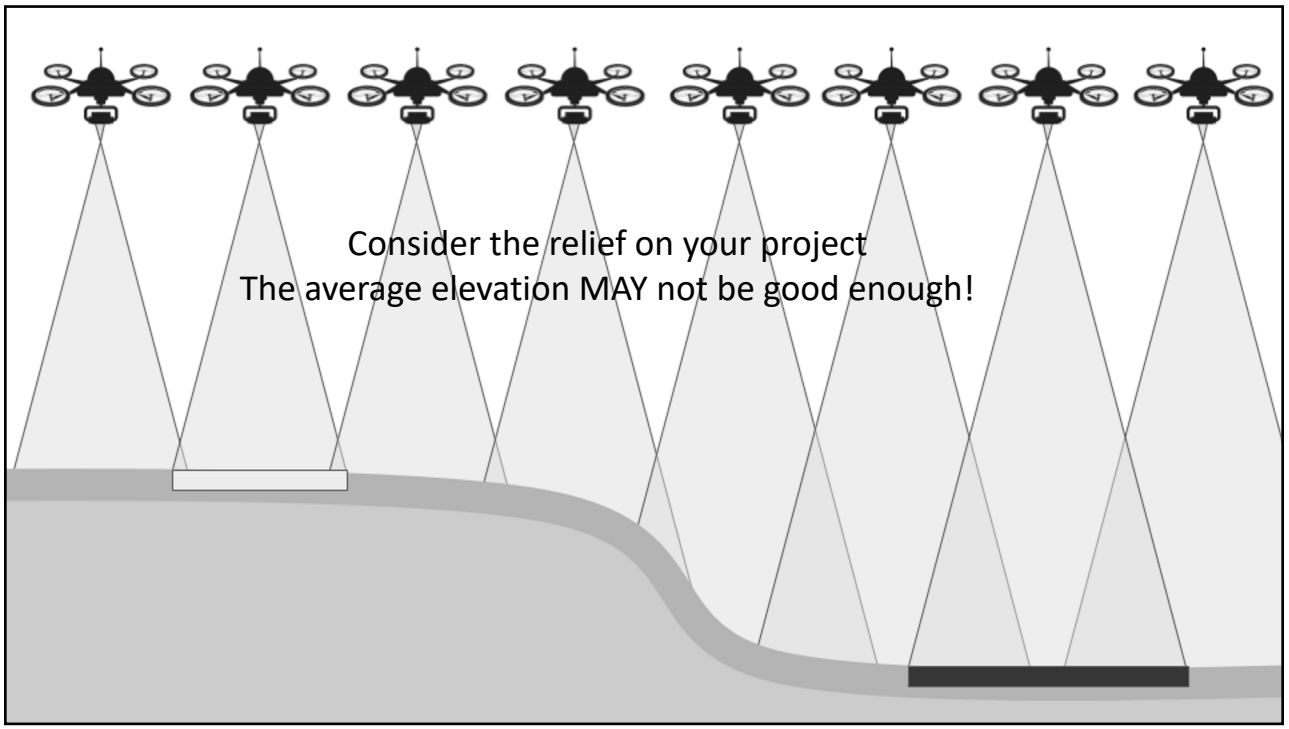
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This example is for conventional photogrammetry.

For UAS photogrammetry, forward lap of 70-90% is used; side lap of 70-80% is used

