Techniques for Quality Control and Quality Assessment of Large Area Lidar Projects

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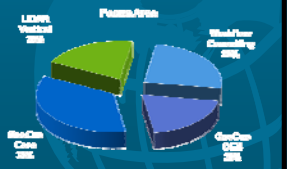
Outline

1. Company/Software Overview
2. Quality Control (QC) & Quality Assessment (QA) Workflow
3. QA Plan for a Large Project
4. QA Tasks at the Tile Level.
5. Lidar Stereo (Lidargrammetry)
6. Summary

Our Business

- GeoCue Core Software Development
  - Geospatial process management system (GeoCue)
  - GeoCue "plug-ins" to realize specific workflows (CuePacs)
- OEM Deployments of GeoCue
- GeoCue Workflow Integration Services
  - Workflow Optimization
  - Workflow as Management Tool
  - GeoCue as Workflow Engine
- Lidar Vertical
  - Lidar Data Processing Support
  - 'One Stop' Shop
  - Best Practices



Lidar Vertical Business

- We continue to support the lidar segment in a fully vertical manner.
- We offer everything from …
  - "Bootstrapping" to get an organization that has never worked with lidar data up and functional with best practices …
  - … to enterprise-enabling integrated lidar data processing workflows.

Terrasolid

- Expanded our partnership to become Terrasolid's authorized sales and support center for all clients in North America.
- Provide all software sales, training and technical support.
- Series of 3-5-10 day courses covering all aspects of working with lidar data.

Terrasolid North American User Group/Training Session:
Sept. 17 – 21 Huntsville, Alabama

Customers (Partial List)

- 3001
- Aero-Metric
- Atlantic Group
- Ayres Associates
- BAE Systems – ADR
- Bohannan-Huston Inc.
- Canaan Valley Institute
- Dewberry and Davis
- EarthData
- GeoEye (M.J. Harden)
- GRW
- HJW
- Intergraph Services Company
- North Carolina DOT
- Ohio DOT
- Optech
- Optimal Geomatics
- Pennsylvania DCNR
- Penn State
- Photo Science
- Sanborn
- City of San Jose
- Santa Clara County
- Santa Clara Water Authority
- Surdex
- Tuck Mapping Solutions
- URS Group
- Western Air Maps
- Woolpert

- 3D Laser Mapping (UK)
- Kokusai Kogyo Co., Ltd.

Iowa DOT is has installed an evaluation version of GeoCue along with the Terrasolid suite of software.

(Alice Welch; Photogrammerty Section)

GeoCue Concept

GeoCue – Geospatial Process Management System

Core

Lidar Processing

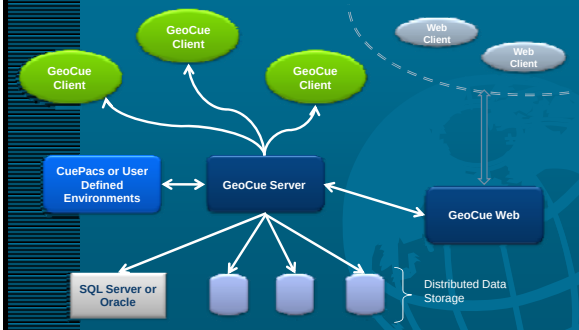
DEM Processing

Custom-Built Workflow Processing

Specialization

CuePac

Client-Server Architecture



Deployment Benefits

The importance of lidargrammetry and its impact on the cost-benefit model for lidar mapping cannot be overstated. … Lidargrammetry has paved the way for a much more effective and efficient use of lidar technology. (pp 69 – 70)

"Base Map Inputs for Floodplain Mapping" (NRC Publication)

Technician

- Integrated Work Environment
- Productivity Tools
  - Coordinate Conversions
  - Grid/Tile Tools
  - dZ Checks
  - 'Z' Probe
  - Lidargrammetry
- File Management
- Application 'Hooks'
- Team Work Assignments
- Tasked 'To Do' Lists

