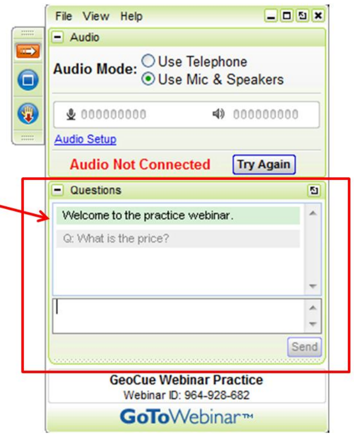
This is Module 2 of a total of 4 Modules in the ASFPM/GeoCue LIDAR Webinar series.

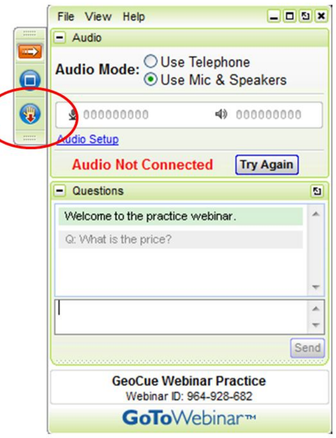
The Webinar Will Begin Shortly

- 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

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- Member of Multihazard Mitigation Council Board of Direction
- Member of HAZUS Flood Committee
- Member of Great Lakes Coastal Flood Study Oversight Committee
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- 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
  - Sept 10, 2012
- Session 2: Specifying LIDAR Collection Projects
  - Oct 22, 2012
- Session 3: LIDAR Acceptance and QC
  - Nov 9, 2012
- Session 4: Using LIDAR Data
  - Dec 10, 2012

Topics

- Product-driven specification methods
- How performance specifications affect project cost
- Cost/Performance trade-offs - extras that should not cost extra
- "Buy-ups" - cost/benefit considerations
- Breakline (e.g. "hydro-flattening") considerations
- Specifying data accuracy
- Specifying data formats and media
- Data Rights
- Monitoring projects

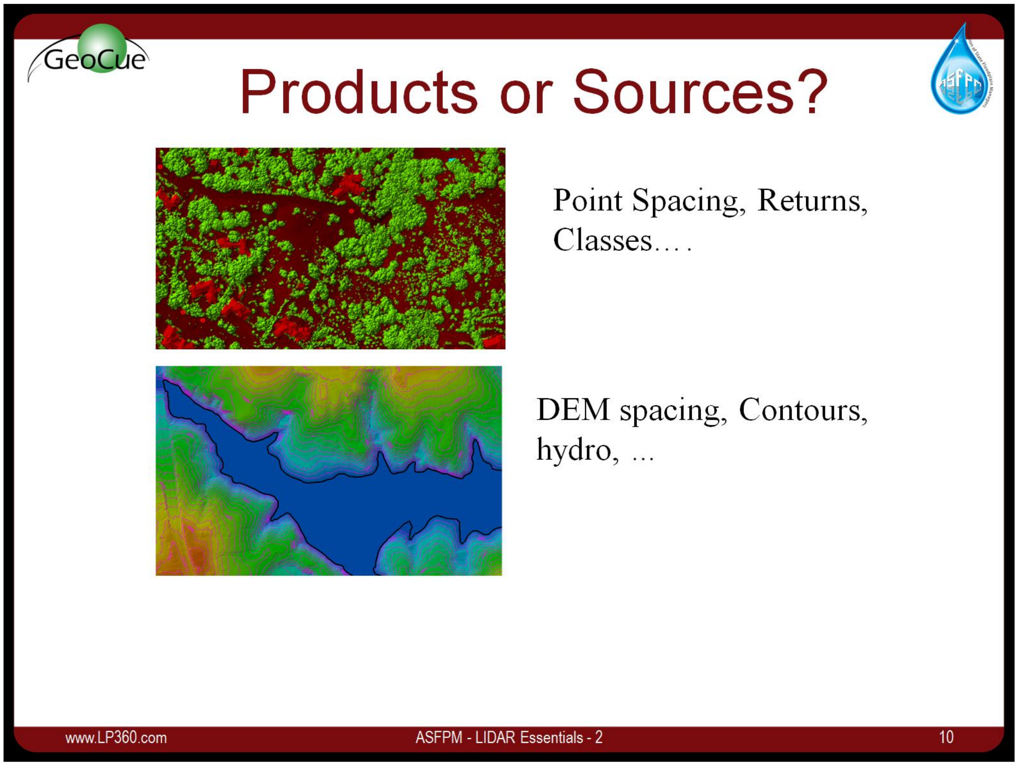
Acknowledgment

We would like to thank Jim Scott, State Geographic Information Officer & Director, Texas Natural Resources Information System TNRIS) for his review and input to this project

You can interactively learn!

- LIDAR Samples:
  - http://www.floods.org/LidarWebinar/SampleData/
- Evaluation Software:
  - www.LP360.com
    - Click the "Download Now" link under "Free LP360 Evaluation"
    - Download Questions/Problems? – info@lp360.com
- A few tutorials on You Tube, LIDARLAB channel

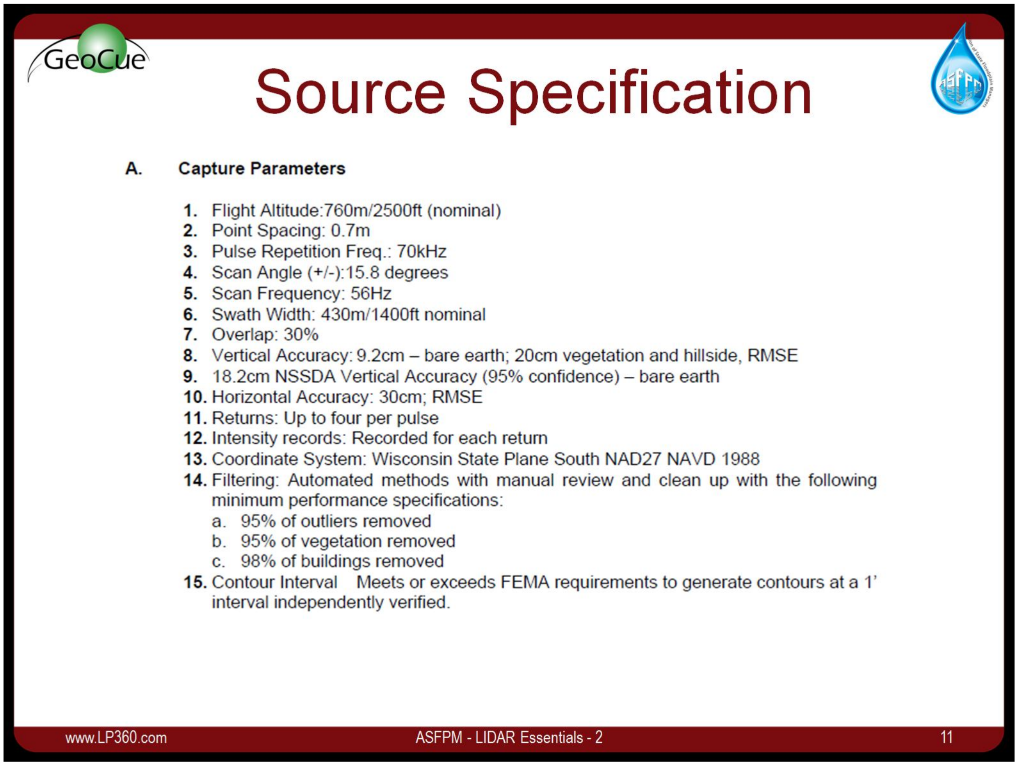
PRODUCT-DRIVEN SPECIFICATIONS



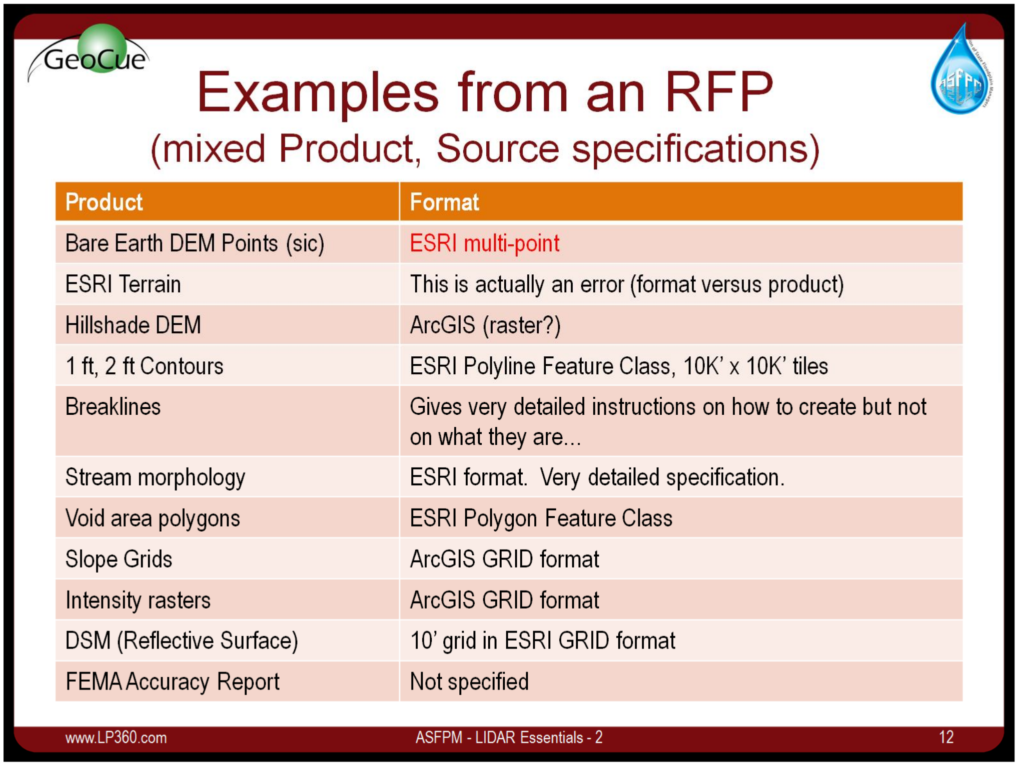
Data Driven Specification → Here you are providing specifications that apply directly to the LIDAR data such as Nominal Point Spacing (NPS), accuracy, overlap shear and so forth.

Product Driven Specifications → In this approach, you specify only the end products (Contours, gridded DEMs, etc.) and let the contractor select the LIDAR criteria that will fulfill these requirements.

We recommend a hybrid approach where the important elements of both are specified.



This is an example of a (real-world) Source-driven specification that focuses on the LIDAR data itself.



