Cooperating Technical Partner (CTP) Information Exchange

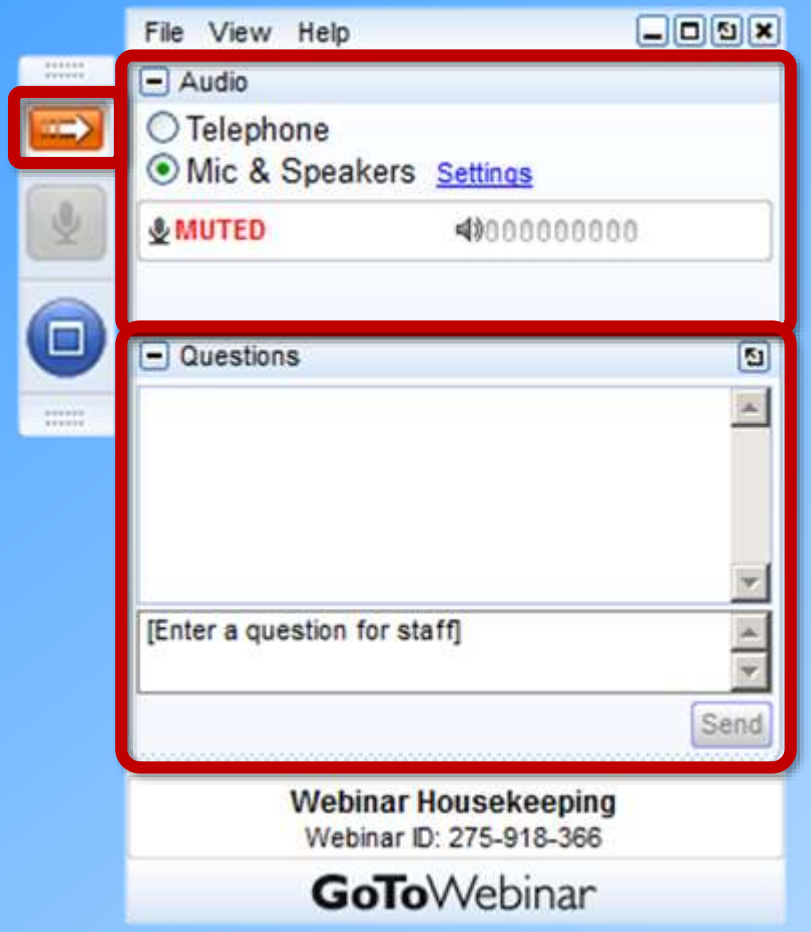
Elevation Data Collection using LiDAR

May 19, 2016
2:00-3:30 Eastern Time

Thank you for joining us today!

- ✓ Presentation will conclude by 3:30pm ET, 2:30pm CT
- ✓ Q&A will follow each speaker with additional questions at the end if there is time left

Attendee Participation



Your Participation

Open and close your control panel

Join audio:

- Choose **Mic & Speakers** to use VoIP
- Choose **Telephone** and dial using the information provided

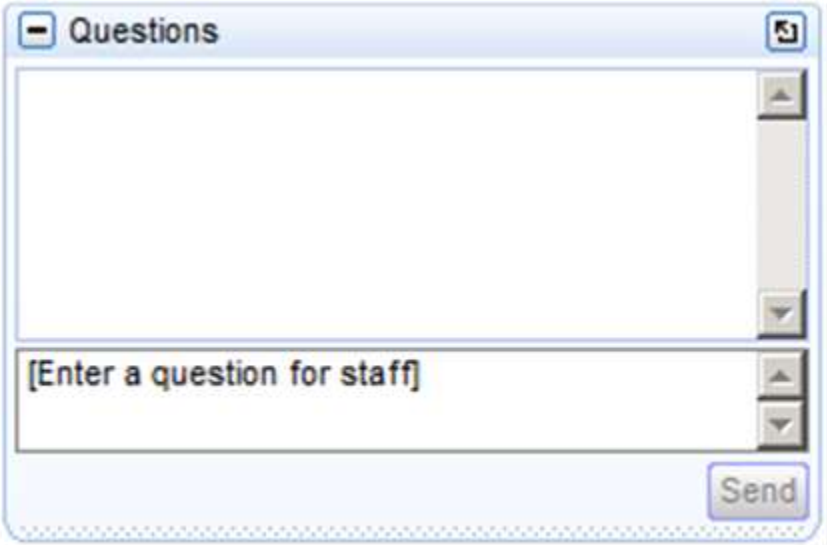
Submit questions and comments via the **Questions panel**

Audio & Web Settings

- All lines will be automatically be muted.
- Use your **Question Panel** to submit questions during the presentation. The moderator will relay questions to the speaker.
- During Q&A at the end, please submit your question using the **Question Panel**.

Chat


Where you are connecting from today?


Questions
[Enter a question for staff]
Send

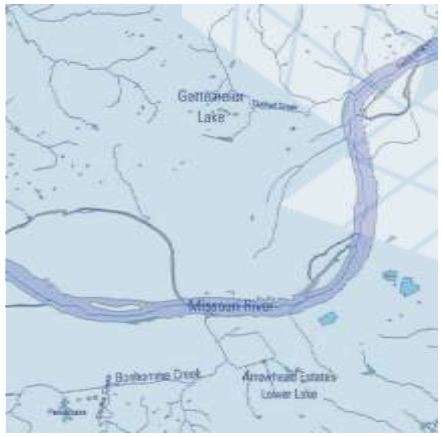
This Session is being Recorded

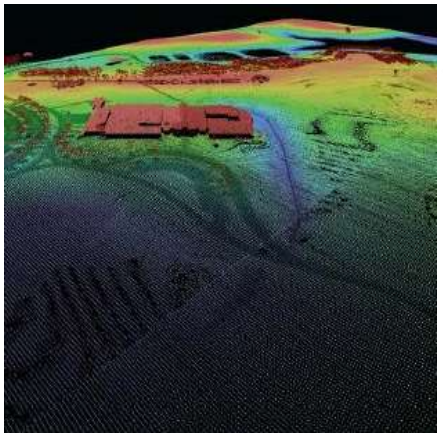
Agenda

- Webinar Logistics: Jason Hochschild - ASFPM
- Introductions: Alan Lulloff, PE, CFM – ASFPM,
  Laura Algeo – FEMA,
  Amanda Flegel, PE, CFM - Illinois State Water Survey

- USGS 3DEP Program: Diane Eldridge - USGS
- FEMA/USGS Partnership: Paul Rooney - FEMA
- LiDAR QA/QC: Lewis Graham - GeoCue Group
- LiDAR Data Storage: Dave Knipe, PE, CFM - Indiana DNR

3D Elevation Program (3DEP)





Diane Eldridge

USGS National Geospatial Program (NGP)

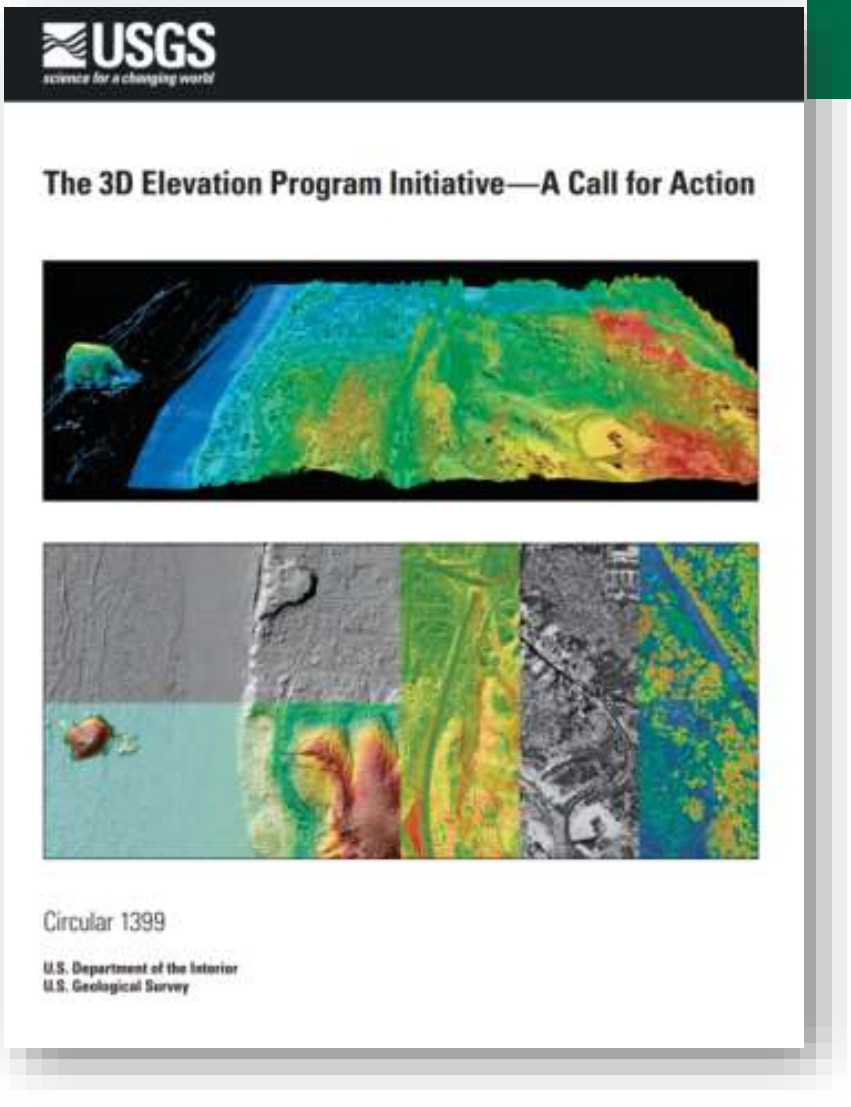
3DEP Data Acquisition Coordinator

May 18, 2016

3D Elevation Program (3DEP)

Overview

- 3DEP Overview
- 3DEP feeds The National Map
  - Elevation
  - Hydrography
- 3DEP
  - Data Acquisition
    - Specifications
    - Contracts / SOW
    - QA/QC
  - Products and Services