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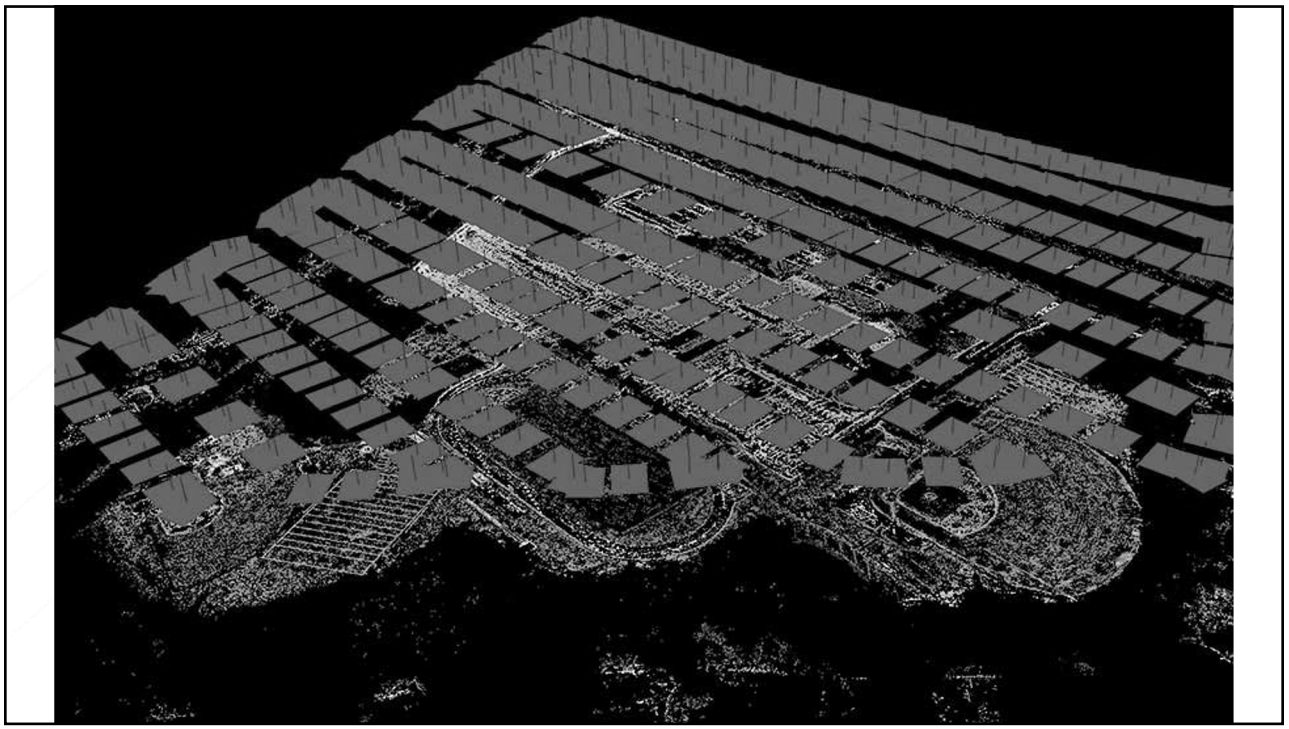
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Overlap

- For good results each point on the ground (with drone photogrammetry) must be visible in 12-15 images

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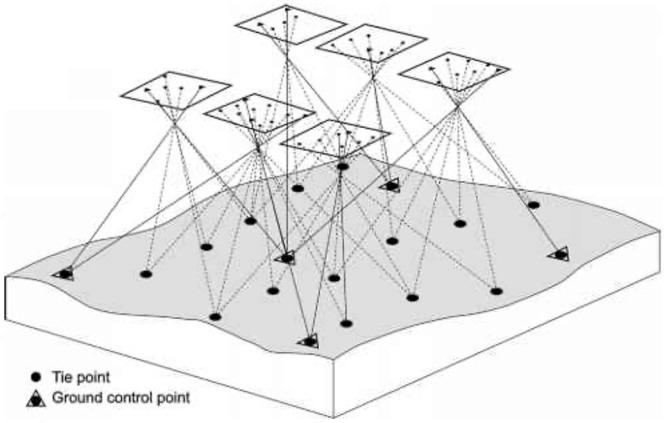
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Finding Match Points

- Where computer vision far exceeds human capabilities
- In conventional photogrammetry a human might find a dozen match points between a pair of photographs
- Hundreds, thousands or tens of thousands are common in drone photogrammetry image pairs

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After Bundle Block Adjustment

- Pixel-by-pixel interpolation is done between the computed positions for the match points
- Result: approximate horizontal accuracy close to that of the ground sampling distance (GSD)
- Result: approximate vertical accuracy close to 1.5 to 3 times that of GSD