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Examples from an RFP
(mixed Product, Source specifications)

Product	Format
Bare Earth DEM Points (sic)	ESRI multi-point
ESRI Terrain	This is actually an error (format versus product)
Hillshade DEM	ArcGIS (raster?)
1 ft, 2 ft Contours	ESRI Polyline Feature Class, 10K' x 10K' tiles
Breaklines	Gives very detailed instructions on how to create but not on what they are…
Stream morphology	ESRI format. Very detailed specification.
Void area polygons	ESRI Polygon Feature Class
Slope Grids	ArcGIS GRID format
Intensity rasters	ArcGIS GRID format
DSM (Reflective Surface)	10' grid in ESRI GRID format
FEMA Accuracy Report	Not specified

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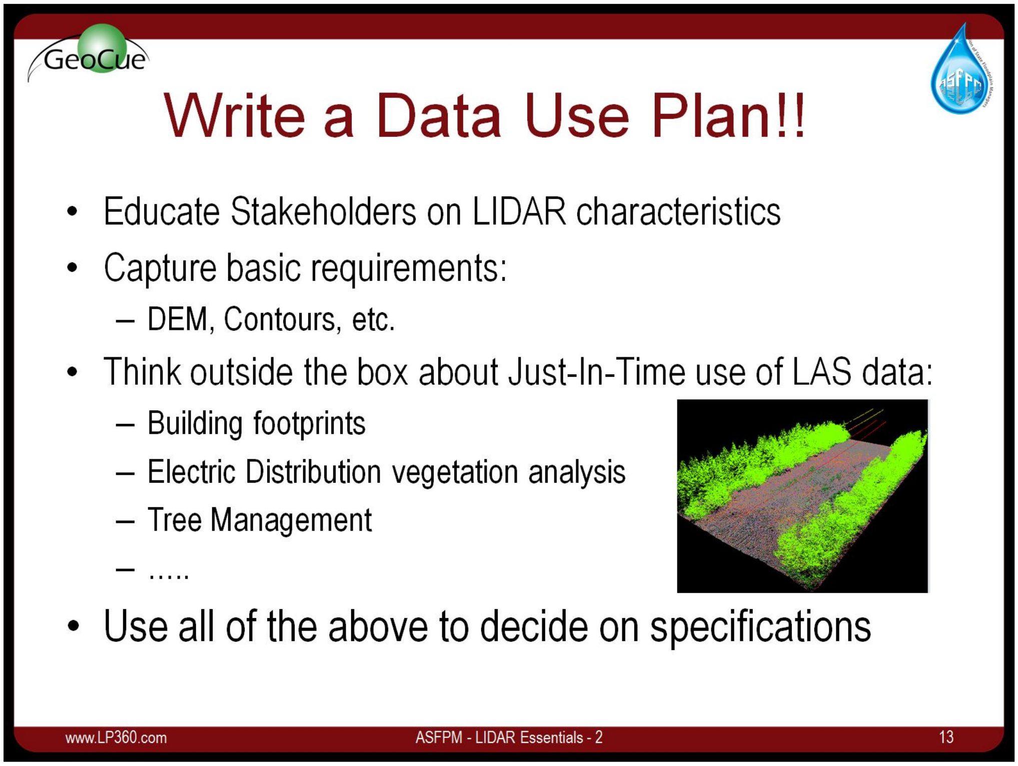
Here is an example (again, a real-world case) of a mostly product-driven specification. Note that this specification has a few issues:

- Bare Earth DEM points → Although not cast in stone, DEM (digital Elevation Model) most commonly means a <u>gridded</u> elevation model of the bare earth. In this specification, we think the intent was the point cloud.
- The point cloud is to be delivered in ESRI multi-point format. This would, in reality, be a terrible format for delivering high density point cloud data. It would have to be converted to something ingestible by processing software (even, and I hate to say this, ASCII would be better). The point cloud delivery format should <u>always</u> be LAS.
- Hillshade DEM – This would need quite a bit more specification to me useful (shaded parameter, spacing, sun angle, shading technique and so forth)

This "product-driven" specification is a classic example of a specification that is so vague that downstream (pun intended) unhappiness is going to occur.



I think a Data Use Plan is essential to specifying a LIDAR project. This plan should include all of the uses that that will be made of the LIDAR data. It is a good idea to write a "pie in the sky" plan (that is, include everything you can think of with a priority assigned to each) and then scale back to fit the reality of your budget. We recently consulted with a client who had typical base requirements:

- Data that can generate a bare earth DEM (by Digital Elevation Model, DEM, we mean a gridded elevation model) with 5 m spacing
- 2' Contours in ESRI shape format (a lot of us would like to see contours go away but I don't see this happening any time soon!)
- Digital Surface Model (DSM - often called the 'first return" data) in a 10 m grid

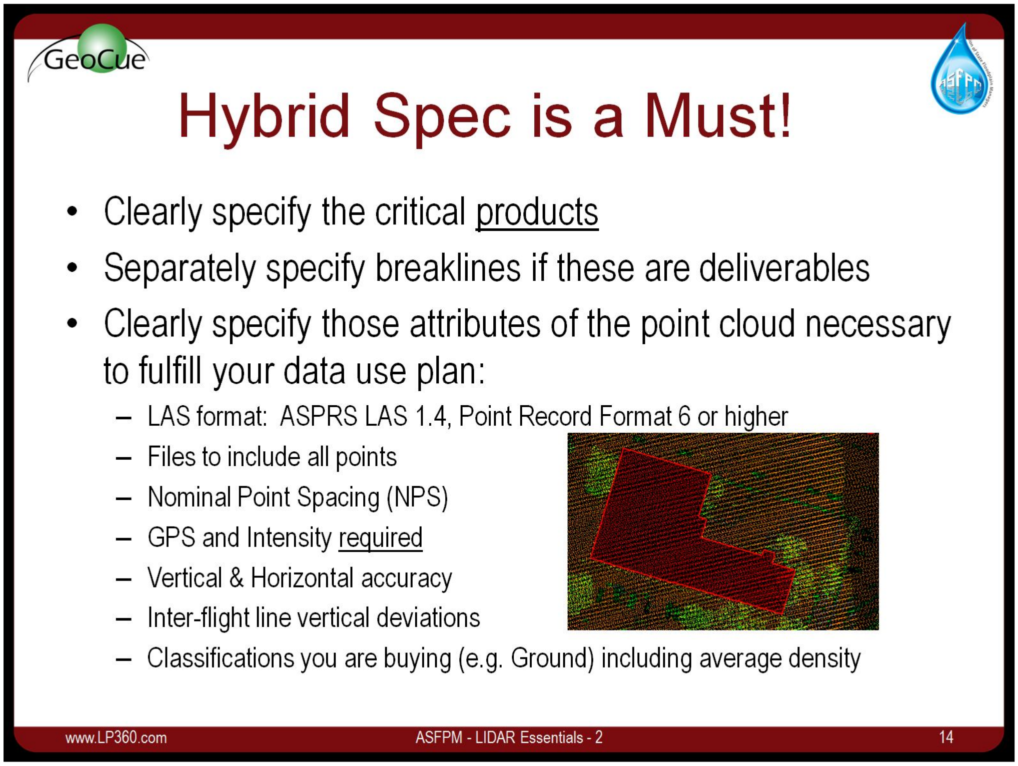
and other similar products.

They then added in non-traditional requirements:

- Classification of every tree in the municipality (this Australian municipality had a pretty impressive tree management program and wanted a current inventory)
- Classification of every building larger than 2 m^2
- 3D footprints, in shape format, of all buildings larger than 4 m^2
- Edge of pavement breaklines

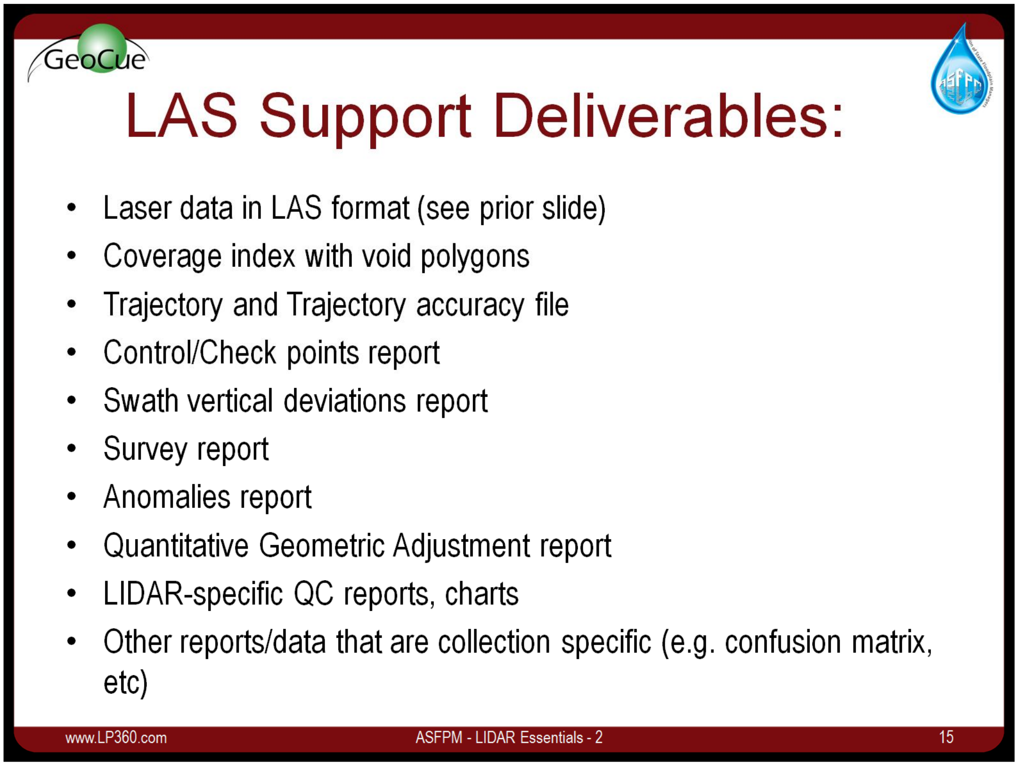
and so forth

The budget would not support the building extraction or the tree classification. This led to a specification that would allow the municipality to do these operations internally on select subsets of the data. The final result was to up the LIDAR point density to 8 points per square meter (Nominal Point Spacing, NPS, of 0.35 m) so that these future operations could be performed.



I have heard a lot about pure "Product-driven" specifications. These are specifications that focus only on the final deliverables such as gridded data, contours and so forth. They may have just a one-line statement in the Request For Proposal (RFP) stating something like "the LIDAR point cloud data shall be delivered on portable disk drive." This is the sort of situation where the client ends up getting the LIDAR in ASCII format with only X, Y, Z coordinates supplied (no return, intensity , GPS, etc.). Thus it is critically important to specify the content and character of the LIDAR point cloud.

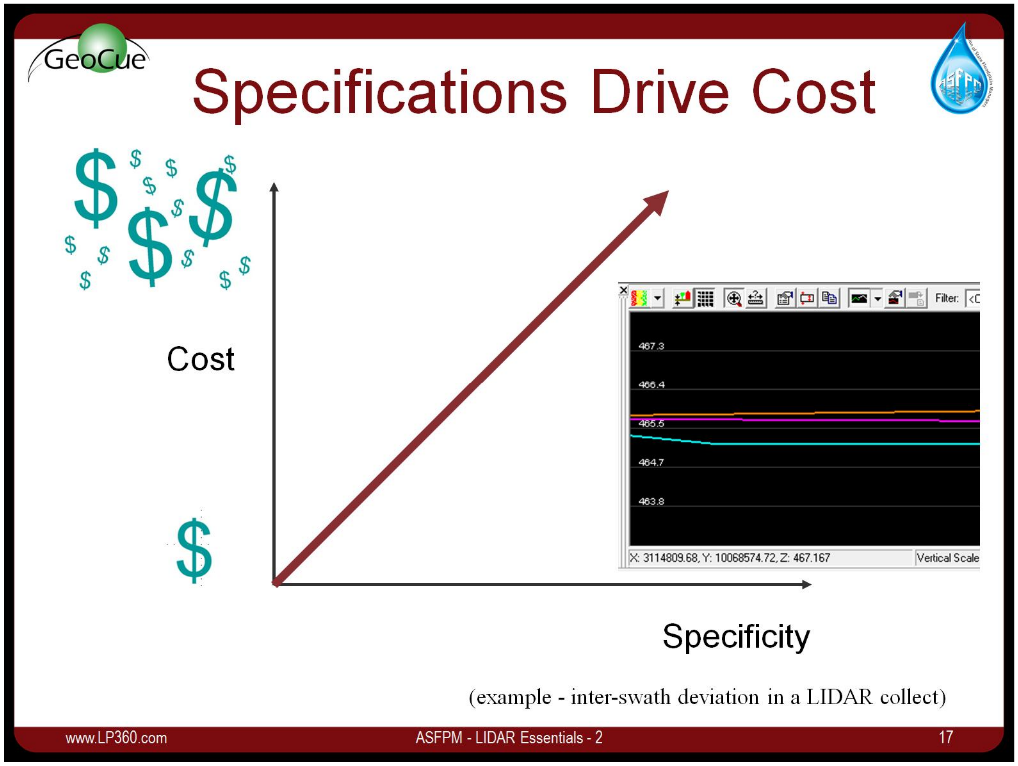
The figure above shows the vector building footprint (a Product) as well as the classified building points (a Source).