The National Map

Geospatial products and services support key priorities

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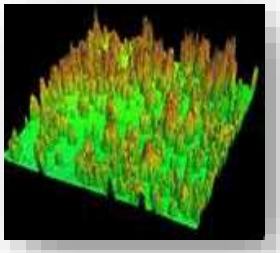
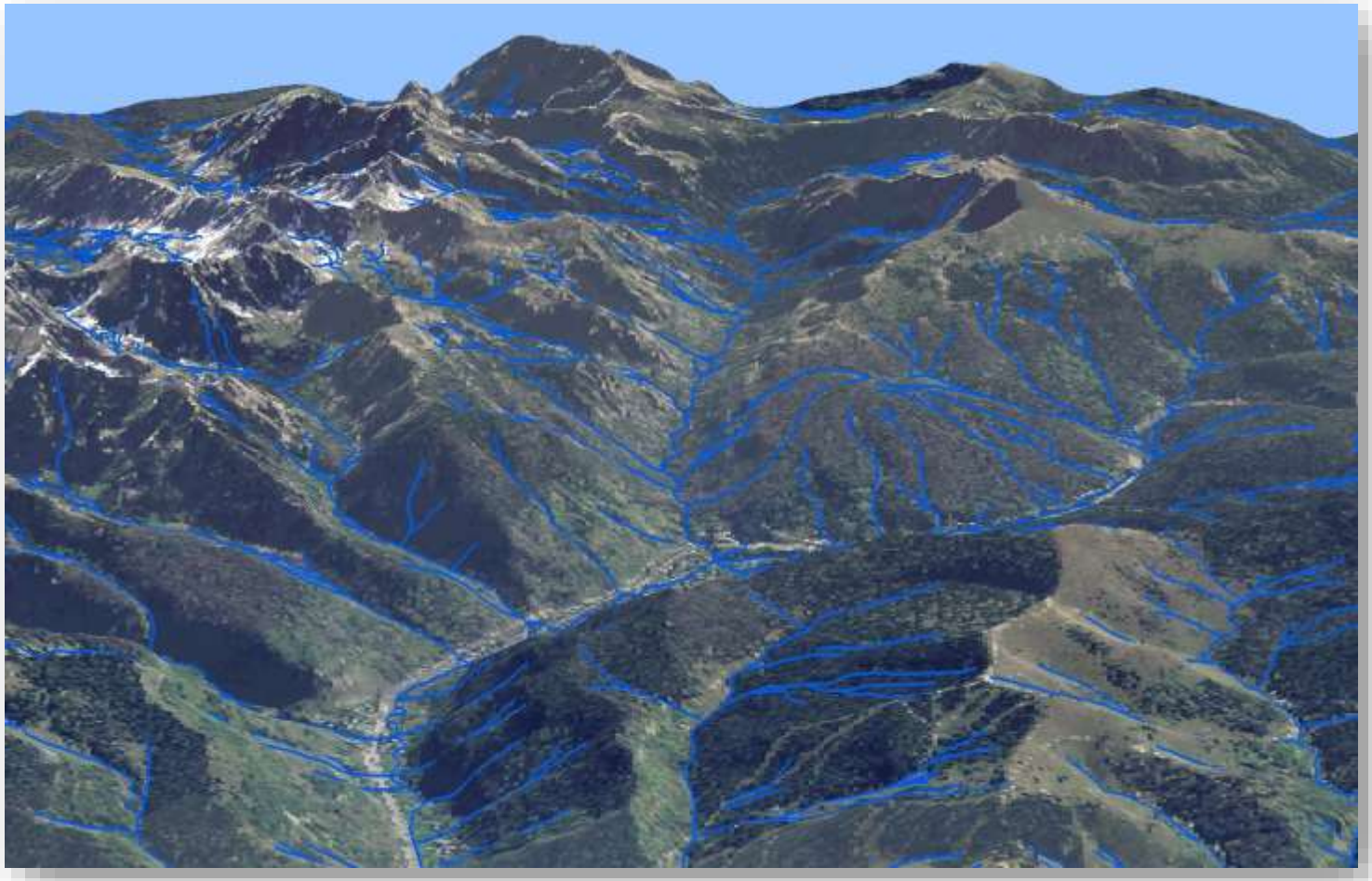


Area of National Leadership	Program Emphasis	DOI/Administration Priorities Supported
A-16 Lead for Terrestrial Elevation	3D Elevation Program (3DEP)	• Climate Resilience • Building a Landscape-Level Understanding of our Resources • Ensuring Healthy Watersheds and Sustainable, Secure Water Supplies • Powering Our Future and Responsible Use of Our Resources • Enhancing America's Great Outdoors
A-16 Co-Lead for Inland Waters	National Hydrography and Watershed Boundaries Datasets, NHD+HR and Open Water Data Initiative	
Nationwide Topographic Maps	U.S. Topo and Alaska Mapping	

Elevation and Hydrography Are Linked

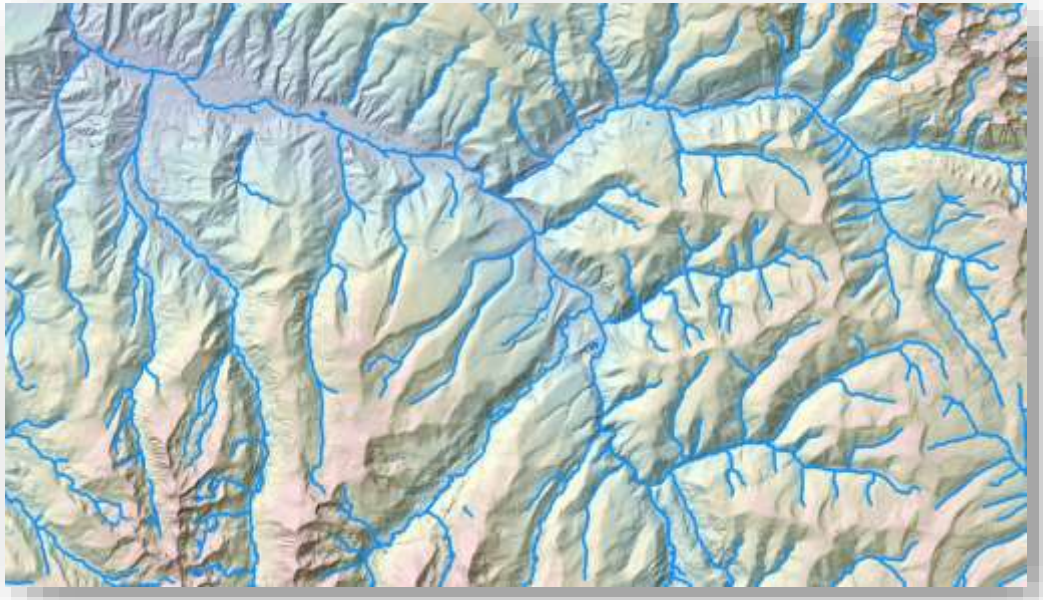
The defining features of the topography



Elevation-Hydrography Integration

What does it mean?

- The alignment of elevation and hydrography such that streams flow in channels
- Data model that links the elements
- Data that are temporally coincident



- Delivery such that the data can be accessed in unison
- Program such that elevation and hydrography can be jointly produced

Ele-Hydro Draft Timeline

Early Stages of Development and Planning

Major Actions

2016

- Establish volunteer committees
- Establish breakline committee
- Event migration for generalization capability
- NHD+HR pilot apps
- Elehydro research (Committee)
- Begin to develop integrated data model

2017

- Improve techniques for automated extraction
- Improve techniques for automated conflation/ replacement
- Develop services and staged product extractions based on data model

2018

- Produce 20% of CONUS lidar derived hydrography
- Produce 10% of CONUS lidar-derived NHD+

2019

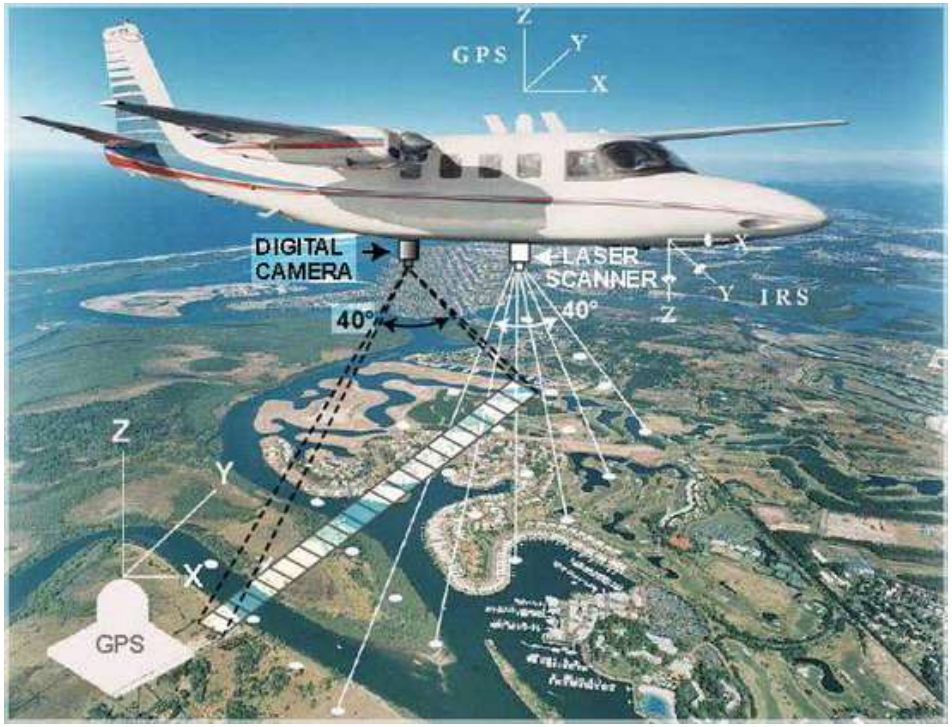
Future State

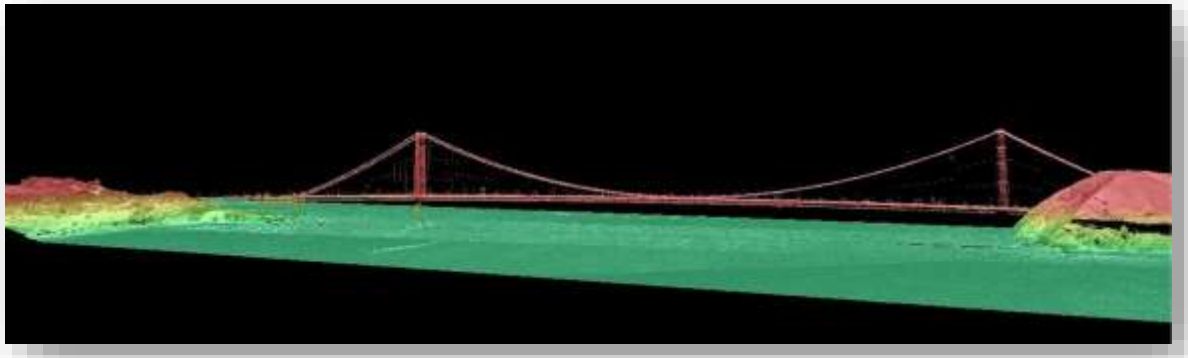
- Hydrography data are acquired from lidar source
- Integrated Z values
- Integrated data model with 3DEP
- Data model can relay hydro, 3DEP, or both
- Interoperability between NHD, WBD, 3DEP, StreamStats