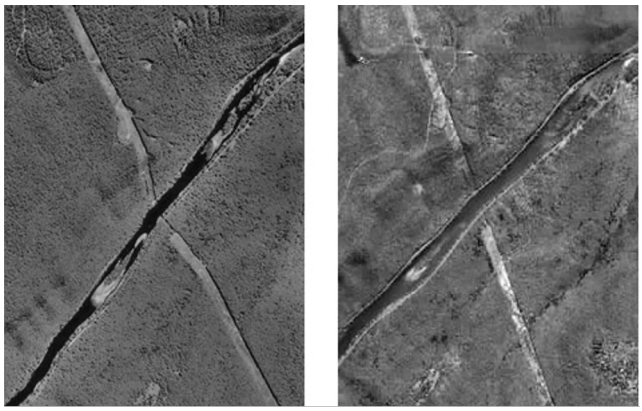
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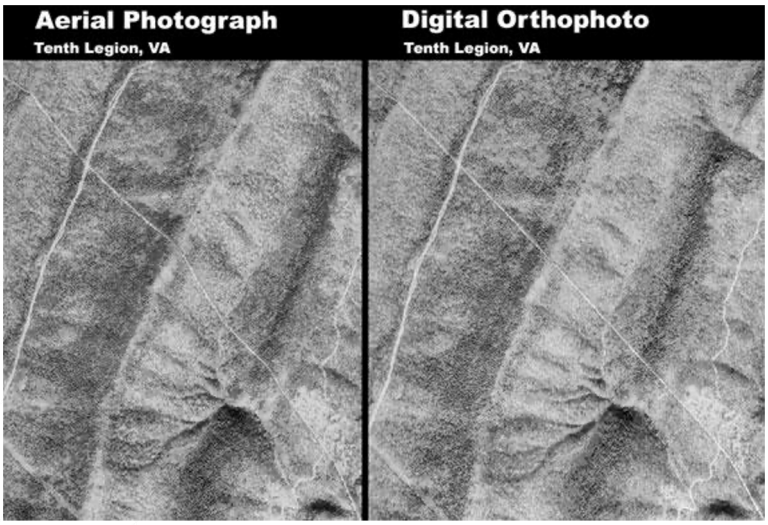
What Orthophotos Are



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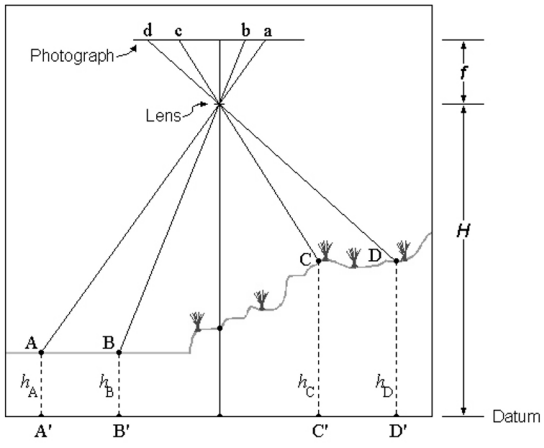
What Orthophotos Are



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Relief Displacement (revisited)



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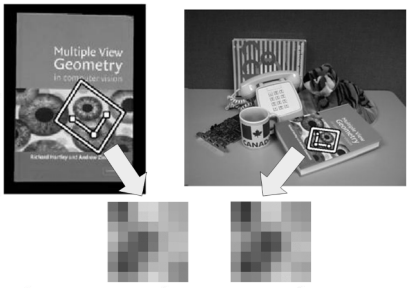
Credit: xyHt/Woolpert

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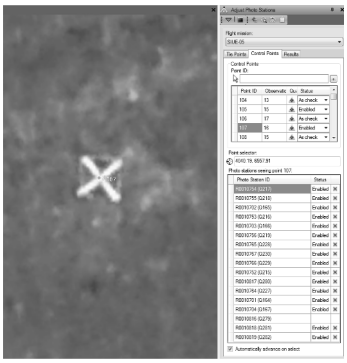
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Pixel Matching (Autocorrelation)