- Production Logs
- Status Reporting
- Time/Effort Tracking
- ETCs/EACs
- Variance Tracking

- Baselining
- Subcontractor Tasking & Management
- Workflow Customization
- Sales Integration
- Finance Integration

QUALITY CONTROL & QUALITY ASSESSMENT

Quality Control (QC)

- Things you do to control and improve the quality of a process or product:
  - Documented processes;
  - Controls to ensure that processes are followed;
  - Random checking of processes and products;
  - Adjustment of processes based on feedback.
- Example – You test a series of *known* check points against your lidar data, measuring delta Z. You use the result to (if necessary) improve your own processes.

Quality Assessment (QA)

- Things done by others to ensure that your processes and products are achieving quality goals:
  - Independent assessment;
  - Independent process inspections;
  - Independent statistical sampling;
  - Independent process reviews.
- Example – You arrange for the collection of a series of *unknown* check points to be used with the lidar data, the QA contractor does the analysis.

Stakeholders

- Various groups have a stake in a project:
  - Production Contractor(s) – Entities collecting and processing data, producing final products.
  - Customer(s) – Entities receiving the final data and products.
  - Quality Assessment Contractor(s) – Entities verifying the data and products meet specifications. This may also be the customer.
- How these various stakeholders interact is critical to a successful project.
- Perspective of this discussion is that of the Customer.

A Poor Choice

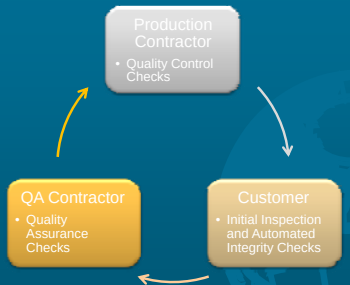
A Better Choice

The 'Best' Choice

Intermediate Products (Points)

Final Products (Surfaces)

Customer in the Loop



Recipe for Disaster

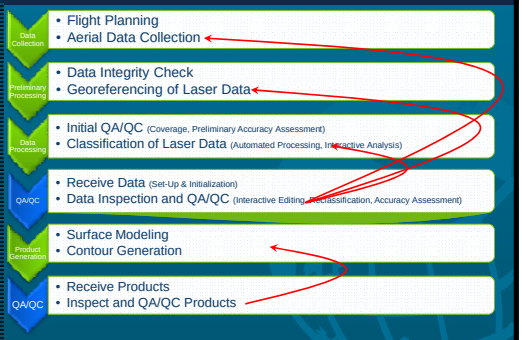
- Not using Quality-Based Selection (QBS) for Contract Award *(Generally, you get what you pay for…)*
- Delivery Specifications that are Vague
- Delivery Specifications that Change
- Large "Block" Delivery Plan *(Versus incremental)*
- No Data Management System
- Ill-Defined/Under-Funded QA Plans
- Out-of-Loop QA *(No feedback on problems/issues.)*
- Delayed QA *(Feedback too late for effective (cheap) correction.)*
- Poor Understanding of Production Processes
- Unrealistic Expectations
- Adversarial Relationship with Contractors

Recipe for Success

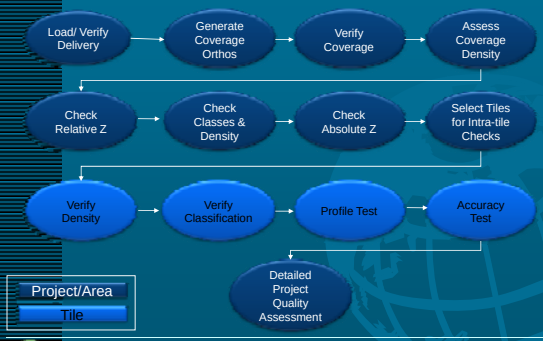
- Use QBS for Contractor Selection
- Rigorous (but flexible) Project Plan
- Very Specific Delivery Specifications
- Clearly Established Expectations
- Well-Defined QA Procedure
- Rigorous Data Management System
- Incremental Data Receipt and Processing
  - Receive data early and often!
  - Provide prototype samples to your downstream customers as early as possible
- Frequent Constructive Communication with Project Team