The LIDAR data itself is going to be an incredibly useful data source for future exploitation. Thus you will need to require all of the ancillary data that will be needed for accessing and/or performing this exploitation.

Above are listed some of the typical reports/data that will be necessary to do future exploitation of the data. It is very difficult, if not impossible, to go back to the contractor a year after a data delivery and request these data. Thus make sure their delivery is in your original data delivery items. Any competent contractor has to generate these as part of the production process so their delivery to you should not be a significant cost impact.

SPECIFICATION’S IMPACT ON COST

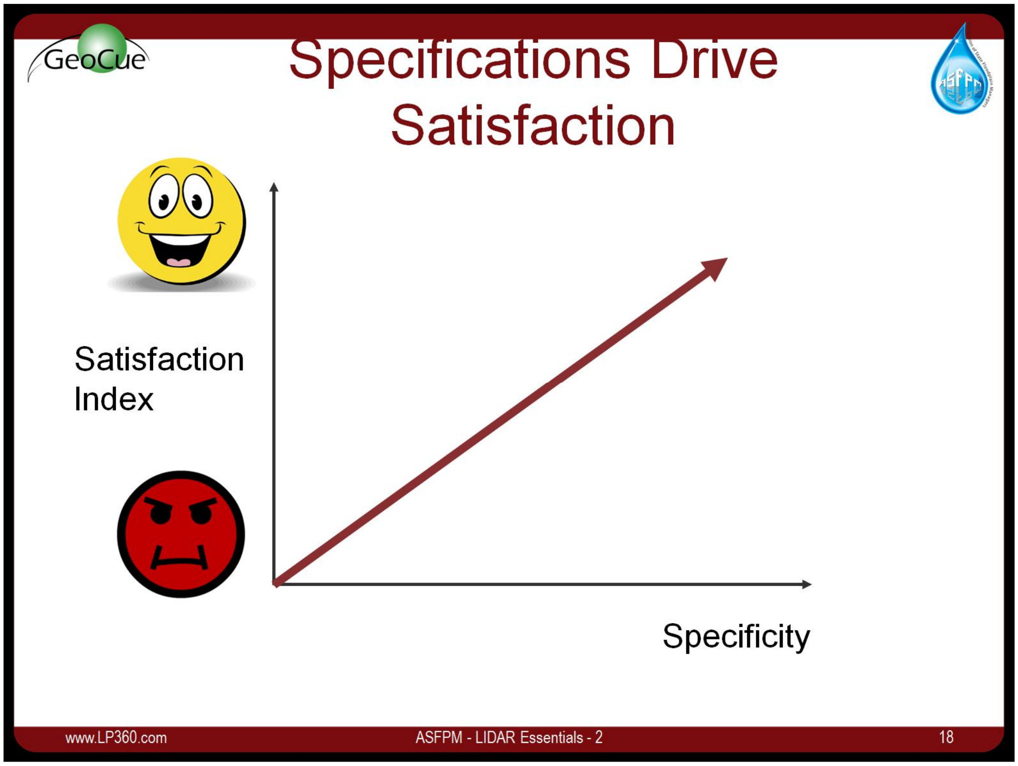


In general, more LIDAR data specificity means higher cost.

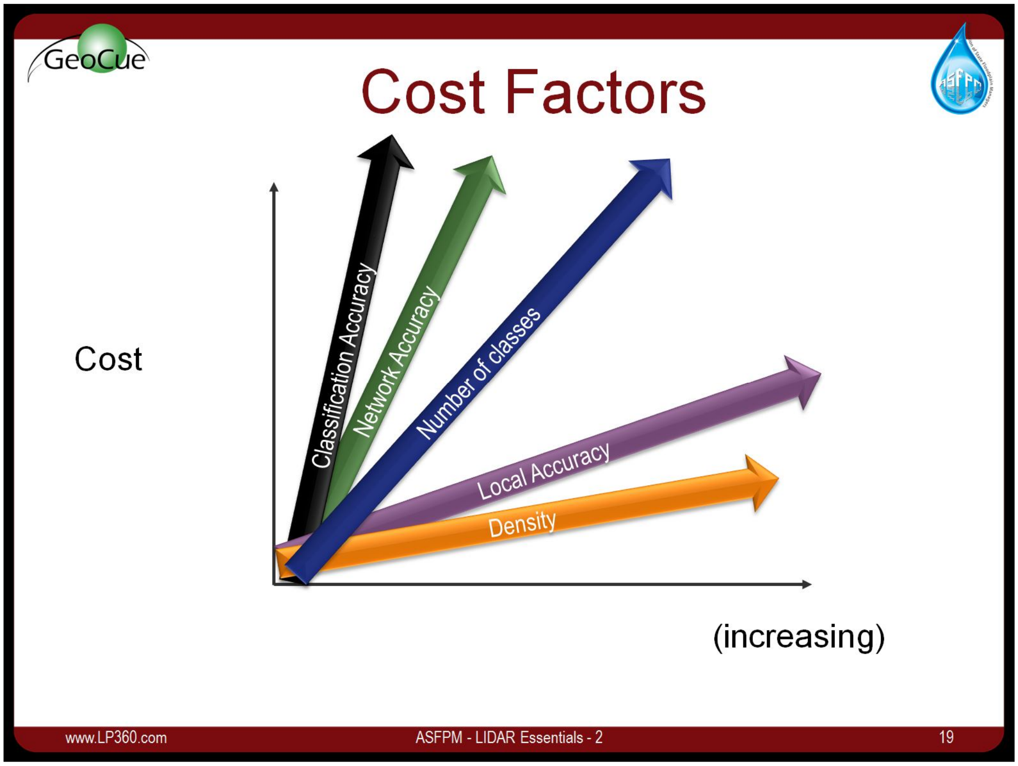
For example, if you do not specify inter-swath vertical deviation limits, the contractor has great latitude so long as the overall vertical accuracy specification is met. If you specify 24 cm vertical accuracy, the contractor could supply you with data having 10 cm of vertical discontinuity at a swath boundary. This would be fully compliant with the specification. However, you would be most unhappy with the data! If you specify something such as no more that 5 cm, randomly distributed vertical deviation at seam lines, you will have a better (meaning more useful) data set but you will drive up the cost (because the contractor will have to correct the joins to your requirements).

The screen shot above shows inter-swath deviations…

Thus focus on requirements that matter in your Data Use Plan.



This was covered in the prior slide. If you have a thorough Data Use Plan and use it to drive specific requirements, you will have data that meets your needs (and you will hopefully be satisfied!). If, on the other hand, you are non-specific, you are bound to be very disappointed when you attempt to use the data for a derived use and find it inadequate.

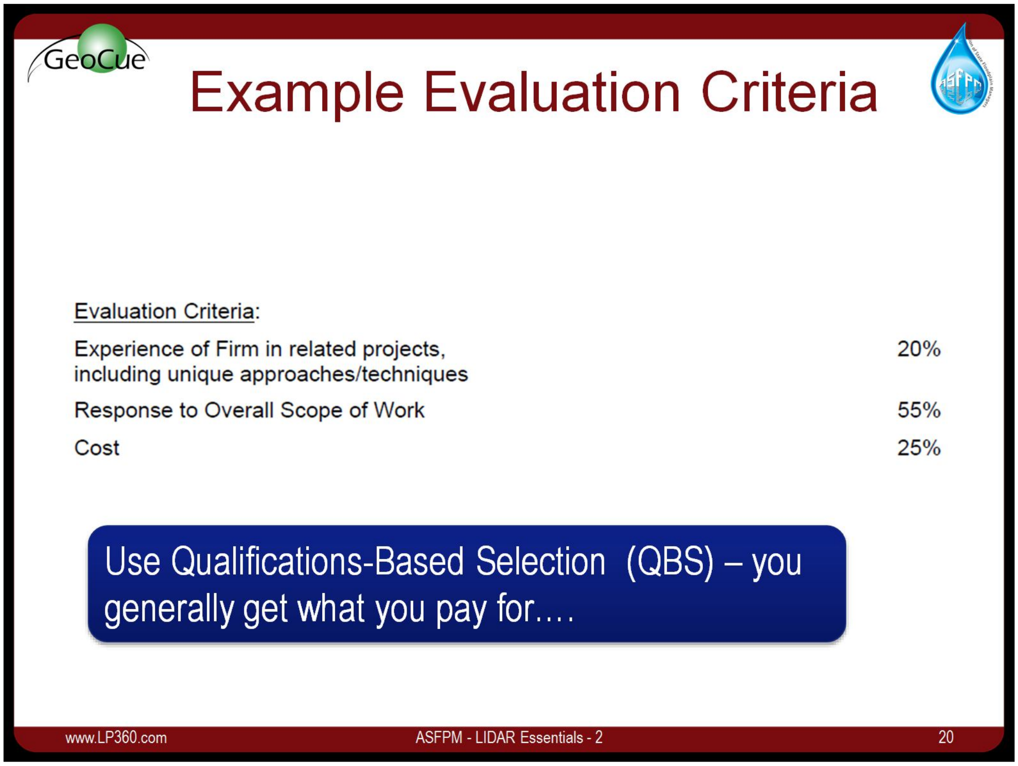


Some attributes of a product specification are, when increased, more expensive than others.

Network (or absolute) accuracy) can be a major cost driver. For example, specifying 8 cm vertical accuracy will be considerably more expensive than 20 cm.

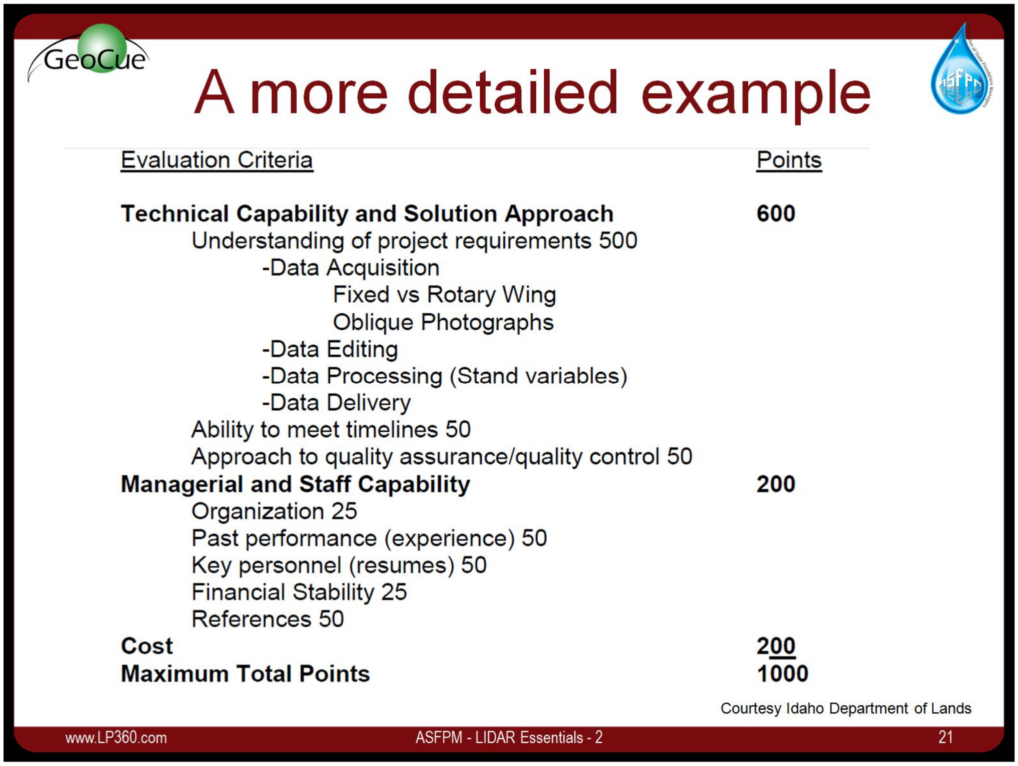
Local accuracy, on the other hand, is a much less expensive attribute than Network. Though I currently seldom see local accuracy specified in collects aimed at general mapping, it could be considered if you have special applications in your Data Use Plan. An example of this could be local deformations in highway surfaces for runoff modeling. You can specify local vertical accuracy higher than the overall network accuracy without significantly impacting project cost.