Measure Targets



Computer Vision & Bundle Adjustment

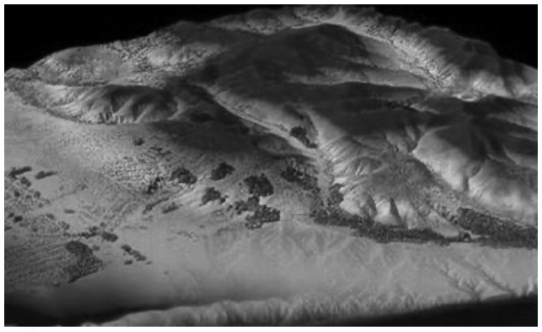


Digital Surface Model (DSM)

- "Point cloud" of all X, Y, Z coordinates
- "Surface" because what you have is what you can see from the air—not anything "below" that surface

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Credit: Corrigan/DronZon.com

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Products

- Orthophotos
- Non- or minimally processed photos
- DSMs/DTMs/photo-draped and colorized
- Point clouds

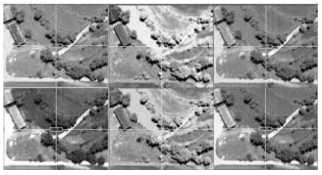


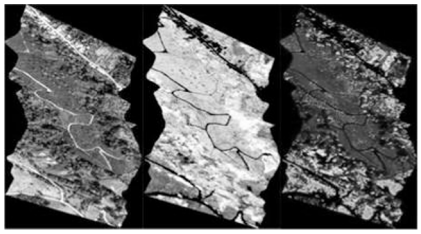


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Products

- Volumes, areas, counts, change monitoring
- NIR and other products
- LiDAR, hyperspectral and multispectral imaging products





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Studies to Achieve Standards

- Flight heights (pixel size)
- Control point spacing
- Other factors: lighting (shadows!), terrain types, weather, camera quality
- Making adjustments for relief of terrain

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Level of Difficulty

Hard	• Digital terrain model (DTM) • Digital surface model (DSM) • Ortho-rectified mosaic • Georeferenced mosaic of "scaled" images
Easy	• Georeferenced images

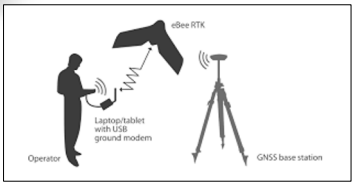
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Geo-referencing

- None (or one lat/long)
- Ground control points (GCPs)
- Navigation grade GNSS
- Real time kinematic (RTK) GNSS
- Post processed kinematic (PPK) GNSS