Basic Lidar Production Workflow

QA/QC Lidar Workflow



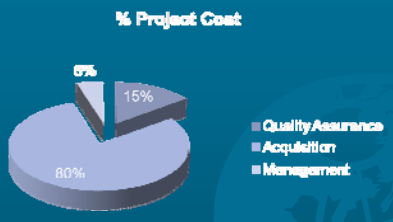
Detailed QA Workflow



When To Use External QA Contractor?

- Yes if …
  - No internal expertise in LIDAR QA.
  - No staff to dedicate to the task.
  - Inadequate infrastructure to manage the process.
- No if …
  - Commitment (budget/staff) to the project.
  - Organic Expertise.
  - Supporting infrastructure.

Budget



Note: The percentages are for discussion only and do not reflect any specific project.

A QUALITY ASSESSMENT PLAN

Preliminary Considerations

- Decide on data organization and workflow model:
  - Spatial distribution of delivery regions or units.
  - Use common process states to track data production – *acquired, processed, shipped for QC, received, inventoried, checked, ….*
- Define a methodical analysis process:
  - Full assessment of every deliverable.
  - Statistical sampling of xx% of deliverables.
  - Categorical statistical sampling; xx% of urban, yy% of rural, zz% of forest, etc.

Use LAS as the Data Format

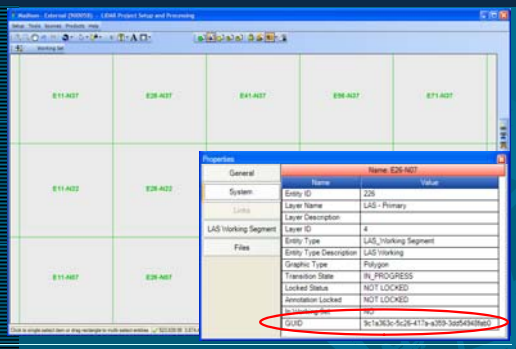
- American Society for Photogrammetry and Remote Sensing (ASPRS) standard for lidar data exchange.
- Rich, extensible format that contain… …ds that are critical for in-depth QA
  - Intensity
  - Original flight line ID
  - Classification
  - …..
- Insist on full data set with "bare earth" as a class
  - You may want to extract other info later on….

Initial Assessment Tasks

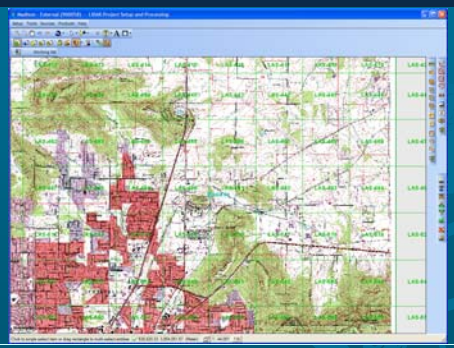
- Common tasks when first starting to assess project deliverables include:
  - Importing the source data into the project.
  - Running automated data integrity checks (scripts).
  - Segmenting (tiling) the source data in to working units.
  - Adding reference data (rasters, geometries, control).
  - Visual inspection of the source data.
  - Verifying area coverage.
  - Verifying sensor calibration (geometric correction).
  - Verifying preliminary data accuracy.
- These project-level assessment tasks are usually only done once per project (… area/region).

Usually can be handled by the Customer, even with limited 'lidar' experience.

Project Tiling Scheme

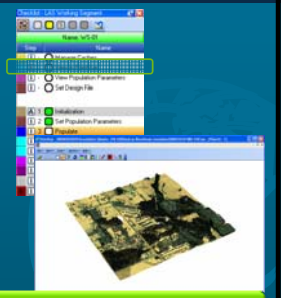


Using Context for Inventory Tracking



Viewing Data

- Data can be viewed using PointVue (lidar) or other third-party viewing tools.
- Typical approach is to include an ad-hoc "View in xxxxx" step to each QA checklist.