Data Density (or, equivalently, Nominal Point Spacing, NPS) used to be a major cost driver in LIDAR projects. Higher density meant lower flying heights and/or more flight lines. This not only increased the acquisition cost of the collector but also results in more complex geometric correction scenarios (simply more flight lines that have to be geometrically corrected). However, modern LIDAR system now offer very high pulse repetition rates (PRR). For example, the Hexagon (Leica Geosystems) ALS-70 LIDAR system has a PRR of 500,000 pulses per second. These dramatically increasing PRRs mean that contractors can collect significantly more points per square meter under the same flying parameters as were used for lower densities only a few years ago. LIDAR point density is an extremely important parameter and should be specified for each desirement in your Data Use Plan. You then select the highest density needed (or that you can afford). One of the major considerations for high density is the ability to accurately delineate water-land boundaries. The horizontal accuracy of this delineation can be no greater than twice the NPS. For example, if your LIDAR data have an NPS of 0.7 meters, the



Qualifications-Based Selection (QBS) basically means that you're primary selection criteria is not cost but rather the probability that the bidder will satisfy your requirements.

Cost is generally a poor indicator, when taken alone. For example, the most incapable vendor may be at the low end of the cost spectrum (which could mean a much lower degree of interactive editing or simply "buying their way in") or at the very high end of the cost spectrum (very inexperienced with LIDAR data processing and hence the cost is heavily padded with contingencies).



We think it is good practice to evaluate responses to RFPs in several phases. The consideration of cost should be one of the final phases of the evaluation. No matter how low the offered price, you will be a very unhappy customer if the winner bidder just does not have the wherewithal to perform the project to your requirements. Thus it is good practice to always have bidders submit cost as a completely separate volume from technical & experience.

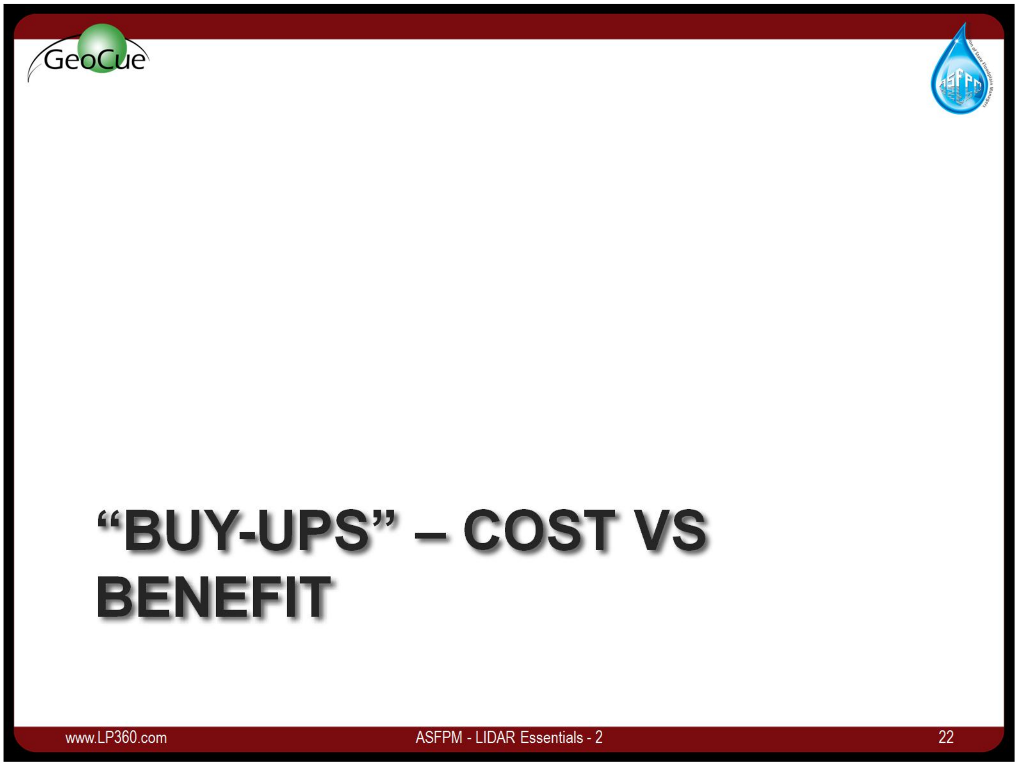
My own recommendation is:

Have the bidders submit a three volume proposal – Project Plan/Experience, Technical, Cost. These volumes contain:

Project Plan/Experience – How the project will be carried out with references to prior projects/experience. For example, I would look for weather contingency planning with references to prior projects, what went wrong/right with those prior projects and how these lesson learned will be applied to your project. Look also for the collaboration inclinations of the bidder. Do they plan to have you in an incremental delivery loop where you can evaluate results early and often?

Technical – How will this project be technically executed? I would want to see the equipment, the plans for achieving the requirements, the technical QC approach and so forth. If you are new to LIDAR acquisition, hire an outside advisor to assist with the evaluation. You really need to know things such as a five year old LIDAR unit with a PRR of 50 KHz is not going to give as high a data quality as a newer system.

Cost and T&Cs. – Standard cost with Terms and Conditions. This volume covers cost, payment milestones (which is, of course, a reflection of your RFP) and Terms & Conditions such as detailed Data Rights.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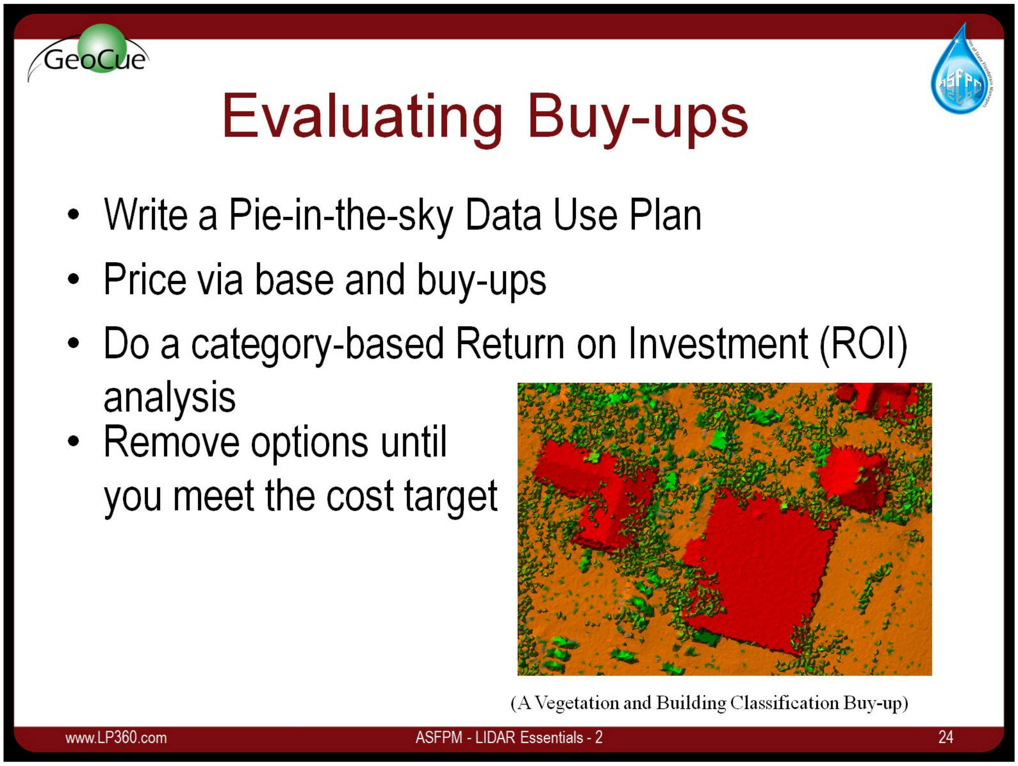
Buy-ups

- Usually occur when you are procuring data as a consortium member
  - Consortium specifies a 'base'
  - Members can select extra cost items from a buy-up menu
- Examples
  - Pay extra for 6" GSD imagery when the base is 12"
  - Pay for hydro-flattening in a LIDAR acquisition



Your Data Use Plan should include everything that you could achieve with LIDAR data (that would be useful, of course) without regard to the cost (the so-called “pie in the sky” model).

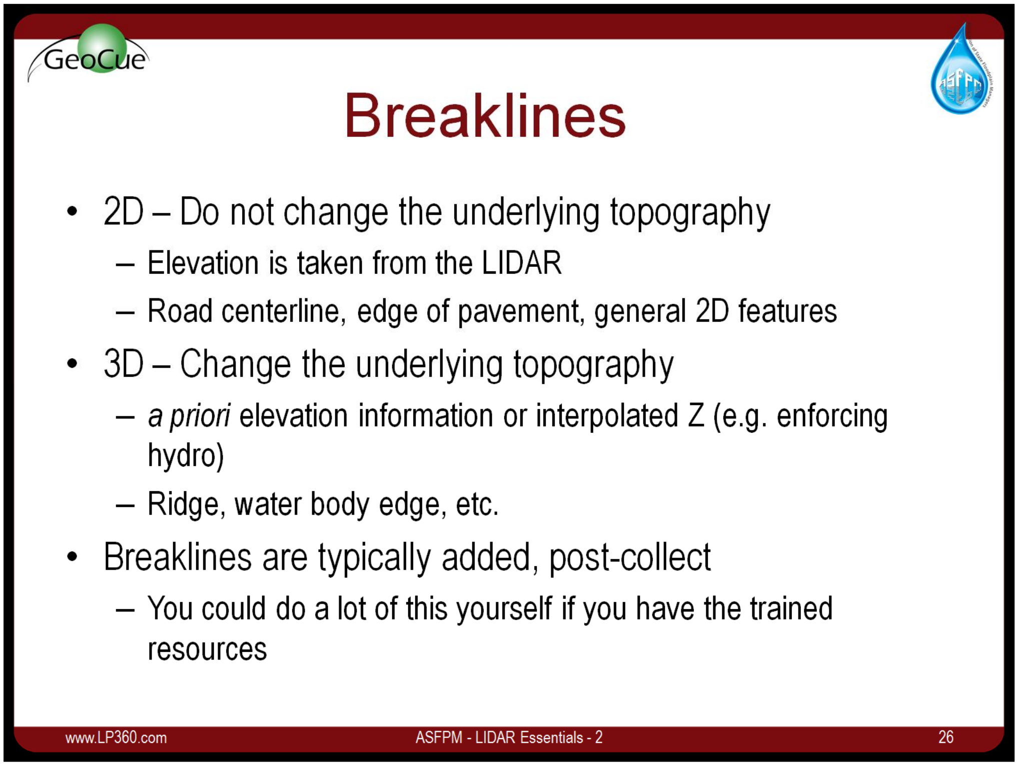
You should try to prioritize the list.

Apply a Return on Investment (ROI) to each item in your Data Use Plan. For example, if you have breaklines in your list (e.g. water body flattening), consider how this would be otherwise accomplished. Compute the cost of the alternative method. This then becomes your ROI for that item.

Be very careful of the cross-correlation of data. For example, water body flattening is highly correlated with down-stream constraints. If, for example, you elected water body flattening but omitted down-stream constraints, you may find vertical errors in the flat water body elevations that make the down-stream constraint inconsistent (e. g. body A and body B collected at the same Z but, in reality, A flows in to B).