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Sensors & Lenses





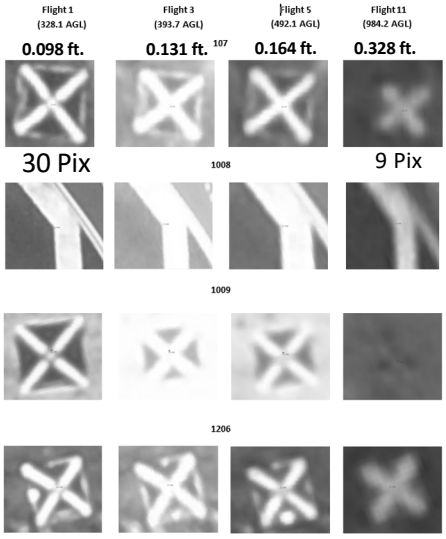






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Resolution vs. Height AGL



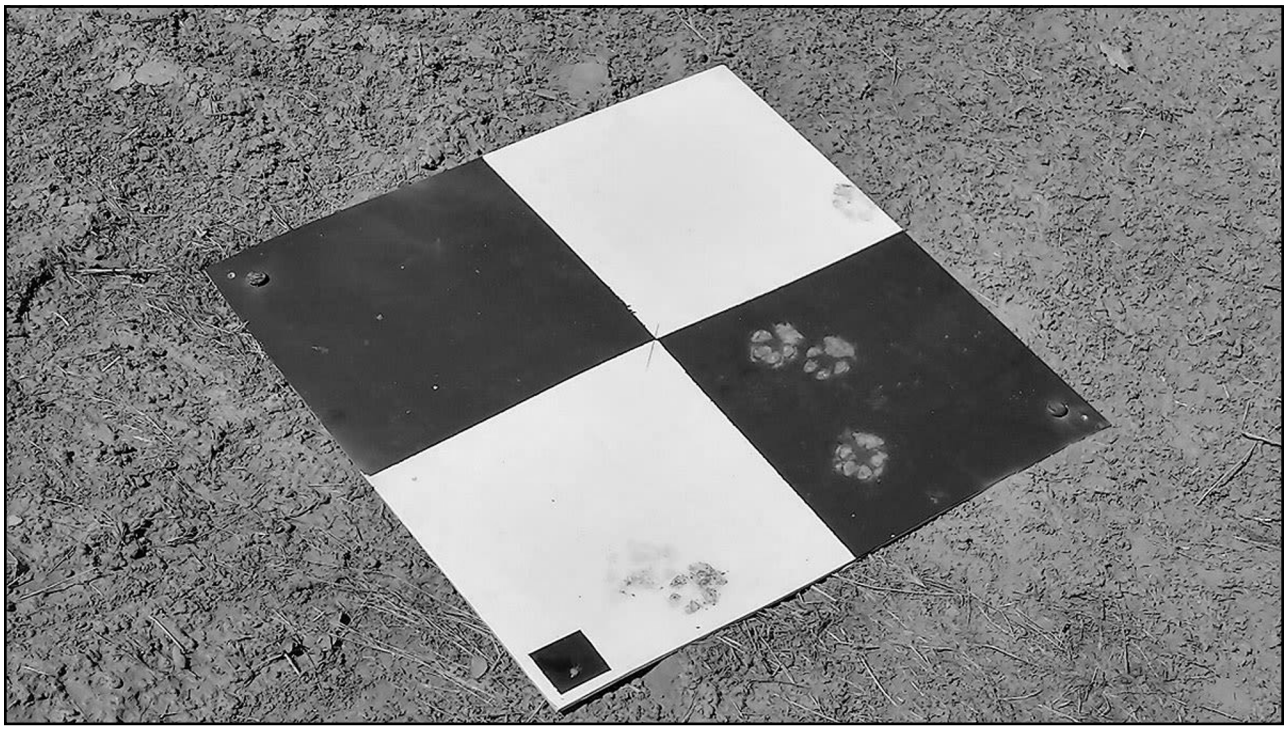
Flight	1	3	4	11
GSD (ft)	0.098	0.131	0.164	0.328
Target Size (ft)	3	3	3	3
# Pixels/Target Length	30.6	22.9	18.3	9.1
Change %	-	-25%	-20%	-50%

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Map Accuracy

- Old – Based on map scale (paper technology)
- NEW – Digital based on ground sample distance (GSD)
  - Horizontal industry standards
  - Vertical industry standards
  - ALL RMSE converted to 95% confidence levels

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Survey Control & Check Points

- Control Points : Included in adjustment
  - How many are required
  - How far apart should they be?
- Check Points : NOT Included in adjustment
  - How many are required?

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Check Points

- ASPRS says no less than 20?
  - Required to produce accurate confidence levels
- Distributed evenly
- Additional in low confidence areas

Table 7. Recommended Number of Check Points Based on Area

Project Area (Square Kilometers)	Horizontal Testing	Vertical Testing (not clearly-defined points)		
	Total Number of Static Horizontal Check Points (clearly-defined points)	Number of Static Vertical Check Points in NVA	Number of Static Vertical Check Points in VVA	Total Number of Static Vertical Check Points
≤500	20	20	0	20
501-750	25	20	10	30
751-1000	30	25	15	40
1001-1250	35	30	20	50
1251-1500	40	35	25	60
1501-1750	45	40	30	70
1751-2000	50	45	35	80
2001-2250	55	50	40	90
2251-2500	60	55	45	100