PointVue is available as a free download at www.geocue.com.

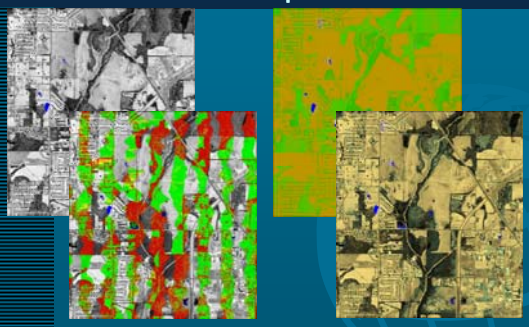
Checking Coverage

- Identifying gaps in coverage early, while field crews are still onsite, can be critical to minimizing costs of reflights.
- Typically should be checked by field data collection subcontractor, but may be used as a data inspection QA/QC test by contractors.
- Producing "Orthos" from the original lidar data with transparent gaps provides a rapid and accurate method to verify coverage.

Lidar Orthos

- Orthos can be generated directly from lidar point data.
- Can be useful for a variety of quality assessment tasks:
  - Coverage checks (gaps/voids)
  - Relative accuracy checks (overlap)
  - Reference raster for editing/QA-QC checking

Examples



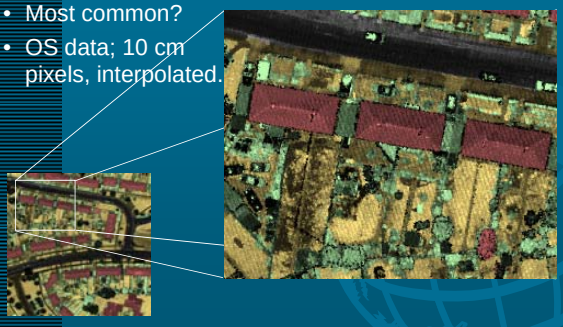
Intensity Modulation (By Class)

No Modulation | Modulated: Adjustment Off | Modulated: Automatic Adjustment

- The specific type of modulation used can vary depending on the data quality and desired vector products.

Intensity Modulated (By Class)

- Most common?
- OS data; 10 cm pixels, interpolated.



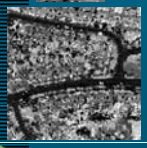
Pixel Size

- Pixel Size:
  - For insertion, ~1.25 x average GSD
  - For interpolation, 1 x GSD – 0.5 x GSD