Sadly, at the end of the data, your budget rears its ugly head. Thus you will have to trim, based on priority, until you meet the budget.

BREAKLINE CONSIDERATIONS



Breaklines are essential for hydro modeling. There is an assumption that the "LIDAR data are correct", meaning these actual measurements from the laser pulses will provide the most accurate ground model. While this is generally true, some complicating factors enter the picture:

The data density (or, equivalently, Nominal Point Spacing) has a profound impact on the resolution of the water-land interfaces. Low density data will require supplemental data to accuracy define this boundary.

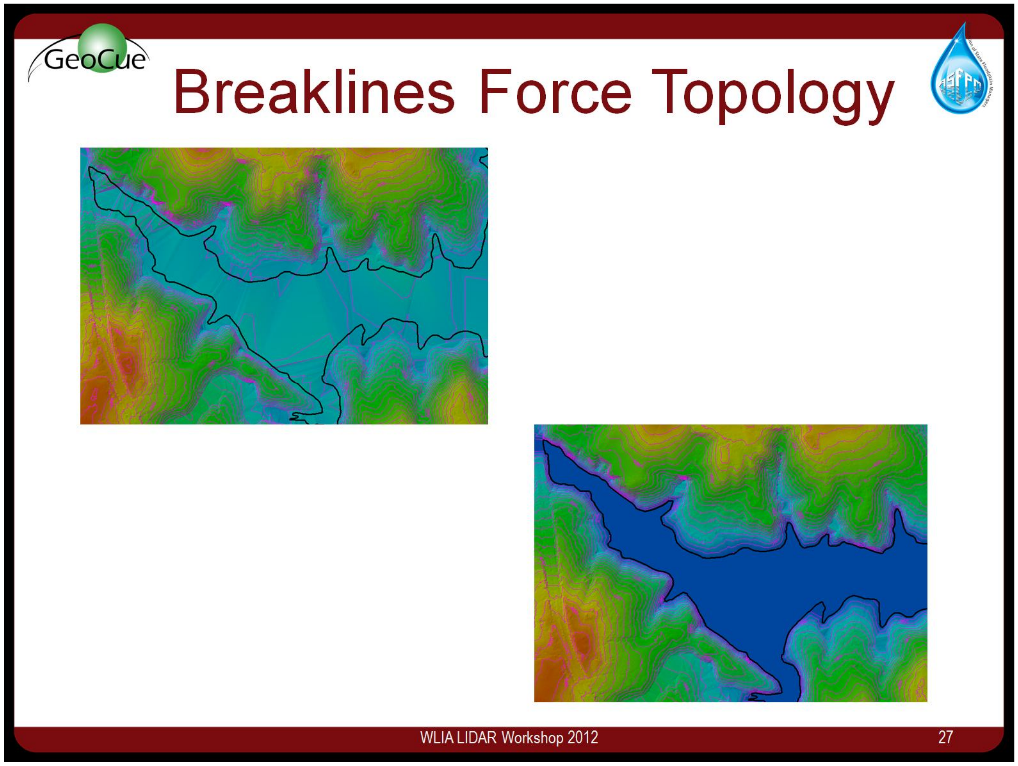
Land-water boundaries are often covered in heavy vegetation. This causes vertical inaccuracies in the LIDAR points at the land-water boundaries (last return reflected from vegetation).

Dry drainage contains a lot of noise creating features (rocks, vegetation and so forth). Additionally, the LIDAR data will not be uniformly aligned with the thalweg. This means that the thalweg will not be monotonically decreasing (flowing down hill).

Wet drainage does not allow the thalweg to be directly imaged by the LIDAR (the laser can be absorbed or mirror reflected away from the receiver). Typically water containing bodies show up mostly as voids in LIDAR data.

Some applications require double line drain modeling (river "flattening").

Proper breakline modeling is an intricate and time consuming process. While it certainly can be performed by your own staff, post-delivery, the complexity must

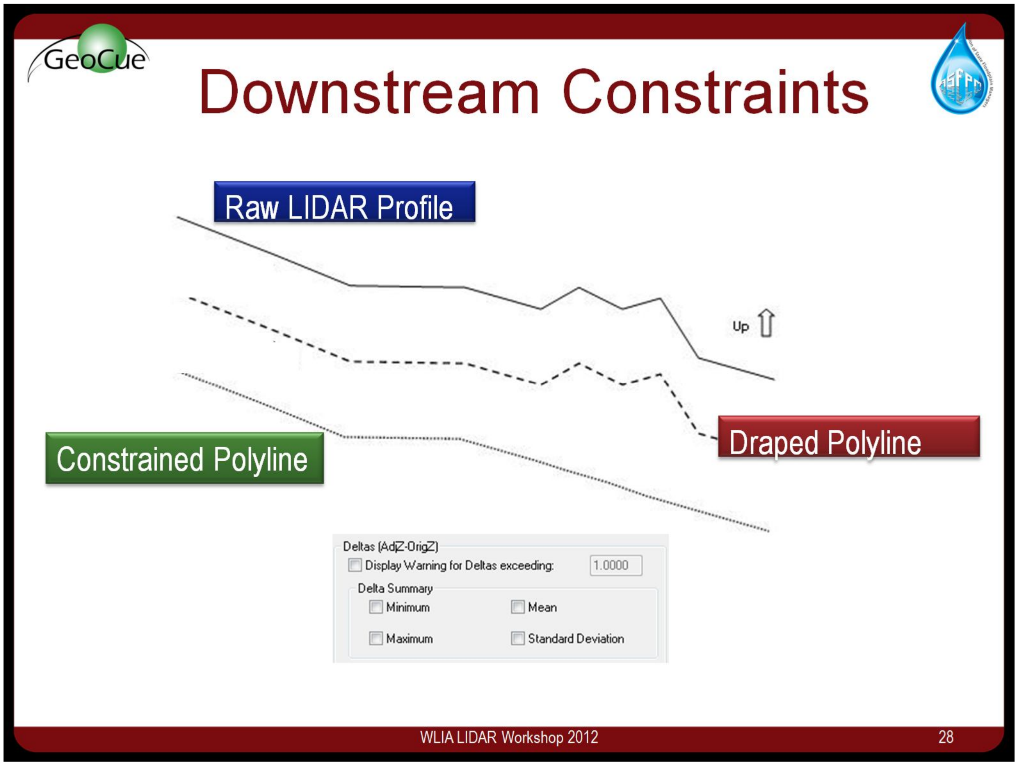


Here is an example of very accurate LIDAR data yet a water body problem exists.

Note (upper left) that the water body is not flat. This is evidenced by the contours crossing a demarcation of constant elevation (the black boundary).

In the lower right, this demarcation ("breakline") is enforced, causing contours to stop at the interface line and the water body to be "flat."

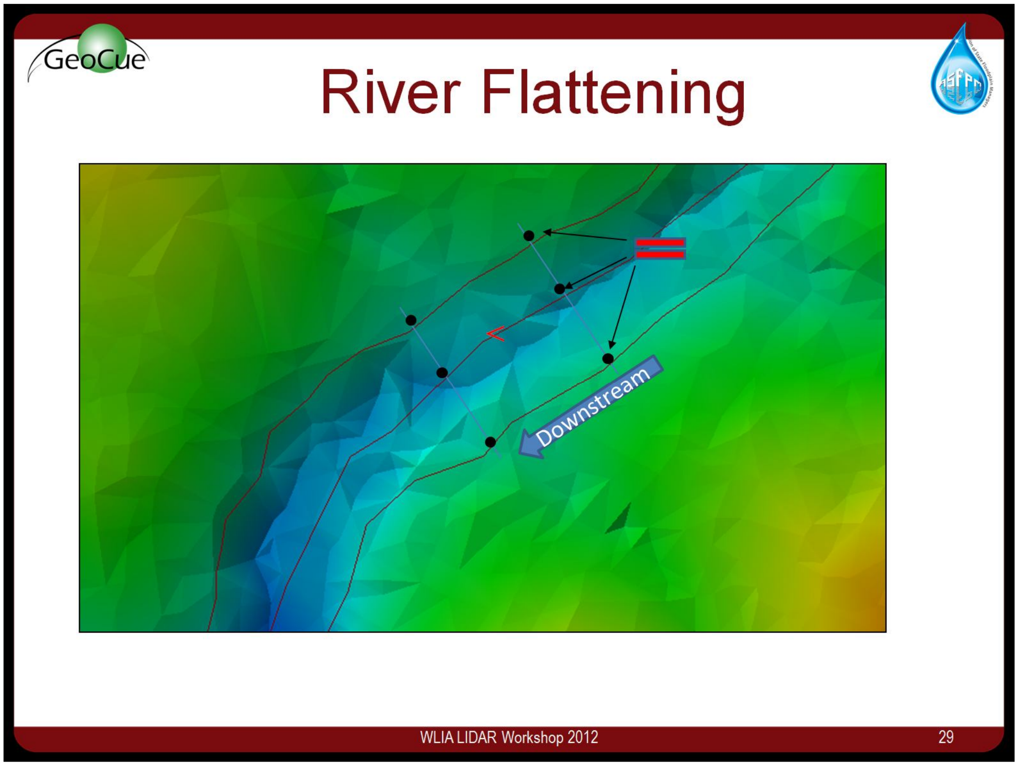
It should be noted that breaklines typically are not used to modify the LIDAR data itself but rather are incorporated in derived products such as the generated DEM.



This diagram shows a typical LIDAR profile for a thalweg. Note that it is not monotonically decreasing as would be the case for a true model.

This is corrected by:

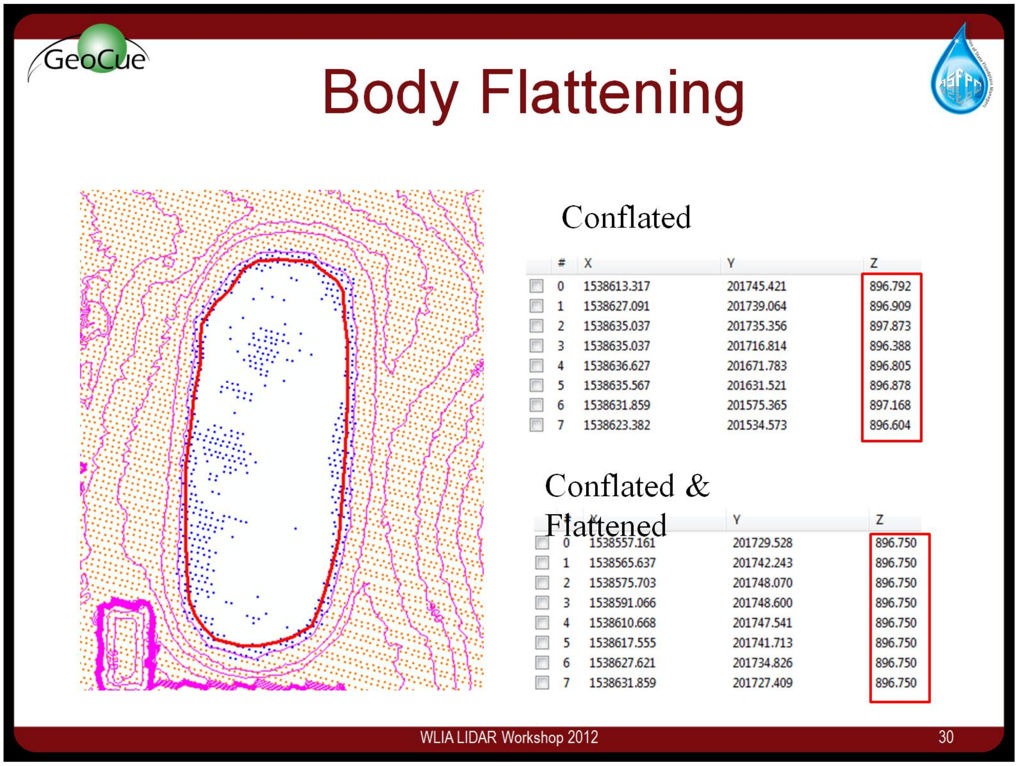
- Creating a stream centerline feature that follows the thalweg (which is often an educated guess)
- Attributing the vertical from the LIDAR data
- Applying a monotonic decreasing constraint on the vertical with a maximum error threshold



River flattening is similar to a downstream constraint with the additional requirement that the water-land elevation be the same at points “directly across the river from one another.”