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Need To Know

- You need to know how your drone/UAS performs
  - Speed
  - Vibrations
  - Duration
  - Altitude Consistency
  - Navigation/Direction
  - Safety

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Computer Vision Image Processing

1. Load photos
2. inspect loaded images, remove unnecessary images
3. Align photos
4. Measure GCPs
5. Build dense point cloud
6. Build mesh (3D polygonal model)
7. Generate texture
8. Build tiled model
9. Build digital elevation model
10. Build orthomosaic
11. Export results
12. Independent Quality Control Checks

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Ground Sample Distance (GSD)

The linear dimension of a pixel's footprint on the ground

- GSD of image assumes near-vertical imagery
- Actual GSD of each pixel is not uniform throughout the raw image and varies significantly with terrain height and other factors
- GSD is assumed to be the value computed using the calibrated camera focal length and camera height above average horizontal terrain

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Pixel

- Pixel size is the ground size of a pixel in a digital ortho-image, *after* all rectifications and resampling procedures

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Resolution

- Ability to distinguish smallest visible objects on a photo
- Resolution: combination of film type and camera lens system
- Medium-resolution aerial photographs are available at ~400 dots per inch (63.5 microns - μ)
  - 15 Mb average file for 9-inch B&W aerial photo and 45 Mb for color
- High-resolution aerial photographs at ~1,000 dpi (25 μ)
  - 120 Mb file for 9-inch B&W and 360 Mb for color

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GSD/Pixel/Map Scale/Resolution

- Map Scale = Map or Image Distance divided by Ground Distance
  - Large, small? Do we even make maps? Paper vs Digital?
- GSD = raw (source), actual, calibrated, final orthophoto
- Pixel = *after* all rectifications and resampling procedures
- Resolution = smallest object visible

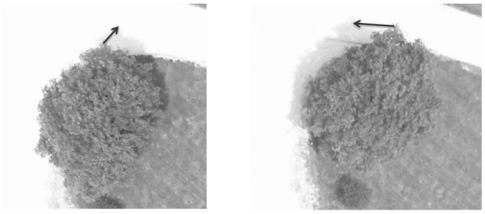
FOR REAL and PRACTICAL QUALITY… They all matter!

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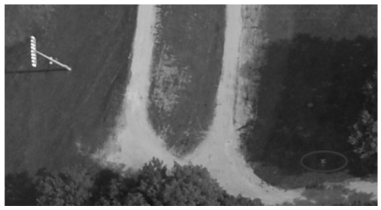
Primary & Secondary Quality Factors

- Light
- Shadows
- Weather
- Procedures
- Keep camera settings consistent
  - NO automatic exposure or zoom

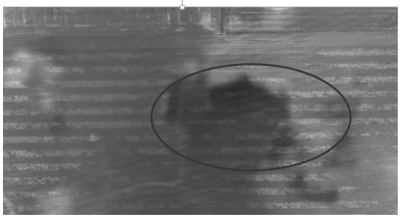
Shadow Movement



Dark Shadows



Clouds



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Primary Guideline Recommendations

- Avoid adverse weather in general; high wind, rain, etc.
- Collect imagery beyond your project limits (if possible)

If any doubt, maximize image overlap
& fly at lower AGL

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Guideline Recommendations

- Camera
  - Good dynamic range & pixel pitch (more important than Mp)
  - Prime focal lens
  - Settings
    - Exposure (ISO as low as tolerable)
    - Shutter speed (avoid image motion/blur)

If any doubt, maximize image overlap
& fly at lower AGL

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Guideline Recommendations

- Targets
  - Optimal target size
  - Avoid poor PIDs
  - Minimum of 5 GCPs?
    - Use as many as you can afford to