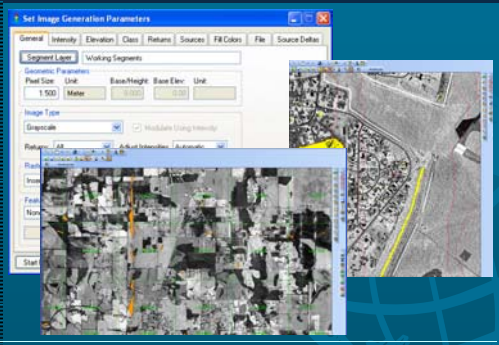
1.5 m

50 cm

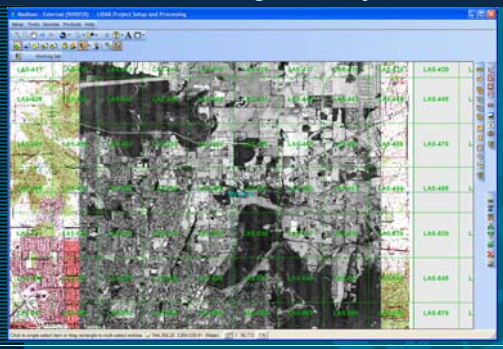
25 cm



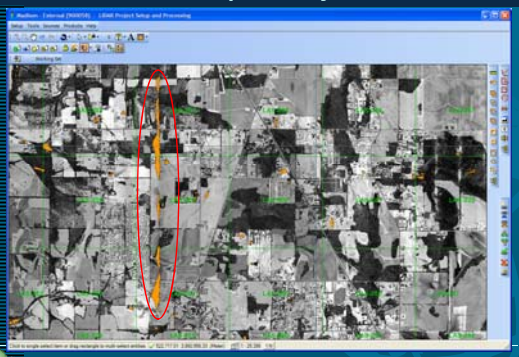
Checking Using Intensity Orthos



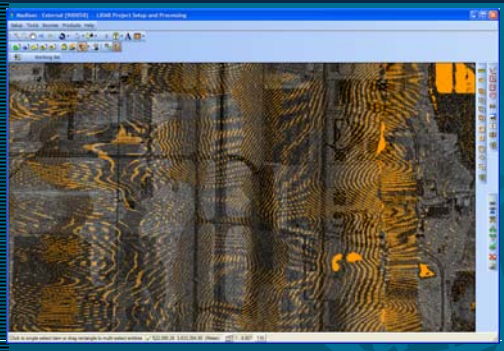
Area Coverage Analysis



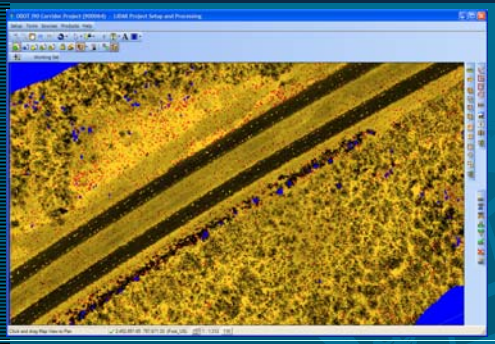
Void/Gap Analysis



General Density Check

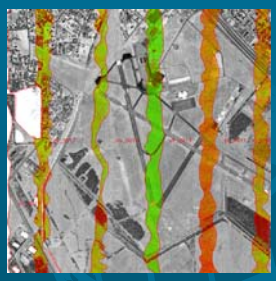


Color by Classification

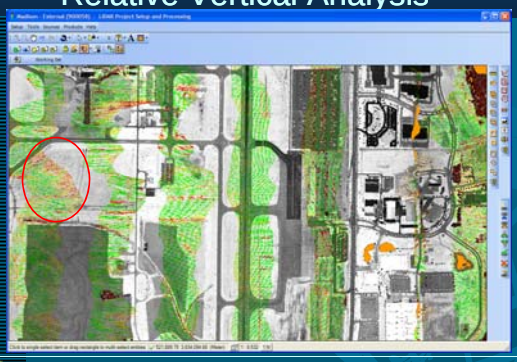


Checking Calibration Using dZ

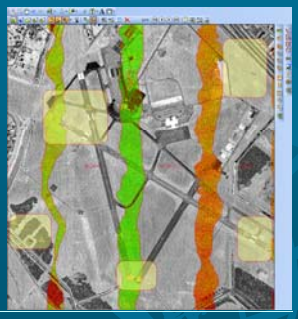
- Sensor calibration (relative data accuracy) can be checked by examining overlap in open, flat areas.
- Poor dZ results can indicate the need for more rigorous geometric analysis and correction.



Relative Vertical Analysis



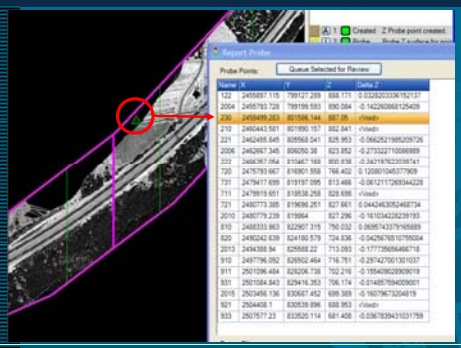
Adding GCP to Project



Z-Probe

- Can use “Z-Probe” for testing LAS elevation surfaces (e.g. determining absolute Z variance for lidar data).
  - Uses a TIN generated from all LAS points on the selected layer.
  - Need to create a ground-only layer if checking ground truth outside open areas. (TerraScan Macro)
  - Probe calculates distance from GCP to TIN surface.
- Transform GCP coordinates on import (both horizontal and vertical) or during analysis.