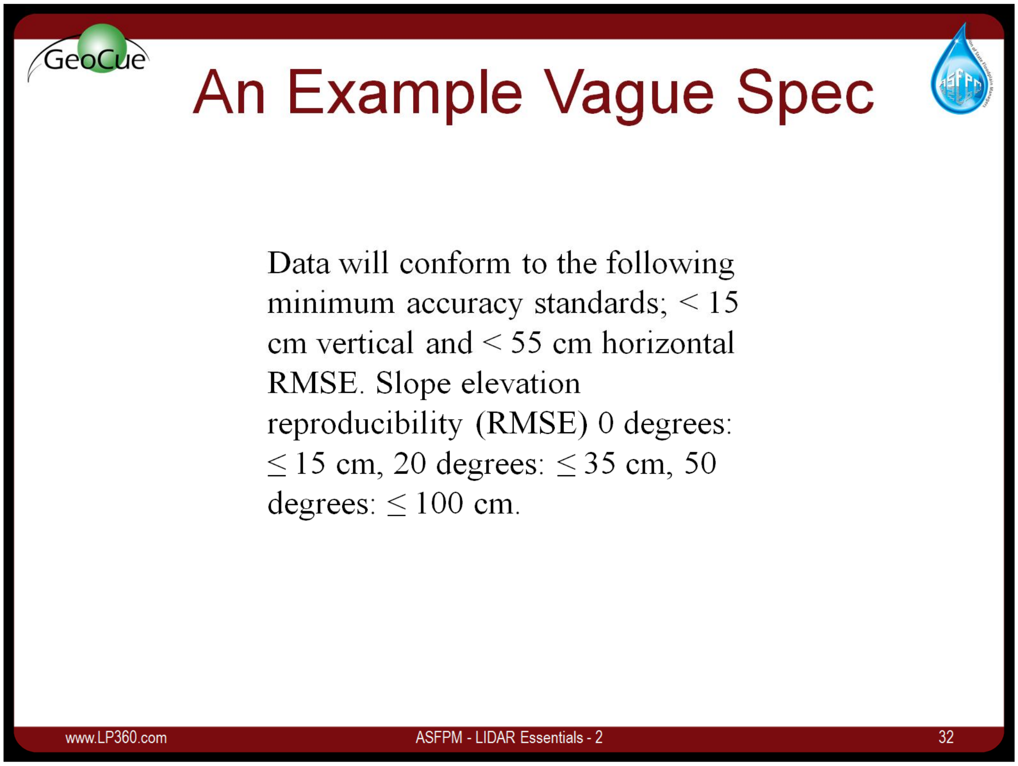
Collecting the edge of the bank can be quite challenging since it is being visualized in somewhat sparse LIDAR point data. We address this issue in LP360 by providing a profile collection view synchronized with the top view. Delineating the edge of bank in a vertical profile is typically much less ambiguous than the top (plan) view.

Obviously this last condition is often ambiguous.



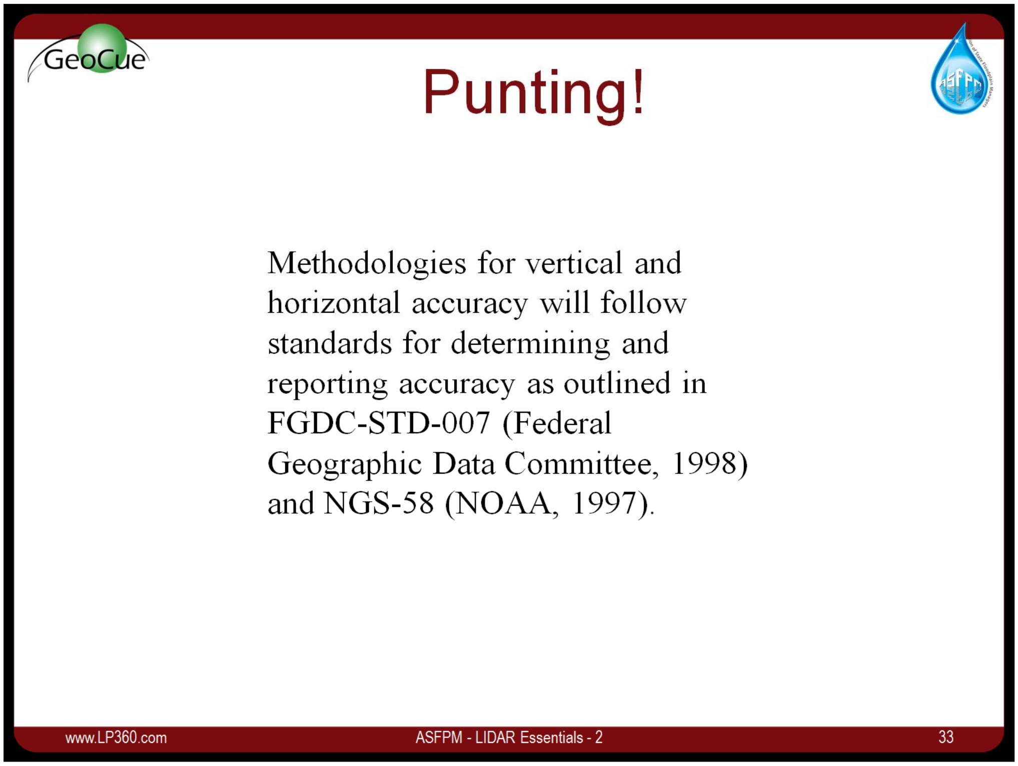
Water body flattening simply says still water must all be at the same elevation. As with all breakline applications, the exact placement of the land-water boundary can be quite ambiguous. If it is critical that this be correct (or if the banks are very steep), supplemental information from water gauges or field survey data must be introduced.

SPECIFYING DATA ACCURACY



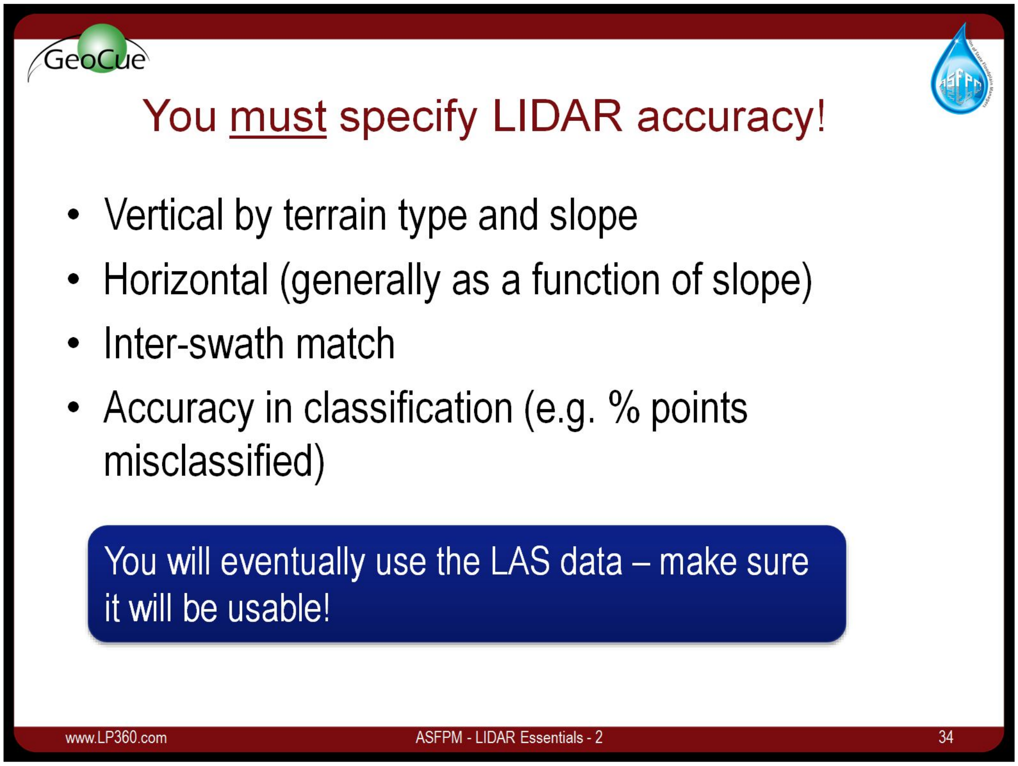
This specification does not contain vital information such as how many check points will be used, where they will be placed and so forth.

It also does not make a distinction based on surface type such as hard surface versus vegetation.



This specification did not try to quantify at all! It simply refers the bidder to external specifications (some of which are out of date).

I am not sure where the person constructing this RFP obtained these references. However, the RFP from which they were extracted was for a standard bare earth LIDAR data collect. Unfortunately, these specification are for bathymetric and harbor elevation modeling!



I think the best reference work for broad area elevation modeling is the USGS "LIDAR Base Specification , Version 1." This document has become a reference document for the FEMA LIDAR specification.

http://pubs.er.usgs.gov/publication/tm11B3

GeoCue

Classification Accuracy

A Classification “Confusion” Matrix

		Ground Truth				
		B	V	C	G	Total
Classified Data	B	**16326**	2178	224	1486	20214
	V	1709	**24635**	62	1535	27941
	C	111	252	**263**	327	953
	G	667	4827	257	**20257**	26008
	Total	18813	31892	806	23605	**75116**

B = Building
V = Vegetation
C = Car
G = Ground

(misclassified Ground and Building

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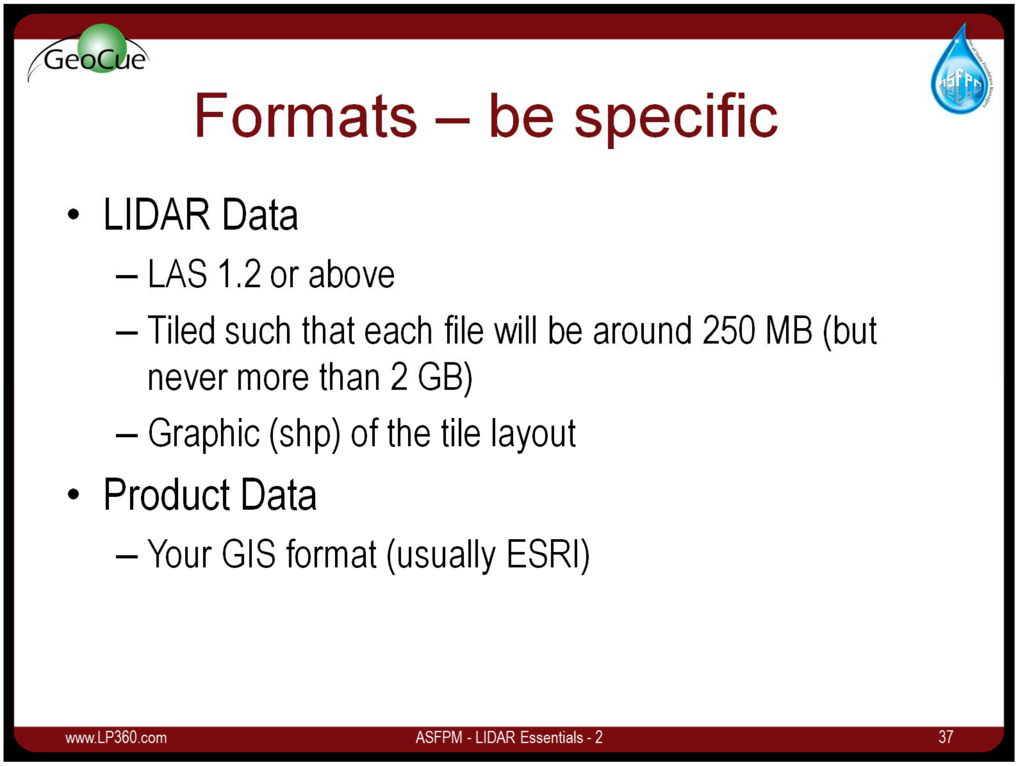
A Confusion Matrix is used to tabulate the accuracy of classification. Typically, classification accuracy is specified as errors of omission (should be in the class but is not) and commission (should not be in the class but is).