If any doubt, maximize image overlap & fly at lower AGL

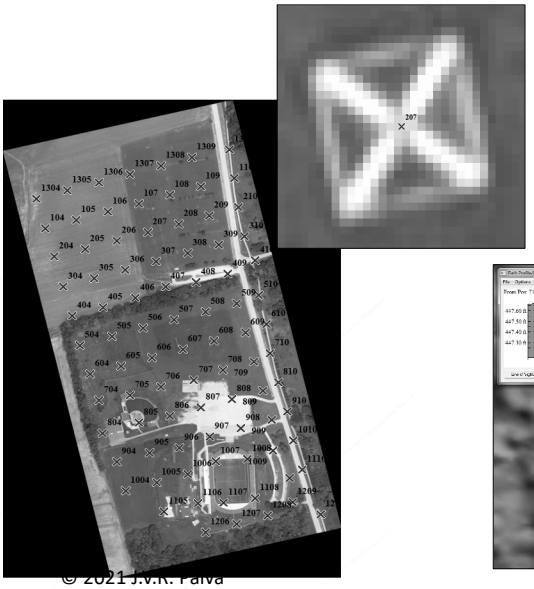
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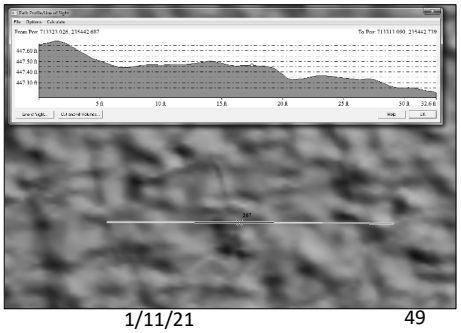
Quality Assurance & Control

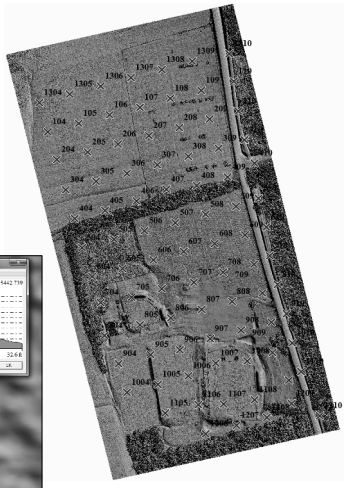
- Quality Assurance : Process
  - Based on expertise and knowledge of entire Drone/UAS process
- Quality Control : Testing
  - According to published standards
  - Independent deliverable testing
  - Check points
  - Map accuracy reporting

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Independent Map Testing





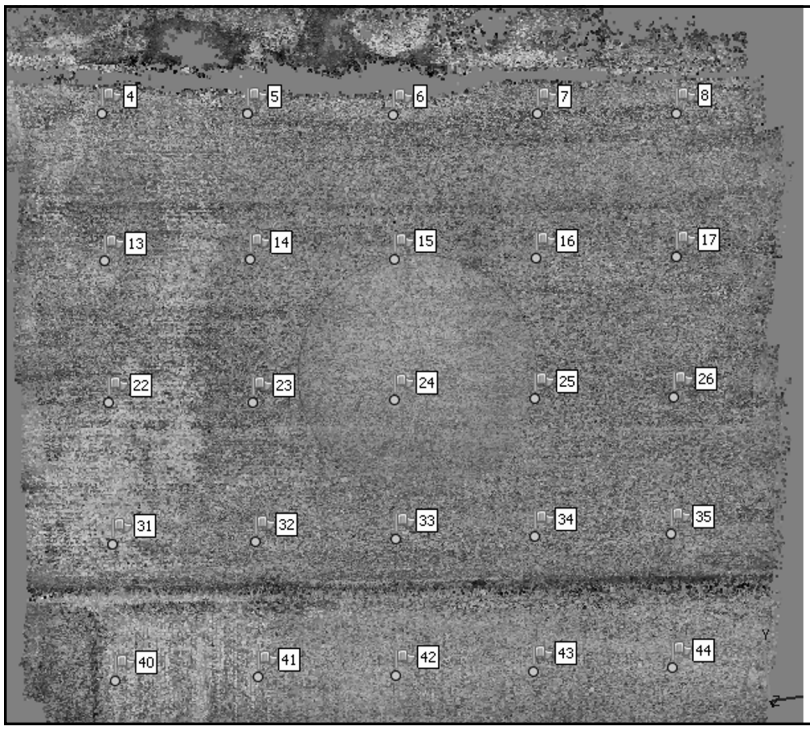


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Survey Control & Check Points