FUTURE STATE

3D Elevation Program (3DEP)

- Applies ground-breaking lidar technology to acquire and distribute 3D data
- Includes surface elevations and natural and constructed features
- Increases the quality level of lidar being acquired to enable more accurate understanding, modeling, and prediction
- Addresses a broad range of critical applications of national significance





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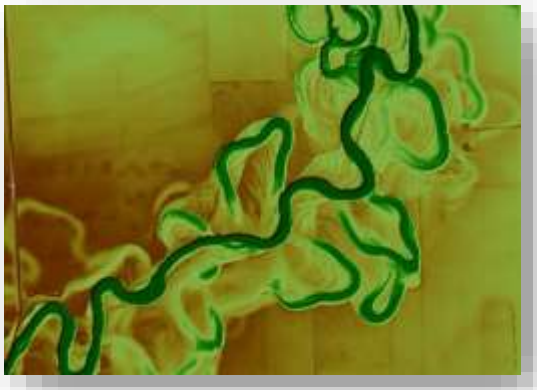
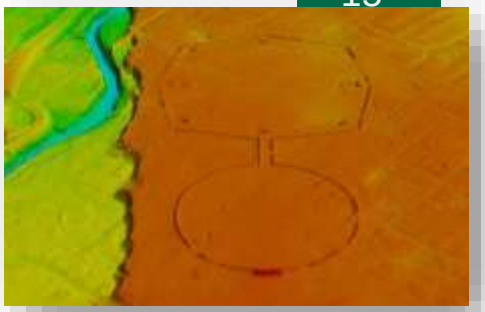
3D Elevation Program (3DEP)

Mission Critical Applications

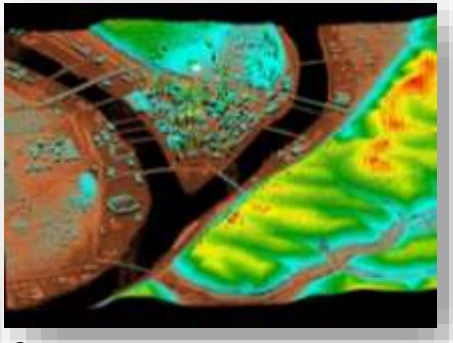


Flood Risk Management

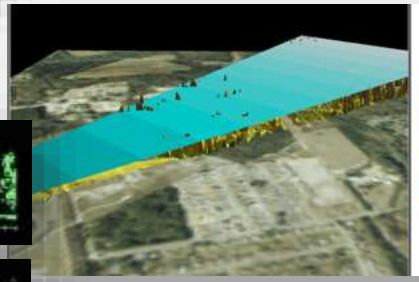
Alternative Energy

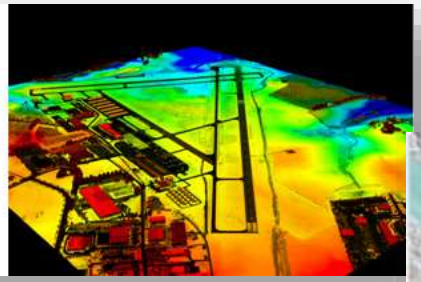


Archaeology

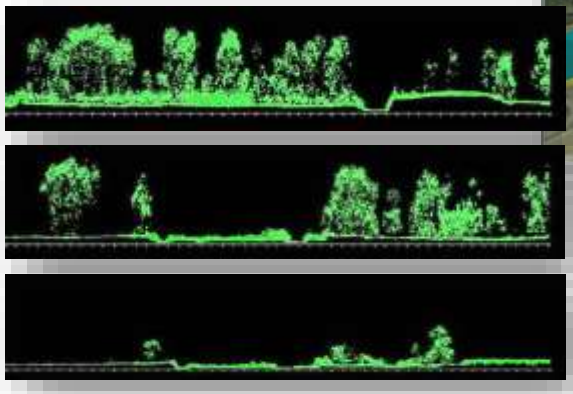


Infrastructure Management

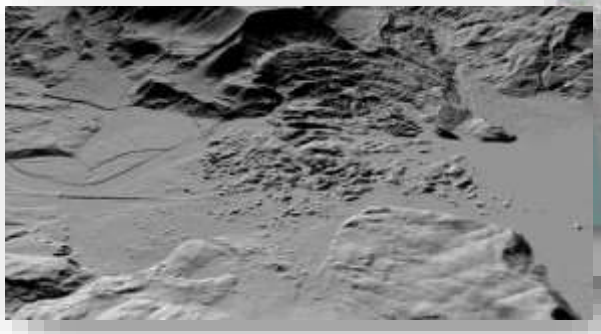


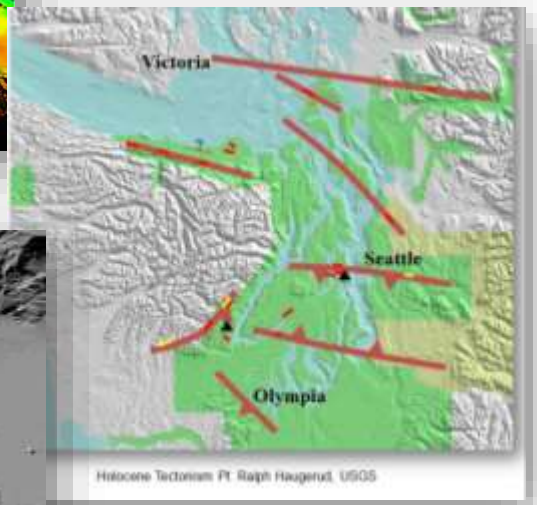


Aviation Safety



Precision Forestry





Geologic Hazards

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What is the 3D Elevation Program?

3DEP is a call for community action to…

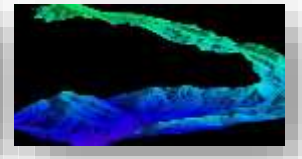
- Address the mission-critical requirements of 34 Federal agencies, 50 states, and a sampling of local governments, tribes, private and not-for profit organizations documented in the **National Enhanced Elevation Assessment**
- Return more than $690 million annually in new benefits, ROI = 5:1
- Leverage collaboration among Federal, states, local and tribal partners to systematically complete national 3D data coverage in 8 years
- Leverage the capability of private industry mapping firms, create jobs
- Achieve a 25% cost efficiency gain by collecting data in larger projects
- Completely refresh national elevation data holdings with new lidar and ifsar elevation data products and services


