LIDAR ESSENTIALS:
Module 1

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The Webinar Will Begin Shortly

- Group audio is disabled for this webinar.
- To ask a question, please type it in your “Questions Box”.
- We will pause at points throughout the webinar to answer questions.
- The webinar is scheduled for 60 minutes.
Audio Check

• Please “raise your hand” if you can hear me.
Webinar Hosts

**Alan Lulloff, PE, CFM**
- Science Services Prog. Mgr. at ASFPM
- Member of Multihazard Mitigation Council Board of Direction
- Member of HAZUS Flood Committee
- Member of Great Lakes Coastal Flood Study Oversight Committee
- Member National Flood Determination Association eLOMA Oversight Board
- Member North Carolina Integrated Hazard Risk Management Advisory Committee

**Lewis Graham**
- CTO/President of GeoCue Corporation
- Division Director, ASPRS LIDAR Division
- Chair of the LAS Working Group
- Member of the Transportation Research Board (TRB) oversight committee for the mobile laser scanning standards development project
- Board member of The ISPRS Foundation
- Author of various chapters of various LIDAR manuals

**Martin Flood**
- Director of Integration Services, GeoCue Corp.
- Past Chair ASPRS LIDAR Committee
- Member of TRB oversight committee on the use of airborne LIDAR for FAA Airport Obstruction surveys
- Co-author of the Topographic/Terrestrial Lidar section of the ASPRS DEM Users Manual
- Author of the ASPRS Guidelines for Vertical Accuracy Reporting for LIDAR Data
The ASFPM Webinar Series

• Session 1: An Overview of LIDAR
  – Today

• Session 2: Specifying LIDAR Collection Projects
  – Oct 22

• Session 3: LIDAR Acceptance and QC
  – Nov 9

• Session 4: Using LIDAR Data
  – Dec 10
Topics

• An overview of airborne LIDAR
• LIDAR Parameters
• ASPRS LAS Format
• Datums and Coordinate Reference Systems
• Accuracy Considerations
• Data Applications
You can play!

- **LIDAR Samples:**
  - [http://www.floods.org/LidarWebinar/SampleData/](http://www.floods.org/LidarWebinar/SampleData/)

- **Evaluation Software:**
  - [www.LP360.com](http://www.LP360.com)
    - Click the “Download Now” link under “Free LP360 Evaluation”
    - Download Questions/Problems? – [kcole@lp360.com](mailto:kcole@lp360.com)

- **A few tutorials on You Tube, LIDARLAB channel**

LIDAR Samples courtesy Brown County, WI
LIDAR Collections by Aerometric, Sheboygan, WI
WHAT IS LIDAR?
Why LIDAR?

• The original primary goal was to directly collect accurate digital elevation data at very high speeds
• Since its inception, the role of LIDAR has expanded to include:
  – LIDAR “Images” for direct true ortho generation
  – Extraction of data that is very difficult via photography (e.g. Transmission Line modeling)
  – Building extraction
  – 3D asset collection
  – General purpose mapping
Competing Topographic Collection Technology

- **Photogrammetry**
  - Well understood, accurate
  - Cannot ‘see’ through dense vegetation
  - Cannot derive 3D points for non-textured surfaces (sand, wires, ...)

- **Interferometry Synthetic Aperture Radar (IFSAR)**
  - Very fast collection
  - Sees through clouds and canopy
  - Very difficult to process to an accurate model
  - Usually delivered as 2 ½ D grid – post-delivery advanced feature extraction is not possible
  - Vertical accuracy is approximately an order of magnitude lower than Photogrammetry/LIDAR (~ 1 meter)
How Does LIDAR Work?