- Control Points : Included in adjustment
  - Quantity and spacing determined
- Check Points : NOT included in adjustment
  - Quantity and spacing determined
  - ASPRS minimum of 20?

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Enabled Target Quality Assurance

- Even distribution

Is this good or bad?

Depends on whether check targets are shown!

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Compare Design to Result

- Did you meet the
  - Scope requirements
  - Quality requirements
  - Standard of care
  - Accuracy requirements

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What Makes Drones Professional?

- The model of drone/UAS is arbitrary (sort of)
  - Consumer?
  - Prosumer?
  - Professional?
- The use of a drone/UAS and process of creating accurate deliverables requires

  Professional Supervision and Intervention

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About seminar presenter Joseph V.R. Paiva

Dr. Joseph V.R. Paiva, is principal and CEO of GeoLearn, LLC (www.geo-learn.com), an online provider of professional and technician education since February 2014. He also works as a consultant to lawyers, surveyors and engineers, and international developers, manufacturers and distributors of instrumentation and other geomatics tools, as well being a writer and speaker. One of his previous roles was COO at Gatewing NV, a Belgian manufacturer of unmanned aerial systems (UAS) for surveying and mapping during 2010-2012. Trimble acquired Gatewing in 2012. Because of this interest in drones, Joe is an FAA-licensed Remote Pilot.

Selected previous positions Joe has held includes: managing director of Spatial Data Research, Inc., a GIS data collection, compilation and software development company; senior scientist and technical advisor for Land Survey research & development, VP of the Land Survey group, and director of business development for the Engineering and Construction Division of Trimble; vice president and a founder of Sokkia Technology, Inc., guiding development of GPS- and software-based products for surveying, mapping, measurement and positioning. Other positions include senior technical management positions in The Lietz Co. and Sokkia Co. Ltd., assistant professor of civil engineering at the University of Missouri-Columbia, and partner in a surveying/civil engineering consulting firm.

Joe has continued his interest in teaching by serving as an adjunct instructor of online credit and non-credit courses at the State Technical College of Missouri, Texas A&M University-Corpus Christi and the Missouri University of Science and Technology. His key contributions in the development field are: design of software flow for the SDR2 and SDR20 series of Electronic Field Books, project manager and software design of the SDR33, and software interface design for the Trimble TTS500 total station.

He is a Registered Professional Engineer and Professional Land Surveyor, was an NSPS representative to ABET serving as a program evaluator, where he previously served as team chair, and commissioner, and has more than 30 years experience working in civil engineering, surveying and mapping. Joe writes for *POB*, *The Empire State Surveyor* and many other publications and has been a past contributor of columns to *Civil Engineering News*. He has published dozens of articles and papers and has presented over 150 seminars, workshops, papers, and talks in panel discussions, including authoring the positioning component of the Surveying Body of Knowledge published in *Surveying and Land Information Science*. Joe has B.S., M.S. and PhD degrees in Civil Engineering from the University of Missouri-Columbia. Joe's volunteer professional responsibilities include president of the Surveying and Geomatics Educators Society (SaGES) 2017-19 and various *ad hoc* and organized committees of NSPS, the Missouri Society of Professional Surveyors, ASCE and other groups.

GeoLearn is the online learning portal provider for the Missouri Society of Professional Surveyors, and surveying professional societies in Kansas, New York, Texas, Pennsylvania, Wisconsin, Arizona and Oklahoma. More organizations are set to partner with GeoLearn soon.

Dr. Paiva can be reached at joepaiva@geo-learn.com or on Skype at joseph_paiva.

Jan 2019