Project Accuracy

A critical decision - Accuracy in a large part determines the cost of a project.

Common Standards:

• National Map Accuracy Standards (NMAS)
• American Society for Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards
• National Standard for Spatial Data Accuracy (NSSDA)
NMAS Specifications

- **National Map Accuracy Standards (NMAS)** – Developed by the U.S. government before WWII and originally applied primarily to small-scale maps such as USGS Quads.
- Developed prior to the existence of digital mapping, when hard copy maps of a fixed scale were the state of technology.
- Basic Specification:
  - Horizontal Accuracy: No more than 10 percent of sampled points may be in error by more than 1/30” at map scale.
  - Vertical Accuracy: Vertical accuracy is tied to a contour interval. Not more than 10 percent of the elevations sampled may be in error by more than one-half the contour interval. Spot elevations are required to be twice as accurate as contours.
American Society of Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Large Scale Maps

- Developed in the early 1990's, as digital mapping was becoming more prevalent

- Three accuracy classes: A map with the highest order accuracy is a “Class 1” map. Class 2 or Class 3 maps have RMSE’s of 2 and 3 times that of Class 1.

- Horizontal Accuracy: Accuracy is expressed in ground units as a limiting RMSE against field-surveyed checkpoints, and associated with a typical corresponding map scale. For example, a 1-foot limiting RMSE correlates with a Class 1 map at 1”=100’.

- Vertical Accuracy: The ASPRS standards set the limiting RMSE for Large-scale Class 1 maps at 1/3 of the contour interval, and for spot elevations at 1/6 of the contour interval.
New ASPRS Specifications are Pending

• The updated ASPRS specifications:
  – Will replace the previous ones
  – Presume digital deliveries (scale independent)
  – Draft complete
  – Final Release May/June 2014 timeframe

• New specification is more demanding
  – Previous Class 1 is now Class 2
  – Technology improvements have enabled better accuracy
New ASPR Horizontal Accuracy/Quality Specification for Orthophotos - 2014

<table>
<thead>
<tr>
<th>Orthophoto Pixel Size</th>
<th>Horizontal Data Accuracy Class</th>
<th>RMSE\textsubscript{X} (cm)</th>
<th>RMSE\textsubscript{Y} (cm)</th>
<th>Orthophoto Mosaic Seamline Maximum Mismatch (cm)</th>
<th>Horizontal Accuracy at the 95% Confidence Level\textsuperscript{a} (cm)</th>
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<tbody>
<tr>
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<td>III</td>
<td>180.0</td>
<td>254.6</td>
<td>360.0</td>
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</tbody>
</table>

\textsuperscript{a} Confidence Level is not applicable for Classes I and II for Orthophoto Pixel Sizes of 2.5 cm (~1 in) and 5 cm (~2 in)
NSSDA Testing Methodology

National Standard for Spatial Data Accuracy (NSSDA):

• Originally released in 1998 by the Federal Geographic Data Committee (FGDC)
• Accuracy is reported in ground units at the 95% confidence level
• Is a **testing methodology** and statistical guideline, not an accuracy standard.
• Sets no limiting errors or pass/fail criteria
Orthoimagery

A raster image that is combined with differential rectification to remove image displacements caused by camera tilt and terrain relief. It is a map-accurate representation of the surface of the earth.
Ground Sampling Distance (GSD) or Pixel Resolution

3” color

6” color

12” color
6-Inch
3-Inch
Color and Near-Infrared Bands

Natural Color

Near-Infrared

Captured simultaneously on current generation digital aerial cameras
Geo-referencing

• Primary image position and orientation information now usually comes from airborne GPS and IMU technologies, which have reduced dependence on ground control.