Usually the concern with ground class centers on two issues:

1) Having sufficient points in the ground class to meet the project density (or Nominal Point Spacing, NPS) requirements. Thus you do not really care if a large number of points that should be in the ground class are left in the “unclassified” state so long as the project density for the ground class is uniformly maintained throughout the project. Obviously if this ratio is high, the collection density will have to be significantly higher than the ground classification specified density.
2) Having a very low number of non-ground points in the ground class. Building, vegetation and other non-ground points classified as ground will cause significant errors in the derived elevation models. Additionally, these errors will cause major issues if you attempt to do value add data extraction such as building footprints.

SPECIFYING FORMATS AND MEDIA



You should be very specific in data formats. If not, you could end up with proprietary data that will not be useable. Remember that content and format are two different things and must be separately specified. For example:

"LAS 1.2, Point Record Data Format 2" is the format.

"The LAS data shall include:

GPS Time Stamp

16 bit intensity

A minimum of 3 returns

…."

is the content

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DATA RIGHTS

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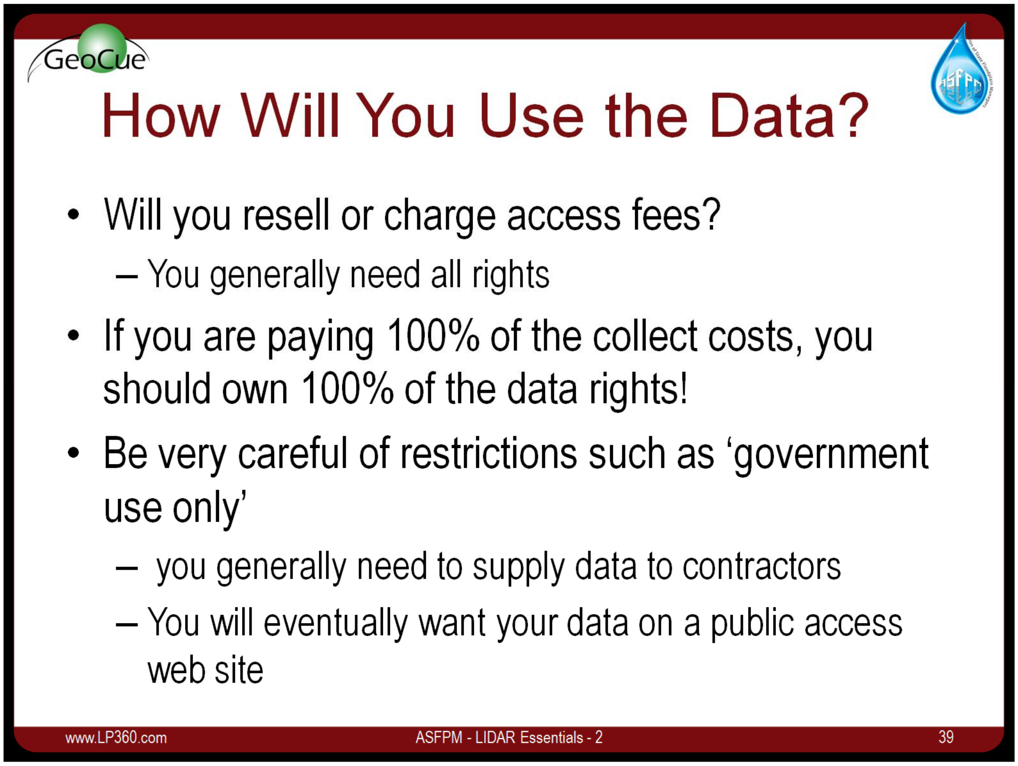


I explicitly avoid taking a position of the "openness" of the data. This is both a function of your intended distribution model as well as pass-down restrictions from the data sources. For example, if you allow augmentation of old elevation data (some prior collect, etc.) then that pre-existing data may have some data restrictions.

Municipalities that acquire LIDAR data sometimes entertain restrictive rights in order to reduce cost. For example, a vendor may offer a big discount for impervious surface classification in exchange for restricted data rights (the municipality has unlimited internal use but the contractor gets to sell the data to outside engineering firms, …)

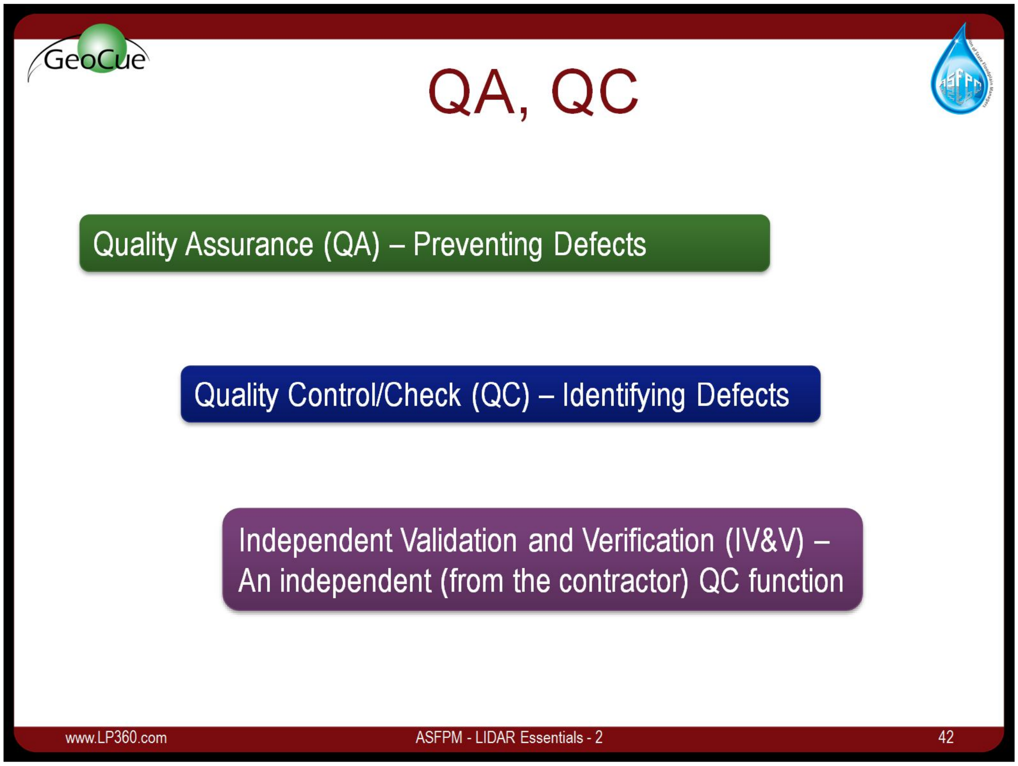
Your Data Use Plan needs to carefully designate each stakeholder for each category of product. It then needs to specify the intended conveyance model for each of these categories (free and unrestricted, free but restricted, licensed and so on). This, in turn, will drive your data rights requirements.

Whatever you do, make very sure these requirements are very carefully spelled out in the RFP and that the RFP requires an executed data rights document as a deliverable.

Example

"All data products must be offered as co-owned or owned outright by Milwaukee County such
that they may be distributed by the owner(s) within the public domain without restriction." – Milwaukee County LIDAR RFP

MONITORING PROJECTS

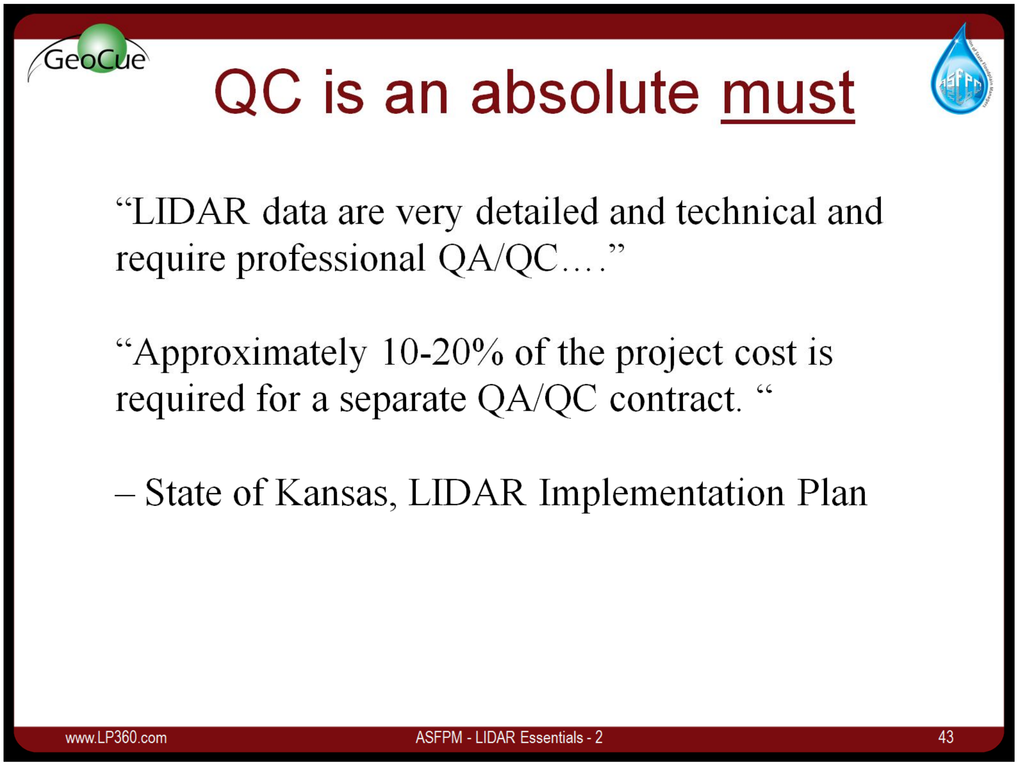


Quality Assurance (QA) is a role of the contractor. It comprises the systems that are in place to identify and correct problems prior to the data being delivered to the customer. It should involve both internal Quality Checks (QC) and feed-in from external QC. It is an integral part of a contractor's continuous improvement process.