Natural Resource Conservation


Infrastructure Management


Flood Risk Mitigation


Precision Farming


Land Navigation and Safety


Geologic Resources and Hazards Mitigation

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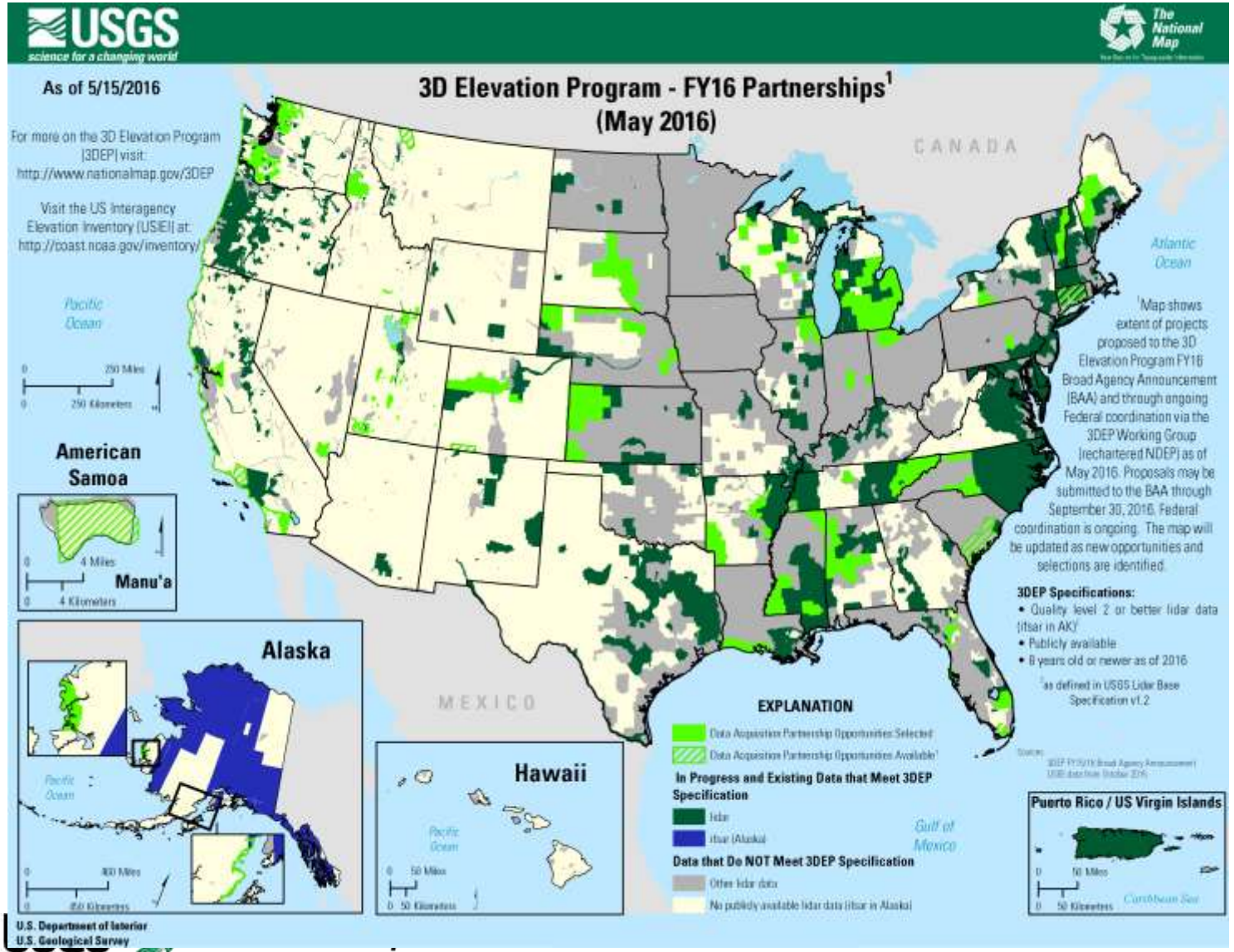
3DEP Status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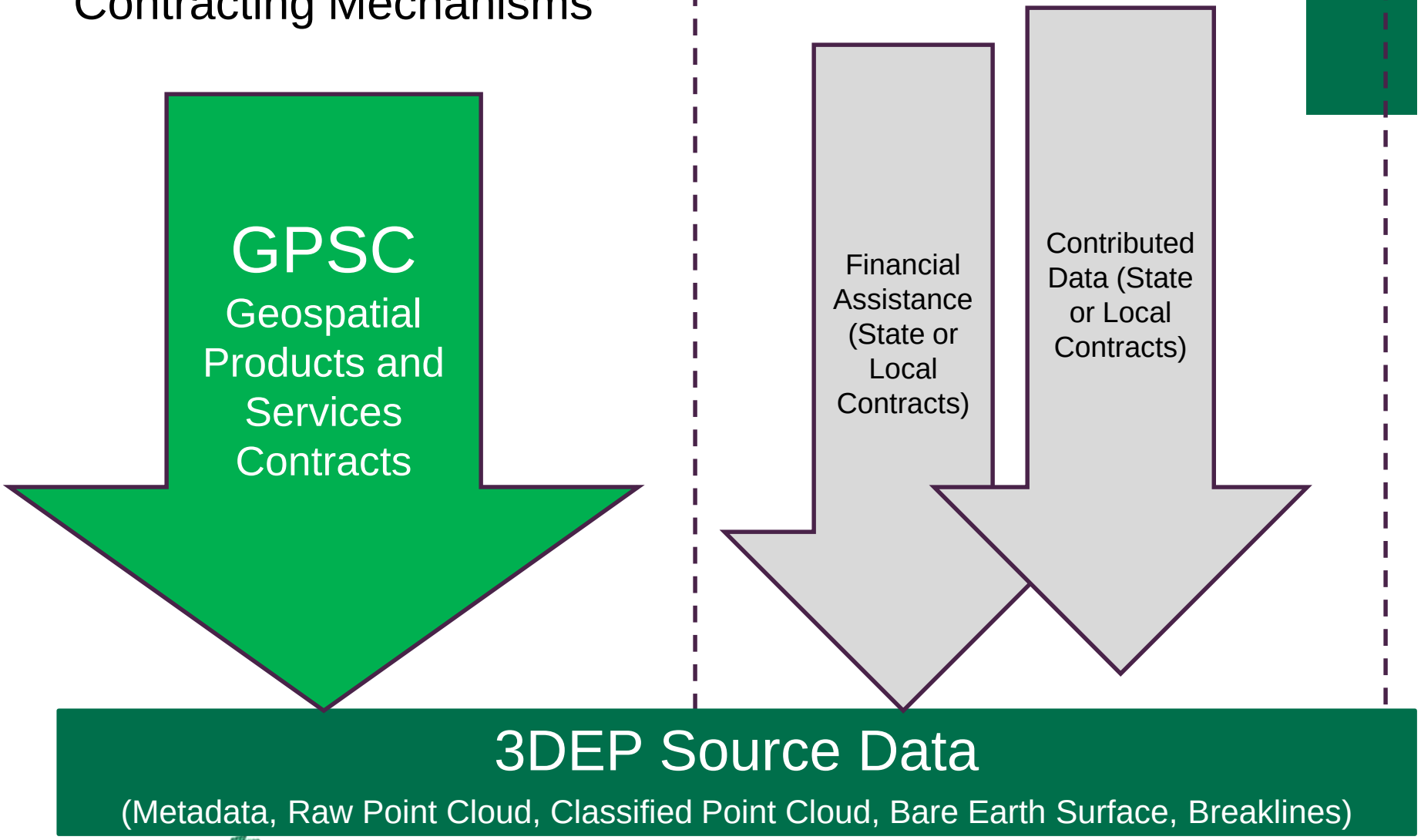
The National Map
As of 5/15/2016
3D Elevation Program - FY16 Partnerships[1]
(May 2016)
For more on the 3D Elevation Program (3DEP) visit: http://www.nationalmap.gov/3DEP
Visit the US Interagency Elevation Inventory (USIEI) at: http://coast.noaa.gov/inventory/
CANADA
Pacific Ocean
Atlantic Ocean
MEXICO
Gulf of Mexico
Caribbean Sea
American Samoa
Manu'a
Alaska
Hawaii
Puerto Rico / US Virgin Islands
[1]Map shows extent of projects proposed to the 3D Elevation Program FY16 Broad Agency Announcement (BAA) and through ongoing Federal coordination via the 3DEP Working Group (rechartered NDEP) as of May 2016. Proposals may be submitted to the BAA through September 30, 2016. Federal coordination is ongoing. The map will be updated as new opportunities and selections are identified.
3DEP Specifications:
• Quality level 2 or better lidar data (ifsar in AK)
• Publicly available
• 8 years old or newer as of 2016
[1]as defined in USGS Lidar Base Specification v1.2
EXPLANATION
Data Acquisition Partnership Opportunities Selected
Data Acquisition Partnership Opportunities Available[1]
In Progress and Existing Data that Meet 3DEP Specification
lidar
ifsar (Alaska)
Data that Do NOT Meet 3DEP Specification
Other lidar data
No publicly available lidar data (ifsar in Alaska)

3DEP Data Acquisition

Contracting Mechanisms



3DEP Data Acquisition $

Partnership Opportunities

GPSC
Geospatial Products and Services Contracts
USGS Manages Acquisition
Partner funds to USGS

Financial Assistance (State or Local Contracts)
Partner Manages Acquisition
3DEP Funds to Partner

Contributed Data (State or Local Contracts)

Broad Agency Announcement (BAA)

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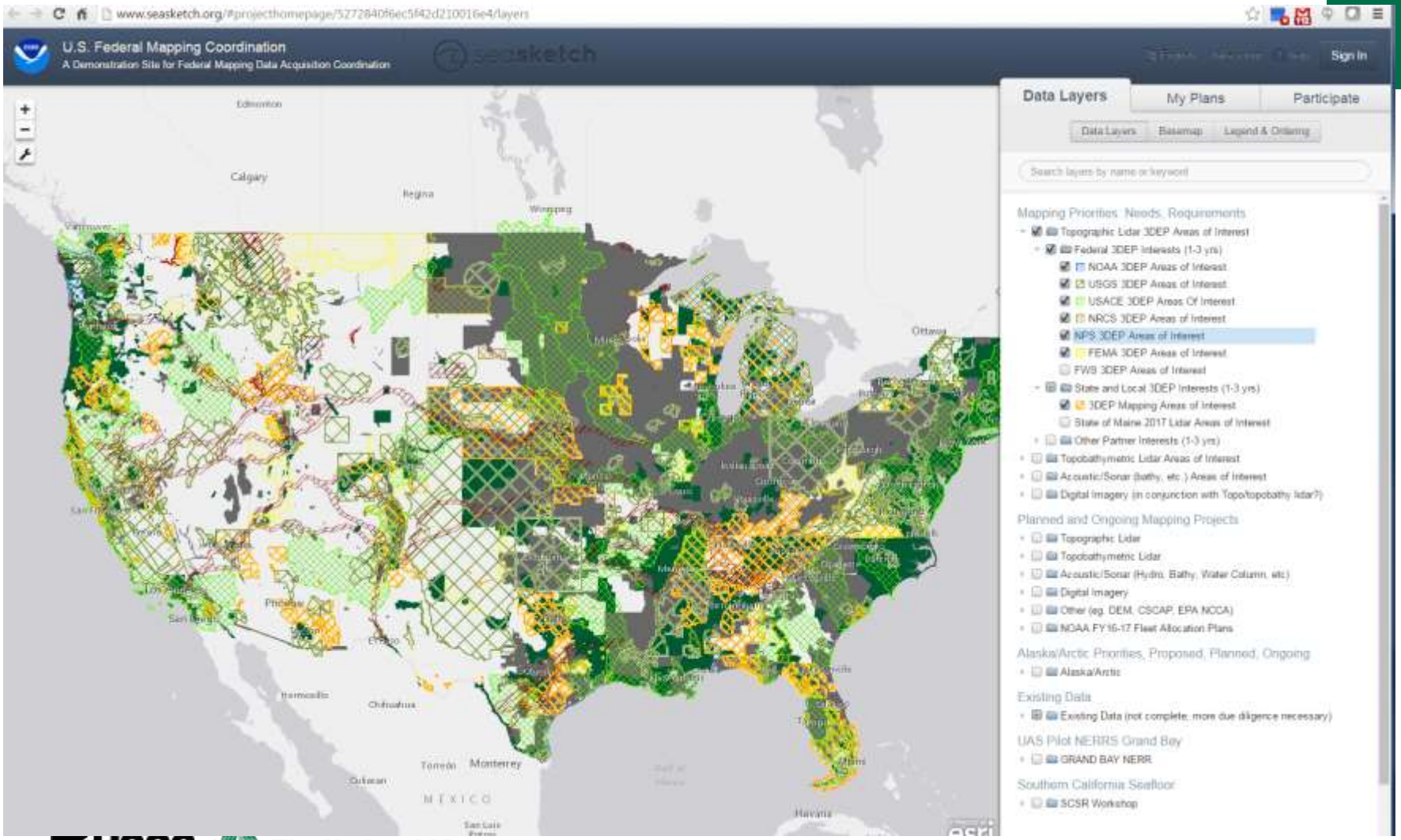
FY16 3DEP Partnerships

Collaborate – Seasketch (http://seasket.ch/hwpR3E-MxO)