• Ground control needs are determined by project accuracy and resolution requirements

• Control must be in correct positions relative to the flight lines and photographic exposure locations

• Targeted control points vs. photo-identification
Photo-Identifiable Control Point
Stereoscopic Coverage

- Overlapping images enable photogrammetric operations – Viewing, analysis and extraction of 3D information
- Typically 60% forward lap/ 30% sidelap
- Adjacent images having overlapping coverage of the ground are known as stereo pairs, with the overlapping area known as a stereo model
Urban Areas - Minimizing Radial Displacement or “Building Lean”

• High Overlap of imagery
  – Standard 60%/30%
  – High Urban 80%/60%
  – Extreme Urban 80%/90%

• True Orthoimagery
  – Results removal of building lean
  – Less obstruction of ground features
Aerial Triangulation

• Provides a statistically bundled image position and orientation solution using the AGPS/IMU and ground control
• Forms the basis for the accuracy of all derivative photogrammetric products
• Rigorous Analytical Aerial Triangulation Techniques
  – Least square adjustment
• Control points used as checkpoints to verify quality of the AT adjustment
• AT Report provided with residual values should be identified in RFP and proposals
• Project should not move forward if residual values do not support the accuracy needs of the project. Should be tested against field checkpoints
Elevation Model Needed for Ortho-Rectification

• **Terrain Data Sources**
  
  – LiDAR
  
  – Extraction from Aerial Imagery
    • Autocorrelation – automated extraction from stereo imagery
  
  – Public Sources such as USGS 10M or 30M DEM
    • Usually not sufficient for 6” or better resolution
    • May need updating
  
  – SAR/Satellite/IFSAR
    • lowest accuracy; atypical for high accuracy/resolution projects
Orthophoto Production

Controlled Digital Stereo Images → Ortho Rectification Process → Digital Orthophoto Imagery

Orthophoto Imagery → Exterior Orientation From A/T

TIN/DEM
Typical Imagery Corrections

Typical Bridge Distortion

Following Correction.

Orthophoto without intelligent seams

Orthophoto mosaic with intelligent seams
Color Balancing Process Flow

1. Target thumbnail zone selected

   Thumbnails are grouped into geographic/terrain-specific areas for local color-balancing. Target tone is selected.

2. “Local” thumbnail color-balance

   Thumbnails are color-balanced against local target(s)... Target parameters are then prepared for global color-balancing.

3. Global high-resolution color-balance

   Local and global color-balancing weights are applied to high-resolution ortho-imagery.

4. Final balanced seamed ortho-image

   Color-balanced and seamed final ortho-imagery is available for client.
‘True’ Orthophotos

Conventional Ortho with Planimetric Overlay

True Ortho with Planimetric Overlay
True Orthoimagery

- Typically used for urban downtown areas with tall buildings
- Buildings are modeled as part of DTM
- Entire building is in its true geographic position
- Results in little or no sidewalk or street obstruction
Airborne Light Detection and Ranging (LiDAR)

Aerial sensor
Collects/scans data, either photons (reflected light) or laser pulses.

Aerial GPS (Global Positioning System)
Based on GPS satellite triangulation, measures the location of the aircraft up to 0.1 second.

IMU (Inertial Measurement Unit)
Measures attitude (pitch/yaw/roll) of aircraft every .002 second.

Ground GPS
Measures the location of the aircraft up to 0.1 second relative to a known ground position.
LiDAR Raw Point Cloud

- LiDAR produces very-high-resolution three-dimensional point clouds
- Base product is called a “raw”, or calibrated-unclassified point cloud
- Contains all collected points, georeferenced, in 3D
- Untiled – delivered by swath
- LAS data format
- Requires software and expertise to exploit
The ability to better penetrate to the bare earth in vegetated areas is a key advantage of LiDAR over other technologies.
LiDAR Project Planning

• Point density and accuracy needed
• Classification requirements
• Derivative data products needed
• Ground checkpoints
  – In different land cover types, if needed (FVA/SVA/CVA)
• Can be collected day or night – no sun angle limitations
• Season of collection
  – Most collects are done in the spring and fall
    • Leaf off or on?
  – Summer collects take place for special applications such as forestry/timber, WiFi or cell signal analysis
• Rain/Fog/Smoke/Sandstorms are detrimental
LiDAR System Calibration
Critical to data accuracy and quality

Fairly flat surface (e.g., runway)

Test field surface

Lidar scans

Flight direction
7,457 sample points, RMSE = 0.11 m, average vertical bias = -0.08 m
LiDAR Terrain Model Terms

What is a DEM, DTM and DSM?