Absolute Z Testing



QA TASKS AT THE INDIVIDUAL TILE LEVEL

Typical QA 'Tool' Requirements

- A typical QA session of a lidar data tile requires a collection of tools that allow the user to:
  - View the laser points.
  - Add a background raster.
  - Draw profiles.
  - Display a TIN model as color-shaded surface or as contours.
  - Perform interactive editing of point classes (from-to) by polygon (top-down) or by above/below line (profile).
  - Create AOI polygons with pre-assigned correction scripts/macros for automated
  - Export AOI polygons to .SHP contractor.

Typically the bulk of the effort by the QA Contractor; requires more 'lidar' experience.

QA Approach for a Tile

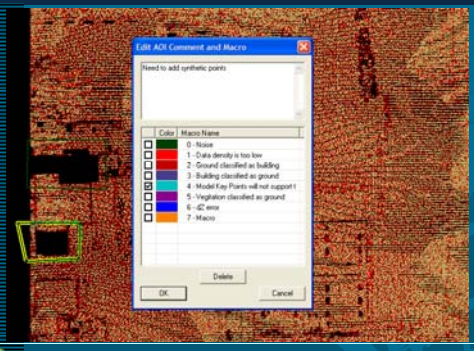
- Typical approach to QA of a lidar tile is as follows:
  - Load and view points.
  - Load and view any reference rasters.
  - Generate TIN from 'Ground' class.
  - View TIN with/without points overlaid and identify 'problem' areas.
  - Draw a profile across problem area to investigate further.
  - Determine cause of problem area and select a correction method:
    - » Reclassify immediately
    - » Designate an AOI for la

GeoCue tool is 'LAS EQC', a low-cost, light-weight package available as an add-on module.

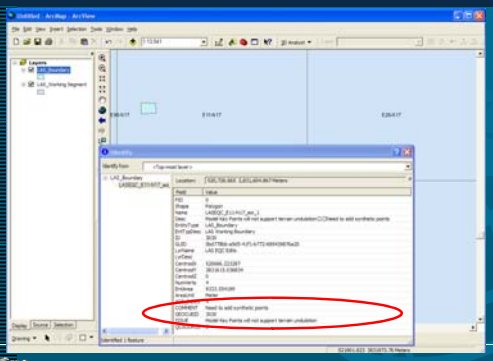
Error Correction Philosophy

- Not all defects are worth recycling through the processing contractor.
- Be realistic! The data will *never* be perfect!
- Need to clearly define error categories
  - Accept
  - Fix in QAC
  - Reject
- Precisely define rejection reasons
  - Spatially denote
  - Specific problem

Error Classes Should Be Specific



Communicating Problems



IMPLEMENTING LIDAR STEREO IN A QA/QC WORKFLOW

Legal Note

The techniques discussed here are based on algorithms developed by GeoCue Corporation and implemented in their GeoCue software suite. GeoCue Corporation has a patent pending on its imaging techniques, including lidar stereo or 'lidargrammetry' and related 'synthetic stereo' generation methods.

Why Lidargrammetry?

- A specific example of a new tool that is impacting overall production efficiency for lidar data producers.
- Demonstrates the benefits of integrating two distinct workflows to improve throughput and scalability of established techniques.

Motivation for This Tool

- Investigate improvements to overall lidar workflow efficiencies.
- Determine if an end-to-end 'lidar-only' workflow for creating established mapping products is practical.
- Capture any cost reductions.

Inferred Stereo Pairs (ISP)

- Traditionally in normal stereo vision systems a pair of 2D images, each taken from a slightly different perspective, is used to derive 3D object space points.
- Or, by creating a second image from a orthorectified source image and an elevation model, an inferred stereo pair can be inferred ('stereo mate').