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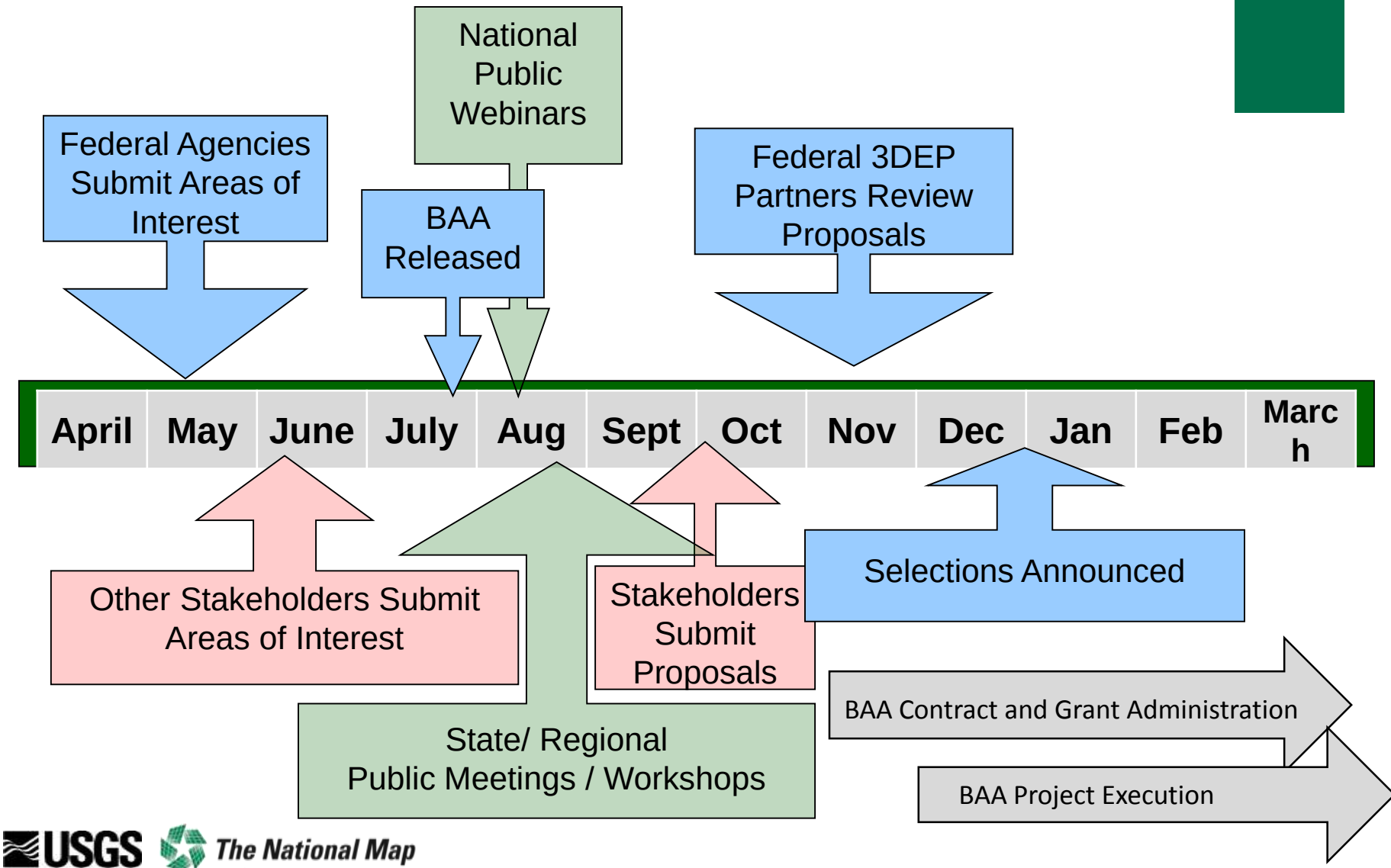
FY16 3DEP Partnerships

BAA

	# of awards	Sq. mi.	3DEP USGS, FEMA HQ, NRCS NGCE $M	Other Partners $M	Total Cost $M
Geospatial Products and Services Contract (GPSC)	20	81,024	$6.7	$11.3	$18.0
Cooperative Agreements	9	41,396	$3.1	$5.6	$8.7
Total as of 5/15/16	29	122,420	$9.8	$16.9	$26.7

- Additional FY16 3DEP acquisitions funded by 3DEP Federal partners are underway
- FY16 increases will help increase overall totals for acquisition
- BAA remains open to new proposals

3DEP FY17 BAA Timeline



3DEP Data Acquisition

GPSC

- Preferred method
- Managed by the USGS NGP NGTOC Commercial Partnerships Team (CPT)
- Firms on the GPSC have been selected based on their qualifications and performance in providing the professional services needed for 3DEP
- Private sector firms in place; awarded through a competitive process, consistent with the Competition in Contracting Act and the Brooks Act.
- GPSC also offered as a service for acquiring elevation data for external organizations

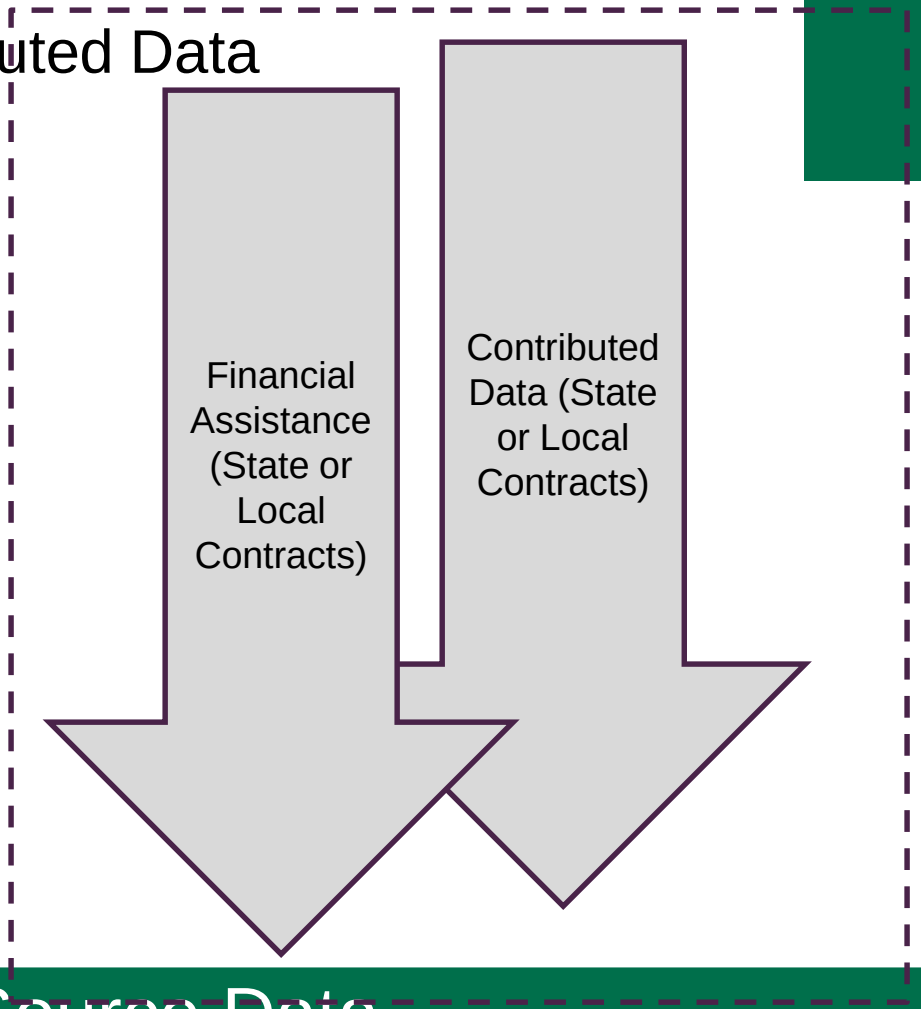
3DEP Source Data

(Metadata, Raw Point Cloud, Classified Point Cloud, Bare Earth Surface, Breaklines)

3DEP Data Acquisition

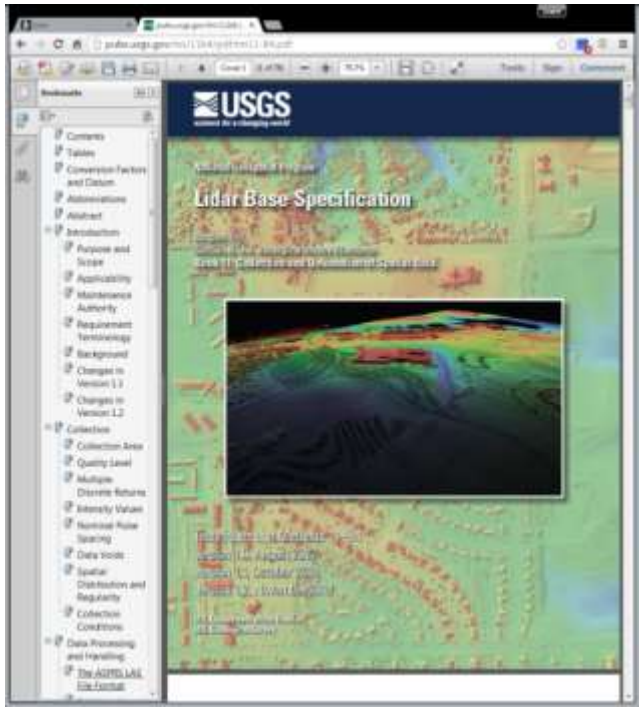
Financial Assistance, Contributed Data

- USGS is committed to assuring data collected through financial assistance awards or as contributed meets 3DEP standards and can be ingested into the National Map
- Technical Assistance and Training
  - Vendors
  - Partners
- Specifications
  - Lidar Base Specification
- Contract Language
  - Award documentation
  - Scope of Work
- Review of Pilot Data



3DEP Data Acquisition

Specifications, Contract Language, Scope of Work



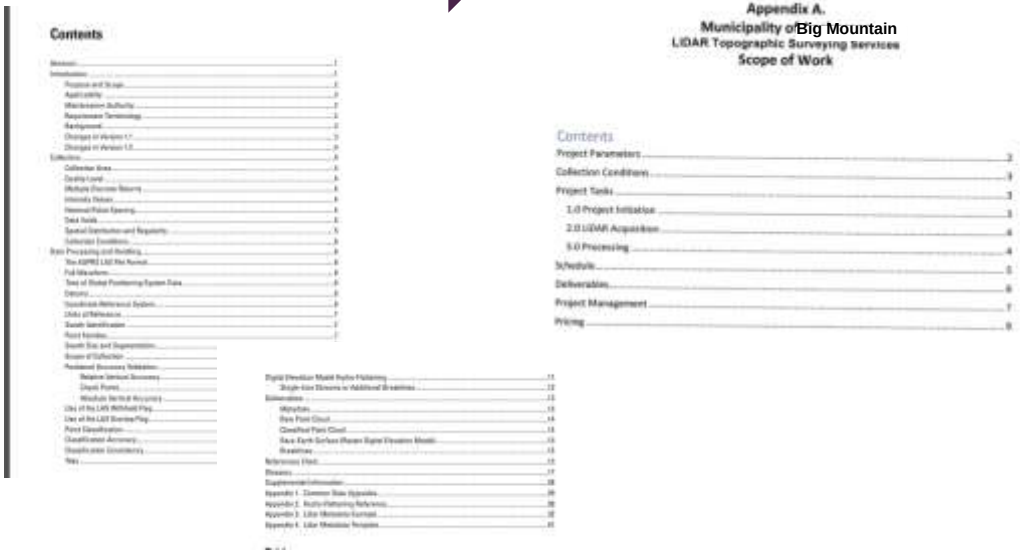
USGS NGP Lidar Base Specification V1.2
http://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf

C.3 Final Data Delivery

Data Delivery Specifications

Data shall adhere to USGS Base Lidar Specifications V1.2 *(Heidemann, Hans Karl, 2014, Lidar base specification (ver. 1.2, November 2014): U.S. Geological Survey Techniques and Methods, book 11, chap. B4, 67 p. with appendixes,)* *http://dx.doi.org/10.3133/tm11B4*.)