- Compact, rugged instrument installed on a small aircraft
- Laser pulses scanned across the path of the aircraft measuring range to surface and reflectance (Intensity)
- LIDAR ranges are combined with aircraft GPS position and Inertial Measurement Unit orientation information
- Post-processing software calculates X,Y,Z position of each spot on the surface
Modern LIDARs can detect Multiple Returns

- First return
- Second return
- Third return
- Fourth return
- Last return
Laser Return Intensity

Wide area mapper $\rightarrow$ 1.064 microns

Corridor mapper $\rightarrow$ 1.541 microns
Because of sensor mechanics and ground undulation, the points are not uniform.
Important Point Attributes

• Attributes produced by the laser scanner:
  – Absolute time of pulse
  – Position (X, Y, Z)
  – Intensity
  – Return number (e.g. return “n of m”)
  – Edge of flight line
  – Scan angle

• All of the above are very important to advanced processing algorithms
Questions?
These Terms are Distinctly Different

- Density
- Resolution
- Precision
- Local Accuracy (Relative Accuracy)
- Network Accuracy (Absolute Accuracy)
Resolution

Higher Resolution

Lower Resolution
Density vs Resolution

While the density is constant, I can measure point spacing at higher resolution with the cm scale than with the inch scale.
Resolution, Accuracy and Precision

- Resolution is the spacing of circles in the target.
- Accuracy is related to $\mu$.
- Precision is related to $\sigma$.
- Knowing $\sigma$ is only useful if you are given the type of distribution (e.g. Gaussian, Poisson, etc.).
Network, Local Accuracy

Poor Network Accuracy, Good Local Accuracy

Network Accuracy – The degree to which positions agree with a reference network

Local Accuracy – The accuracy of local measurements (point-to-point, local length, local area)

Good Network Accuracy, Good Local Accuracy

(▲ = Network Control)
How Dense are the Data?

Point data are generated at 100,000s of points per second, resulting in point densities significantly greater than traditional ground/photogrammetric survey methods. Density depends on:

- Pulse Repetition Rate (modern sensors can achieve up to 500,000 pulses/second)
- Flying height
- Forward aircraft speed
- Swath width (in degrees)
Point Spacing/Density Measurement

• Measured as:
  – Density - Points per unit area (e.g. points per square meter, ppm)
  – Nominal Point Spacing (NPS)/Ground Sample Distance (GSD) – average distance between points

\[ NPS = \frac{1}{\sqrt{\text{Density}}} \]

(e.g. A 40 ppm helicopter scan has an NPS of ~16 cm)
Typical Achievable Accuracy

<table>
<thead>
<tr>
<th>High Altitude Area Mapper</th>
<th>Corridor Mapper</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical:</strong></td>
<td><strong>Vertical:</strong></td>
</tr>
<tr>
<td>5 – 15 cm</td>
<td>5 – 10 cm</td>
</tr>
<tr>
<td><strong>Horizontal:</strong></td>
<td><strong>Horizontal:</strong></td>
</tr>
<tr>
<td>1/5,500 x Altitude</td>
<td>1/3,000 x Altitude</td>
</tr>
<tr>
<td>e.g. 18 cm at 1 km flying height</td>
<td>e.g. 4 cm at 125 m flying height</td>
</tr>
</tbody>
</table>

½ Rule: Data with a vertical accuracy of $x$ cm (at 95% confidence) will generally support a contour interval (CI) of $2x$ (e.g. 1 ft. vertical accuracy will support 2 ft contours)

Note: These examples are from Optech LIDARs but are typical of this general class of sensor.
LIDAR vs Photogrammetry

Laser-based mapping systems are active sensor systems, as opposed to passive imagery such as cameras:

• Penetrate gaps in forest canopy to map the floor beneath the treetops.
• Provide accurate elevation data in areas of low relief and contrast such as beaches.
• Accurately map the sag of electrical power lines between transmission towers
• Do not generate “correlator blunders” common in photogrammetrically derived data
Questions?
ASPRS LAS FORMAT
LAS History

• In the beginning….
  – LIDAR data were exchanged via proprietary ASCII formats

• 1998: An industry group created an open binary format called LAS, using the .las extension