Lidar Data – No 'True' Image

- The source data consists of actual 3D points in object space.
- May also capture additional object information /attributes.
- 'Lidargrammetry' works by reversing the traditional process, taking 3D object space points and rendering an inferred pair of 2D images from an additional object attribute.

Possible Object Attributes

- Current lidar sensors capture various object information that can be used for generating raster images:
  - Intensity
  - Class
  - RGB
  - Polarization
- Integrated sensors (or data sets) might add others such as spectral data ….

ISP

- The inferred images are generated as if captured at positions determined via a pseudo base-height parameter and related parameters of the data set.
- The object information being used to generate the image, usually the intensity, determines the value of the pixel.

Stereo Generation

- Base to Height:
  - Determines stereo exaggeration (higher more stereo).
  - 0.3 for moderate to high relief terrain.
  - 0.6 for low relief terrain to add exaggeration.
  - Note that image quality will degrade with increasing B/H, especially near breaks (buildings).
- Base Elevation:
  - Average elevation across the tile.
- Can specify a feature file for compilation.

In-Flight Parameters

Lidar intensity samples from three gain and attenuator settings.

Factory specifications push histogram to bright values.

Advantages

- Removes need for separate imagery collection.
- Lidar data can be viewed as a stereo model in standard photogrammetric software.
- Production technicians can use established viewing, measurement and compilation techniques.

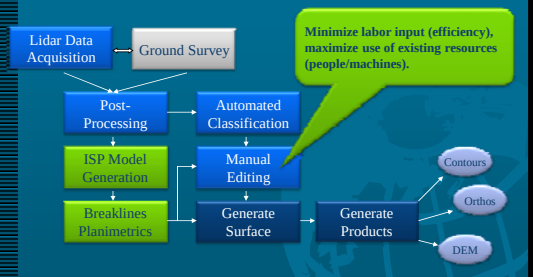
Qualitative Observations

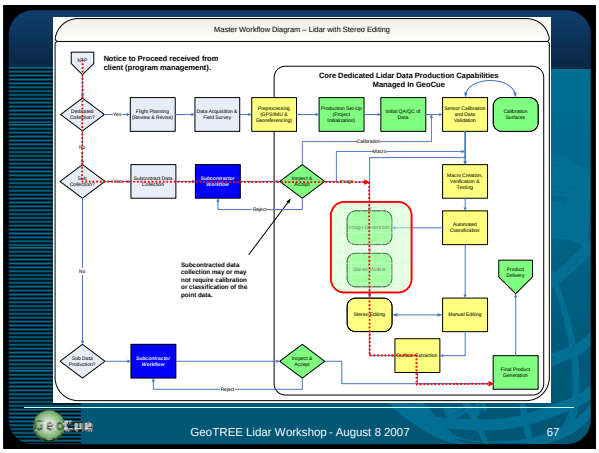
- Requires a dense data set for accurate image creation.
- Collection parameters critical to intensity image quality.
- Breaklines collected from 2 meter posting lidar data is equivalent to 1”=200’ scale imagery (horizo
- Low vegetation stereo models.

Comparing Photogrammetry Enhanced Lidar to 2D and Lidar Stereo Breakline Techniques; (ILMF 2007 Proceedings)

Layton Hobbs (Woolpert)

‘Lidargrammetric’ Workflow





Summary (QA/QC)

1. Understand that you generally get what you pay for …
2. Nurture a team environment; we have never worked with a company who did not care about doing the best possible job given the project constraints.
3. Start and stay organized!!
4. Have specific, written production and quality plans that are:
   - In clear, understandable language;
   - Actionable
5. Use various techniques for checking and reviewing data and products, not just "points". (orthos, stereo)
6. Manage data in small areas, not huge blocks.
7. Thread QA/QC throughout the process with the Customer-in-the-Loop.
8. You *must* have an *independent* QA system.