Specifications → Scope of Work



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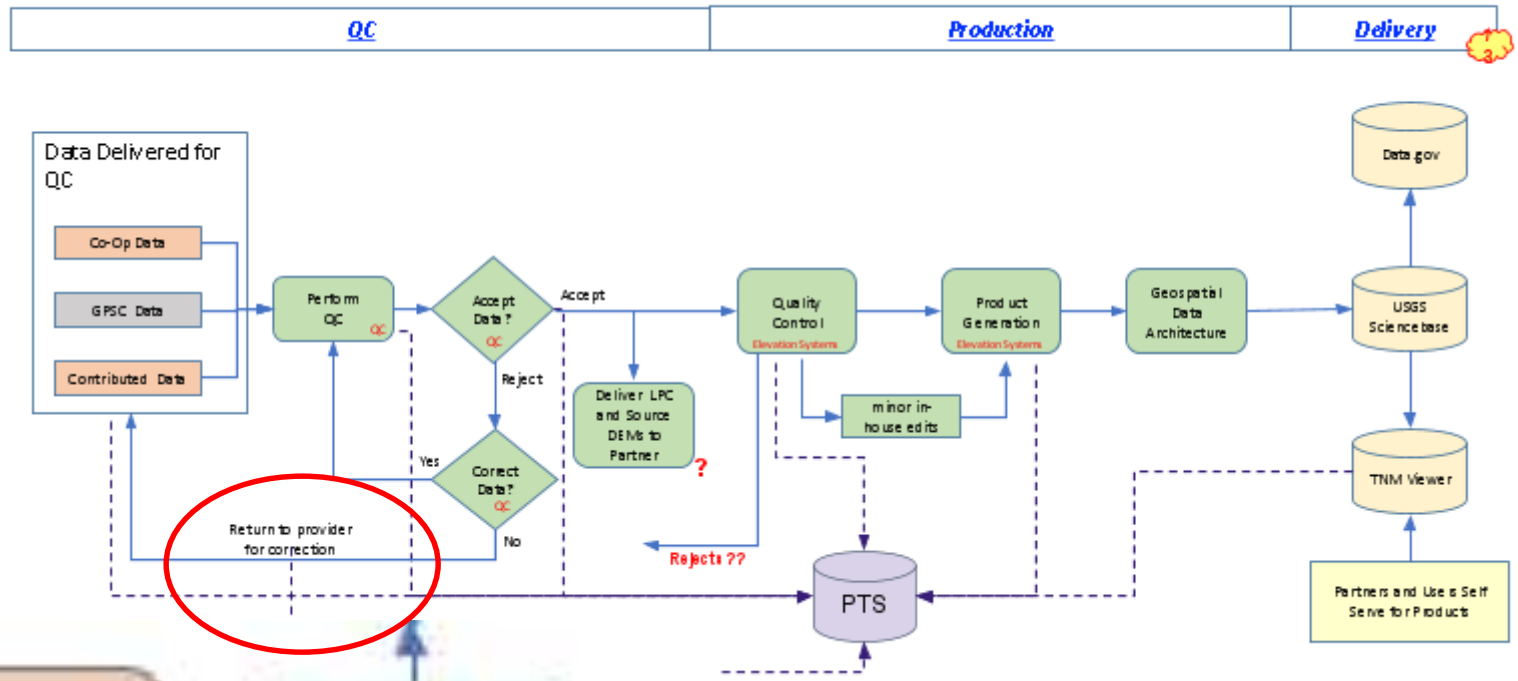
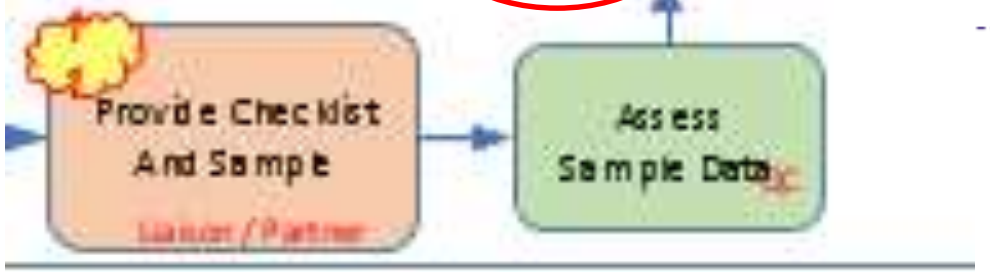
3DEP Data Acquisition

Quality Control; Review of Pilot Data

Return to Provider is very time consuming; Results in a delay in the generation of products and services





USGS enhancing QA/QC process to enable the submission and review of pilot data

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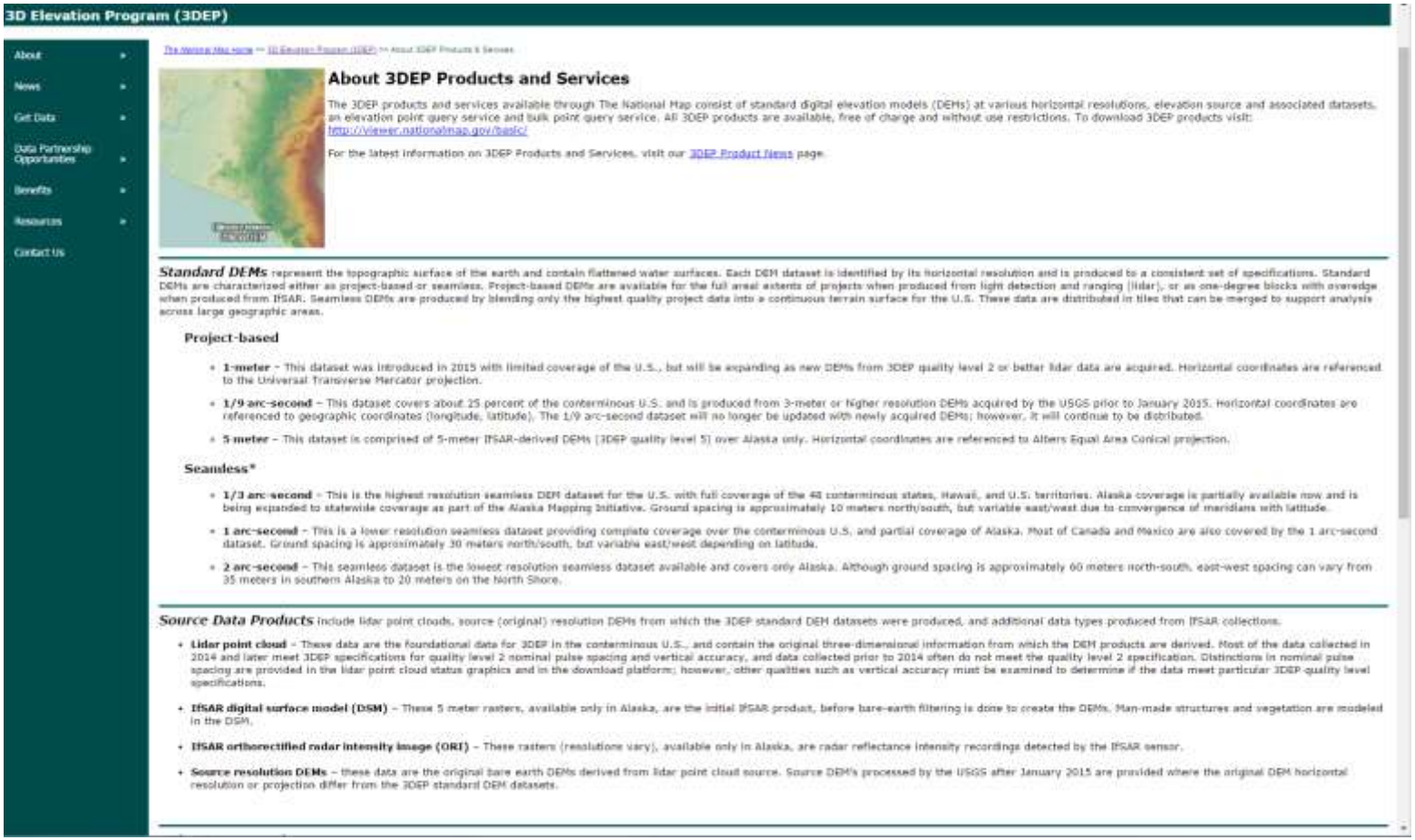
3DEP QA/QC

QC Steps

- Was everything delivered?
- Metadata Review
- Automated Checks
  - LAS files meet ASPRS file format requirements
  - Vertical Accuracy Assessment
  - Metadata are FGDC Compliant
  - Breaklines
- Visual Checks
  - LAS files are appropriately classified
  - LAS files are geometrically correct
  - Does DEM meet USGS Lidar Base Specifications and/or project requirements