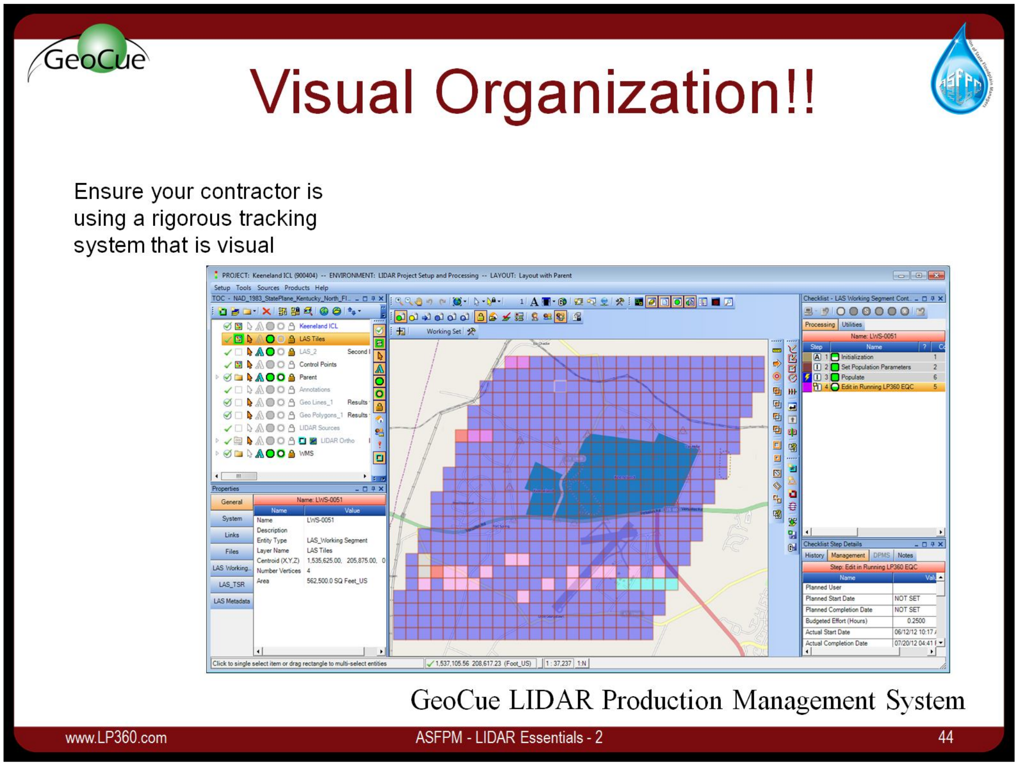
Quality Checks are the inspection of results to ensure the QA system works! Continuous QC is an absolute must. The contractor must perform internal QC, of course, to ensure that his QA processes are working. However, an independent QC function must be in place for all contracts. Unless you have a skilled staff with the appropriate tools, you must budget for an external and independent QC contractor. That said, if you have a competent GIS staff, they can be easily trained to supervise and perform QC. We have seen a number of very successful projects where the in-house GIS team supervised QC of LIDAR data and the actual QC work was performed by student interns (GeoCue offers QC training for data recipients).

If you are not capable of performing in-house QC (due to lack of staffing, lack of skills, etc.) then you must contract for Independent Validation and Verification (IV&V). This will require you to budget for and issue a separate RFP.

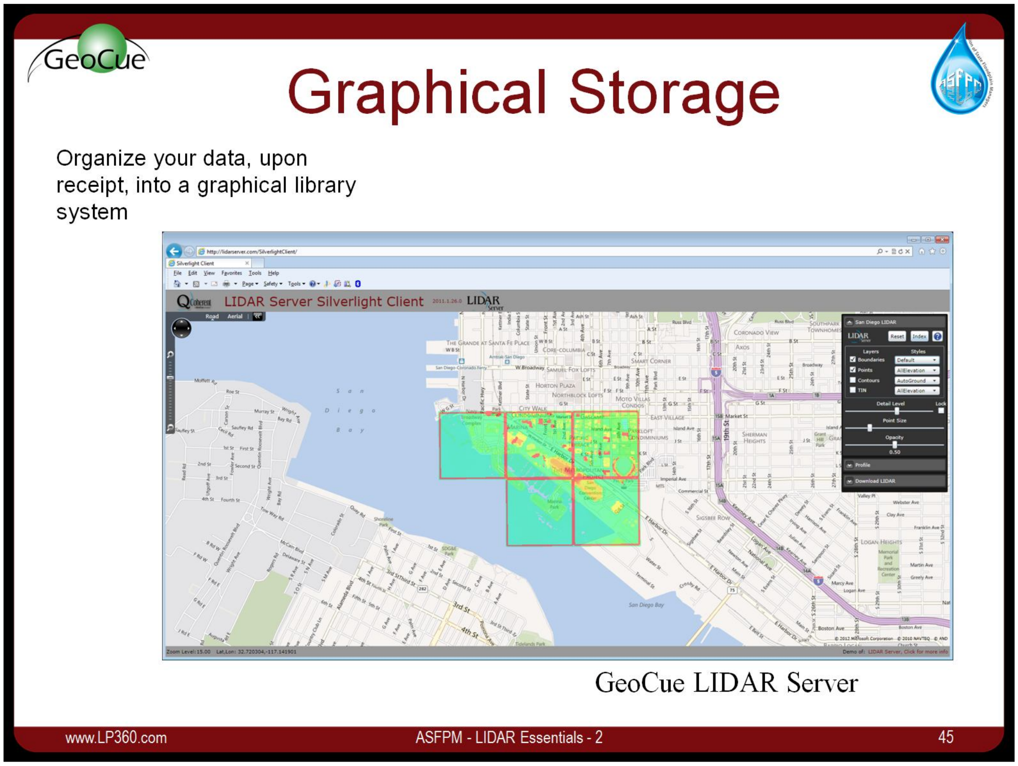
You should allocate about 15% of the total acquisition budget for basic data management and QC.



Sadly, the majority of LIDAR acquisition contracts leave the Quality Check up to the contractor.

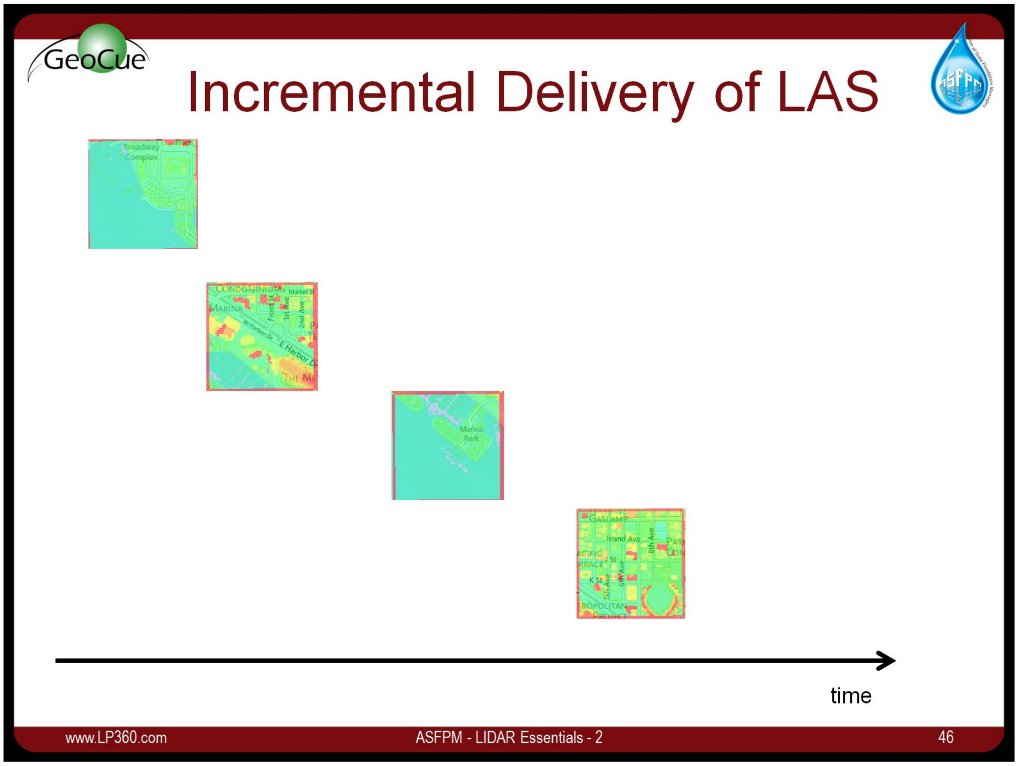


Part of the Project Management (PM) Plan that you will require the bidding contractors to submit as part of their proposal must include a rigorous data management plan. Ideally this will be an on-line system that will allow you to visualize the status of the project, on a per tile basis, in real time.



A contentious contractor might also recommend a data management system or methodology for you, the customer, if you do not already have an in-place system. The most common mistake we see is a customer accepting large quantities of tiled files on USB external drives with no process in place for visually managing the data.

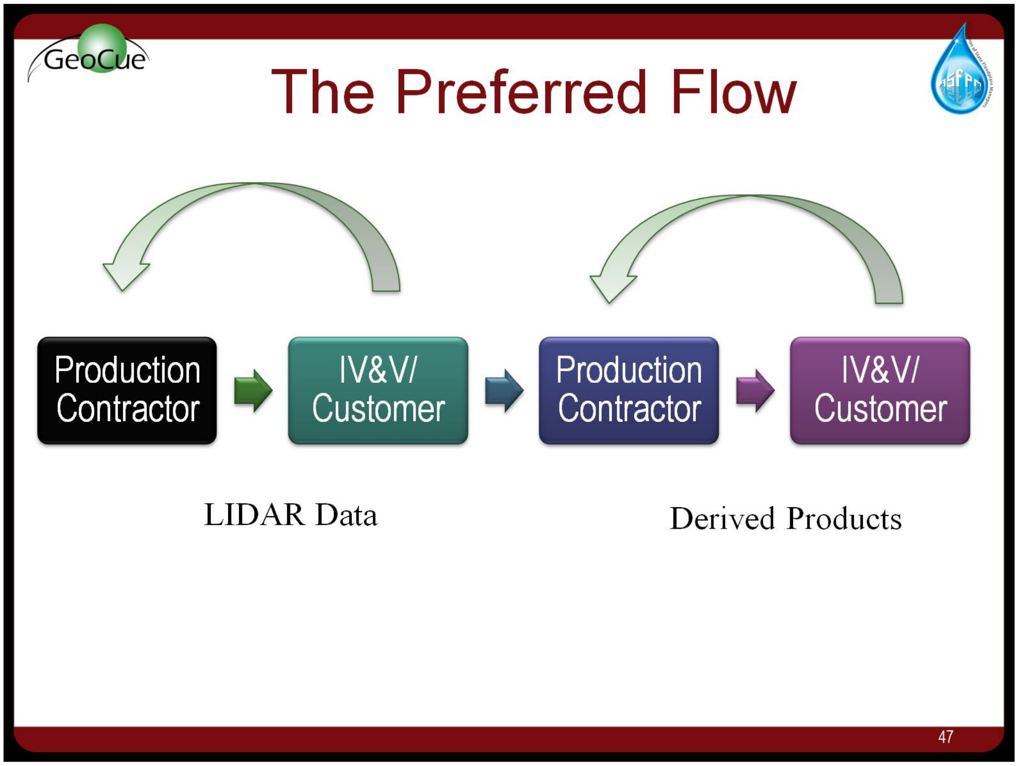
Establish a graphical LIDAR data management system that allows you to incrementally add tiles of LIDAR data to the library. Such a system will pay for itself many times over by ensuring that you have meticulously managed the QC process and by making the data readily available to stakeholders. You can quite often enlist your stakeholders to perform secondary LIDAR QC if they have easy access to the data. The advantage here is that these stakeholders usually represent a range of skills that differ from yours. The more eyes on the data, the more likely you are to have a comprehensive QC process.



Make certain that you are positioned to receive regular increments of data (of course, you must specify this in your RFP!).

You will want to do the initial QC as early in the project as you possible can. The maxim: “the cost of a problem escalates with time” is absolutely true.

I recommend that all projects include a pilot phase where a small set of data are provided for your review. These data should be representative of the most critical project areas. This will allow you to work out any issues wit the contractor prior to full scale production. The contractor will be much more amenable to process changes at this phase than after delivering most of the project tiles.



Staging data through incremental production and QA phases is the flow that results in the highest "first time success" and hence lowest rework rate.

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Useful References

- Minimum LIDAR Data Density Considerations for the Pacific Northwest
  - (http://www.oregongeology.org/sub/projects/olc/minimum-lidar-data-density.pdf)
- Lidar Base Specification Version 1.0 (USGS)
  - http://pubs.usgs.gov/tm/11b4/
- Procedure Memorandum No. 61 - Standards for Lidar and Other High Quality Digital Topography (FEMA)
  - http://www.fema.gov/library/viewRecord.do?id=4345

Thank You!

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

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