• **DEM:** Digital Elevation Model
  – ‘Bare Earth’; Data structure made up of x, y points with z-values representing elevations
  – No breaklines, mass points only

• **DTM:** Digital Terrain Model
  – A data structure made up of x, y points with z-values representing elevations
  – Bridge removal
  – DEM + breaklines = DTM

• **DSM:** Digital Surface Model
  – A model that includes features above ground (buildings and vegetation)
  – Used to distinguish a bare-earth elevation model
DEM vs DTM

Breaklines needed to more accurately define surface
DTM Made Up of LiDAR Masspoints with Breaklines

Breaklines improve surface fidelity

Breakline
LiDAR: All-Return DSM
LiDAR: Bare-earth DEM
LiDAR - The Classified Point Cloud

• Classification process separates LiDAR points into different categories
• Most basic objective is usually to separate ground points from non-ground points to create a bare-earth surface
• Delivered as tiles or swaths
• LAS data format

<table>
<thead>
<tr>
<th>Ground/Non-Ground Classification</th>
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<tbody>
<tr>
<td>Class 1</td>
</tr>
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<td>Class 7</td>
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<td>Class 9</td>
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<td>Class 10</td>
</tr>
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<td>Class 11</td>
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# LiDAR – The Classified Point Cloud

<table>
<thead>
<tr>
<th>Enhanced Classification</th>
<th>Class 0</th>
<th>Created, Never Classified</th>
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</thead>
<tbody>
<tr>
<td>Class 1</td>
<td></td>
<td>Unclassified</td>
</tr>
<tr>
<td>Class 2</td>
<td></td>
<td>Bare Earth Ground</td>
</tr>
<tr>
<td>Class 3</td>
<td></td>
<td>Low Vegetation</td>
</tr>
<tr>
<td>Class 4</td>
<td></td>
<td>Medium Vegetation</td>
</tr>
<tr>
<td>Class 5</td>
<td></td>
<td>High Vegetation</td>
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<td>Class 6</td>
<td></td>
<td>Building</td>
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<td>Class 7</td>
<td></td>
<td>Low Points (Noise)</td>
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<tr>
<td>Class 8</td>
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<td>Model Key Point</td>
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<td>Class 9</td>
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<td>Water</td>
</tr>
<tr>
<td>Class 12</td>
<td></td>
<td>Overlap</td>
</tr>
</tbody>
</table>

![LiDAR point cloud image](image-url)
LiDAR Sensors: Supervised Classification

Macro 1: Urban Classification
Macro 2: Low Veg Classification
Macro 2: Dense Veg Classification
Macro 4: Water/Shore line Classification
Macro 5: Steep Terrain Increase
Macro 6: Bare Earth Only
Manual Editing
Need for Hydrologic Breaklines

• Why Hydro Breaklines
  – LiDAR is an active, IR beam
  – LiDAR doesn’t provide an accurate return (elevation value) off of water
  – Without hydro breaklines, water surface irregular, provide false elevation values, not aesthetically pleasing
  – Hydro breaklines flatten surface to lowest adjacent ground elevation
• **Hydrological Conditioning** - Enhancement of a DEM so you have a uniform, continuous hydrological surface.
• **Hydrological Enforcement** - Processing of mapped water bodies so that streams flow downhill
LiDAR – The Intensity Image

- Each LiDAR return has an intensity value
- Intensity image is a collective display of the intensity values.
- White areas show high reflectance (strong return) while black areas show low reflectance (weak return).
- Useful for:
  - Quality controlling LiDAR
  - Breakline extraction
  - LiDARgrammetry
  - Feature Extraction
Current LiDAR Specifications