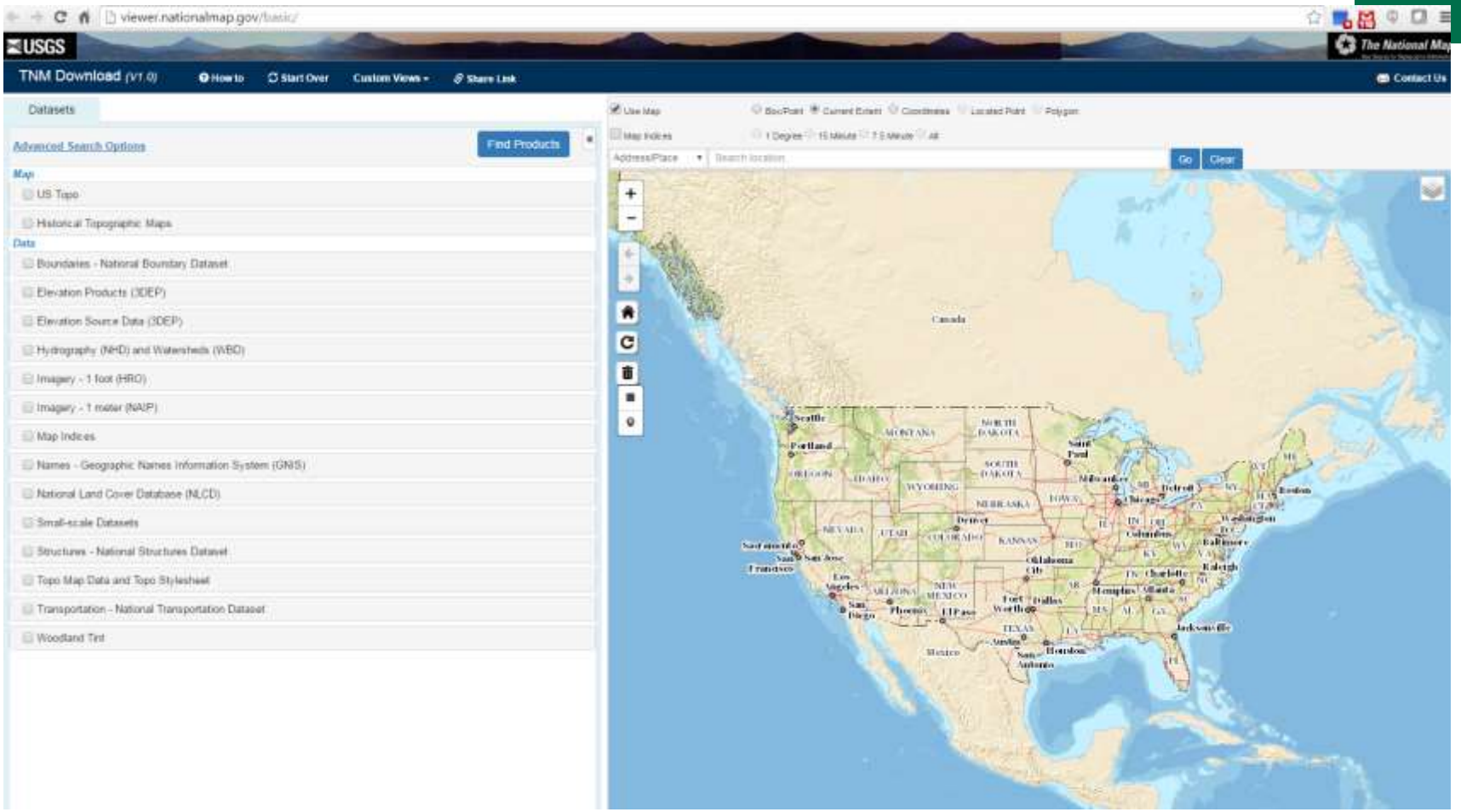
3DEP Products and Services



http://nationalmap.gov/3DEP/3dep_prodserv.html

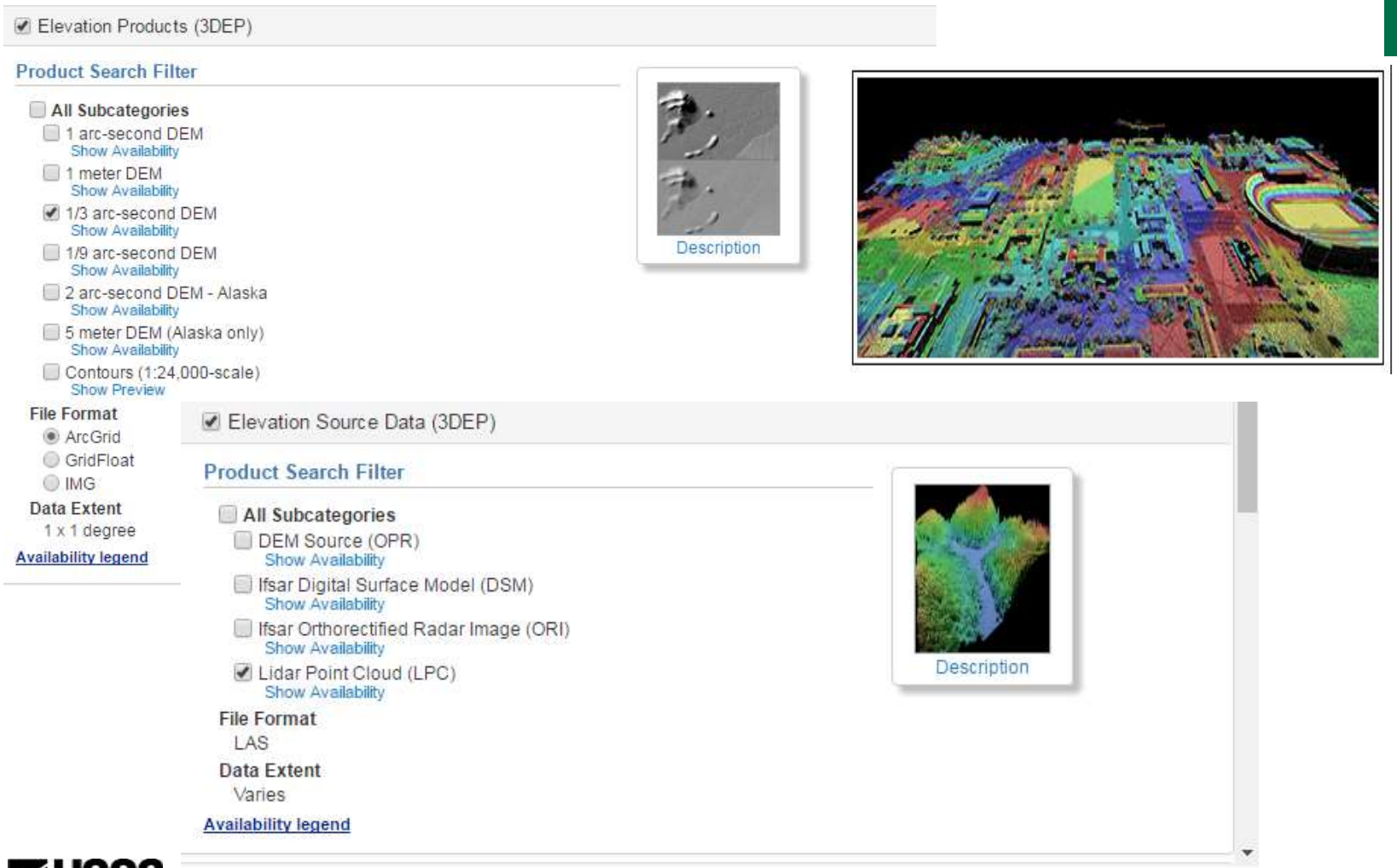
3DEP Products and Services

The National Map



3DEP Products and Services

The National Map



3DEP Resources

Resources 3DEP@usgs.gov

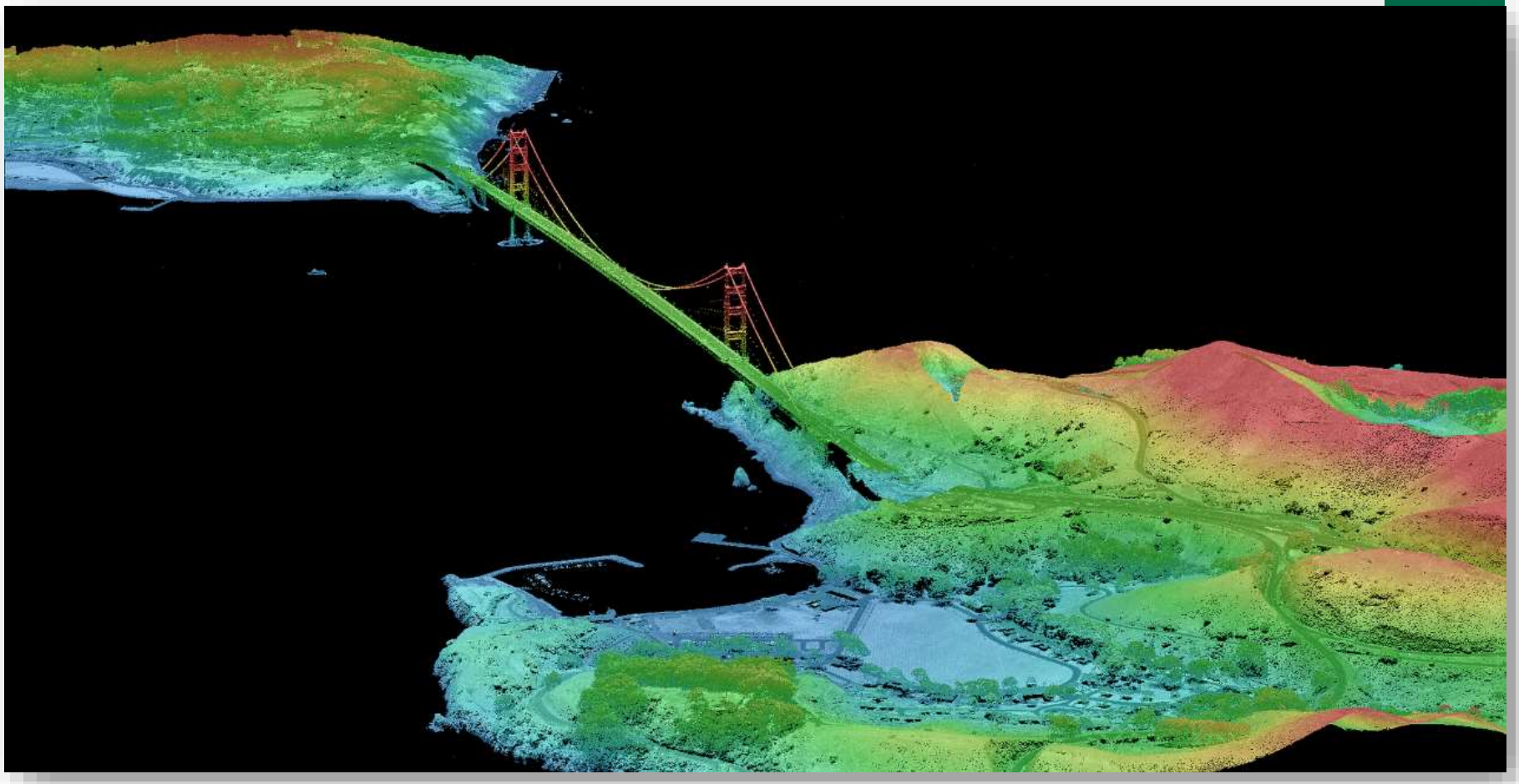
3DEP Data Acquisition
http://nationalmap.gov/3DEP/3dep_about.html
Diane Eldridge
deldridge@usgs.gov

3DEP Products and Services
Integration of New Technologies
http://nationalmap.gov/3DEP/3dep_prodserv.html
Jason Stoker
jstoker@usgs.gov

Geospatial Products and Services Contract (GPSC)
http://geodatacontracts.er.usgs.gov/gpsc_information_sheet.html
Tim Saultz
tsalutz@usgs.gov

Lidar Base Specifications
http://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf
Karl Heidemann
kheidemann@usgs.gov

Thank you!