• 1999: Format ‘donated’ to the ASPRS

• 2000’s: LAS incrementally updated

• Nov 2011: LAS 1.4 approved
LIDAR Data Format

• **Always** require LAS format (Version 1.2 or above) as the deliverable

• **Never** accept ASCII!!!
  – You will always lose vital information

• Always require delivery of the geometrically corrected raw data in addition to your normal project deliverables – more on this in a later Module
DATUMS & COORDINATE REFERENCE SYSTEMS (CRS)
Datums, CRS

- Datum – A reference system and model on which measurements can be based. An example would be the information necessary to describe a mathematical ellipsoid model of the earth
  - Example: North American Datum, 1983

- Coordinate Reference System (CRS)
  - A particular projection, referenced to a datum
  - Example: Kentucky State Plane North, Survey Feet, NAD83
Vertical Systems

Ellipsoid – Flexible but you will have to convert to Geoid

Geoid – What you must have for modeling but can be problematic to get back to the ellipsoid...

Water flows based on the physics of the true Geoid
Always be precise in what you want. Include all aspects of the Datum, CRS. Datums, unfortunately, come in numerous realizations. Example:

- **NAD83 (2011)**, KY SP N, survey ft.
- **NAVD88 (Geoid 2012)**, survey ft
ACCURACY
CONSIDERATIONS
General Thoughts
(More on this in a later module)

Accuracy Specifications include:

- **Geometric Accuracy**
  - Network (absolute accuracy)
  - Local accuracy

- **Classification Accuracy**
  - Commission Errors – points in a class that should not be present (e.g. tree points in the ground class)

- **Supplemental Data Accuracy**
  - Example: Hydro breaklines

- **Delivery Accuracy**
  - Adherence to CRS, LAS validity, tiling schemes, …..
Other Stuff…

• Some critical issues are not accuracy but specification compliance:
  – Point density (e.g. adherence to a minimum points per meter$^2$ in the ground class)
  – Errors of omission – e.g. breaklines missing in thalwegs
  – etc.
Questions?
DATA APPLICATIONS
What Is LIDAR Mapping?

- It is a tool used in the airborne survey field that employs LIDAR to rapidly generate elevation data that are:
  - high-density
  - accurate
  - digital
  - geo-referenced
Typical Point Cloud Products
(In all cases, we assume geometrically corrected clouds)

• All returns, unclassified point cloud
• “Surface” cloud
  – This is a first return, unclassified cloud. No need for this if you specify the “all returns” data
• “Bare Earth” classified cloud
  – Should include all other points but unclassified
• Supplemental classes;
  – Vegetation
  – Buildings
  – etc.
Supplemental LIDAR Derived Data

- **Breaklines - Hydro**
  - Water bodies ("flattening")
  - Downstream constraints
  - Double line drains

- **Breaklines – Other**
  - Edge of pavement
  - Retaining walls
  - (Geo)Morphological interest
Feature Extraction

• Water bodies
• Shoreline
• Planar surfaces
  – Roof footprints, etc.
• Tree envelops
• Specialty assets—roads, bridges, rails, etc.
Visualization

- LIDAR “Orthos”
- 3D visualization
- Profiles
Output products

• Gridded elevation models
  – Canopy
  – Surface
  – Breakline enforced surface
• Contours (but should be used only for visualization)
• Raster visualization products
• Features
Summary

• LIDAR has become the standard for elevation modeling
• Migrating from a gridded DEM to point cloud processing will enable rich, supplemental data extraction
• Care in specifying LIDAR data and rigorous Quality Checks of the received data will ensure maximum project value (much more on this in subsequent sessions)
Download Evaluation Software from: www.LP360.com

Download Sample Data from: http://www.floods.org/LidarWebinar/SampleData/

View tutorials on You Tube from the LIDARLAB Channel

Direct questions to Kelli Cole at GeoCue: kcole@lp360.com