- U.S. Geological Survey, 2009 (draft), National Geospatial LiDAR Guidelines and Base Specifications; Version 1.0 (2012 published)
  - For the first time, a comprehensive national LiDAR guideline and specification document
  - All stimulus funding through USGS had to follow spec, most of the other federal agencies have started to follow this spec, many state agencies and some local government follow this spec and some add additional language to scope of work
- FEMA document, 2010 – Procedure Memorandum No. 16; Standards for LiDAR and Other High Quality Digital Topography – much of the LiDAR specs are based on the USGS National LiDAR specs
USGS Required LiDAR Products Under Base Specification V1

- Raw point cloud (LAS file format)
- Classified point cloud (LAS format)
- Bare earth DEM (hydro-flattened)
- Breaklines
- FGDC Metadata
- Acquisition/Survey LiDAR Report
- Ground checkpoints & accuracy assessment
National Enhanced Elevation Assessment (NEEA)

• 2011 federally commissioned study on nationwide LiDAR cost/benefits

• Primary Reasons for study
  – Document national-level requirements for improved elevation data
  – Identify program implementation alternatives, costs and benefits of meeting priority Federal, State and other national needs
  – Evaluate multiple national-level program-implementation scenarios
### NEEA Quality Levels

Each 602 mission critical activities requires one of the levels listed below.

<table>
<thead>
<tr>
<th>Quality level</th>
<th>Horizontal pt spacing (m)</th>
<th>Vertical accuracy (cm)</th>
<th>Contour Accuracy</th>
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<tbody>
<tr>
<td>1</td>
<td>0.35</td>
<td>9.25</td>
<td>1’</td>
</tr>
<tr>
<td>2 *</td>
<td>0.7</td>
<td>9.25</td>
<td>1’</td>
</tr>
<tr>
<td>3</td>
<td>1–2</td>
<td>≤ 18.5</td>
<td>2’</td>
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<td>4</td>
<td>5</td>
<td>46–139</td>
<td>5-15’</td>
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<td>5</td>
<td>5</td>
<td>93–185</td>
<td>10-20’</td>
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</table>

* Identified as most bang for buck for 3DEP program – QL2 is the minimum data quality needed for USGS partnership funding.*
LiDAR Specifications 2014

3D Elevation Program (3DEP) specifications, USGS currently requires Quality Level (QL) 1 or 2

http://nationalmap.gov/3DEP/

<table>
<thead>
<tr>
<th>Quality level</th>
<th>Horizontal point spacing (meters)</th>
<th>Vertical accuracy (centimeters)</th>
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<td>1</td>
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<td>93–185</td>
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<table>
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<tr>
<th>Equivalent Contour Accuracy</th>
<th>FEMA Specification Level</th>
<th>RMSE&lt;sub&gt;e&lt;/sub&gt;</th>
<th>NSSDA Accuracy&lt;sub&gt;e&lt;/sub&gt;, 95% confidence level</th>
<th>SVA (target)</th>
<th>CVA (mandatory)</th>
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<td>0.60 ft or 18.2 cm</td>
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<td>Highest</td>
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<td>High</td>
<td>1.22 ft or 37.1 cm</td>
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<tr>
<td>5 ft</td>
<td>High</td>
<td>1.52 ft or 46.3 cm</td>
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<td>8 ft</td>
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<td>12 ft</td>
<td>Low</td>
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<td>7.15 ft or 2.18 m</td>
<td>7.15 ft or 2.18 m</td>
<td>7.15 ft or 2.18 m</td>
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LiDAR Accuracy

LiDAR should be tested against field checkpoints prior to delivery and an accuracy report provided.

• FVA: Fundamental Vertical Accuracy
  – Based on testing against well-distributed checkpoints located only in open terrain, free of vegetation, where there is a high probability that the sensor will have detected the ground surface

• SVA: Supplemental Vertical Accuracy
  – Based on testing against checkpoints in a single land cover category (e.g. forest, grassland)

• CVA: Consolidated Vertical Accuracy
  – Based on testing against checkpoints in multiple land cover categories combined, normally including open terrain and vegetated terrain representative of the land cover for the project area being tested
Questions?