FEMA and 3DEP

- Risk MAP is a major supporter of 3DEP and has provided a significant portion of the Federal funding so far, along with USGS and NRCS
- FEMA HQ in has provided funds directly to the USGS 3DEP shared funding pool under the BAA which gives FEMA needs priority over other Federal needs and can be used to direct specific lidar acquisition if needed.
- The current 3DEP shared funding approach is opportunistic – so there is no guarantee that the grant funds will target your short-term needs
- There are ways FEMA can and should steer the 3DEP shared funding
- If FEMA buys lidar on our own, it is still part of 3DEP

Planning Lidar in Risk MAP

- **It is reasonable to expect that 3DEP shared funds will meet some of Risk MAP's lidar needs over the next few years, but not all**
- **The primary requirement to steer 3DEP shared funds to FEMA / flood mapping priorities is to maintain a multi-year plan of future projects, coordinated with cross state government.**
  - 3DEP will use the FEMA plans on an annual basis to prioritize which applications to award funds to
  - Coordination with the states by regional offices, particularly aligning the flood mapping interests with the other lidar interests within the state will help steer the applications submitted to Risk MAP priorities
  - Regions can offer cost-share funding to state and local applicants for 3DEP grants to further improve the chances a project is selected for a 3DEP grant
  - Could fund a current year CTP agreement, or "promise" funding for successful BAA applications

Annual Acquisition Cycles

- Planning and coordination for 3DEP grants begins in Feb-March with the collection of draft priorities from Federal Agencies.
- FEMA Regions should have tentative plans for the current year lidar purchases and future year lidar needs. These should be coordinated with the states.
- Draft priorities are shared with public
- Several months are set aside for public meetings and other coordination to discuss potential projects
- In June FEMA can update our future year plans which are then incorporated into the 3DEP Grant Guidance
- In parallel, FEMA Regions finalize their current year purchases and share the information to avoid duplication with 3DEP grants
- In November / December the 3DEP grants are announced

Current Year Planning

- Because no one can be sure which 3DEP projects will get funded, FEMA Regions must plan assuming the projects they need in the current year may not get funded by 3DEP.
- At this point, most of the current awards have been announced.
- In the spring and summer, if near-term a lidar need is not already funded by 3DEP, the FEMA Region should generally go ahead with the purchase.
- Because it typically takes 9 months for delivery of lidar from task order to product and because using lidar for automated engineering is expected to produce big efficiency benefits for mapping watershed we generally need to decide on a lidar purchase in the year before we want to begin Discovery.
- FEMA is planning substantial lidar purchases in FY16. These are shared on the 3DEP / Seasketch site.

Current 3DEP Status

- FEMA has compiled and published initial FY16 planned purchases and "wish list" for next BAA cycle
- We are sharing the information about the wish list project plus planned and ongoing Risk MAP lidar projects through this interagency mapping coordination site: http://seasket.ch/2MlmlhjU61

FEMA Lidar Standards and Guidance

- New Lidar must be QL2. Standard allows project to exclude some bare earth processing and water flattening.
- Virtually all FEMA projects follow standard QL2 product
- Guidance discourages excluding bare earth processing or water flattening unless partnership strategy is in place to finish the products and incorporate into 3DEP
- FEMA needs to adapt our long-term strategy to build in the assumption that full lidar coverage is affordable and allows very high efficiency automated analysis for many areas
  - Planning ahead to obtain lidar to support Automated Engineering
  - Assume national coverage is coming via 3DEP, so plan for the long term, not short-term only
- Currency, resolution, data availability, and the magnitude of difference in nominal accuracy should be considered in determining the "most accurate" elevation data under the revised elevation standard
- Incorporating small areas of more accurate lidar into project

General Requirements

- All FEMA funded lidar must allow full, unrestricted distribution
- Must be certified by licensed professional or certified photogrammetrist
- All FEMA funded lidar must be submitted to the FEMA Engineering Library following the Data Capture requirements
  - Point cloud, plus bare earth DEM
  - Source data, plus any edited modeling surfaces
  - New Data Capture requirement for U.S. Interagency Elevation Inventory record

Review Question

- **How can FEMA and partners influence funding award through the 3DEP BAA?**
  - Coordinate across state government to guide FEMA priorities that are input into BAA process
  - Establish CTP agreements for lidar projects that can be expanded through a BAA award
  - Plan future year lidar projects that FEMA may fund if a state or local partner receives funding through the BAA process
  - All of the above

LIDAR Terms, Specifications and QC

Lewis Graham

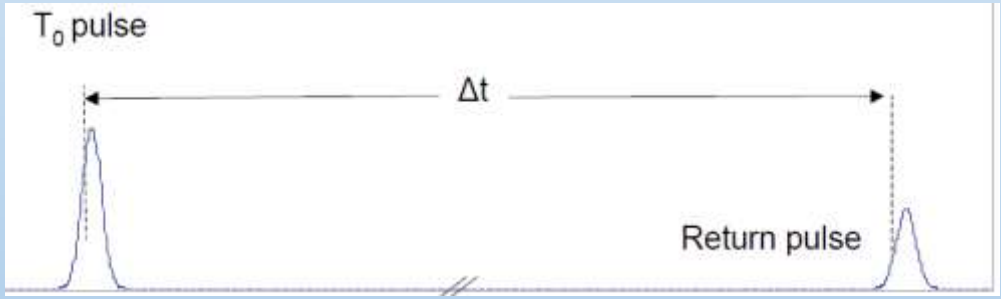
GeoCue Group, Inc.

www.geocue.com

LIDAR Overview

What Is LIDAR?

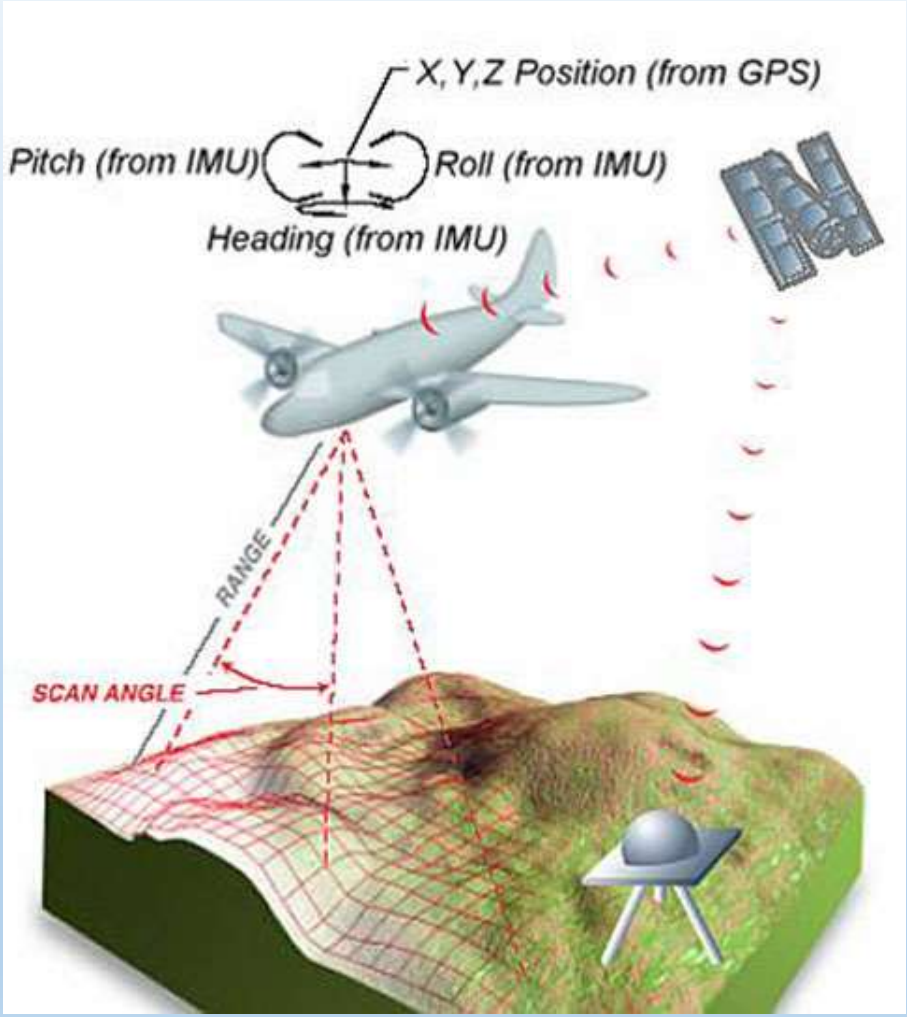
- Light Detection And Ranging (LIDAR) is the optical equivalent of radar or sonar but using an optical source – a laser - instead of microwaves or sound waves
  - NOTE: I prefer "Laser Imaging, Detection And Ranging" to emphasize the importance of the intensity return of LIDAR
- An optical pulse is emitted from a laser at a precisely known time, the pulse reflects from something in the 'object' space and the instrument measures the precise time a return pulse ("echo") is detected
- The time of flight is converted to a distance to the target using the constant speed of light



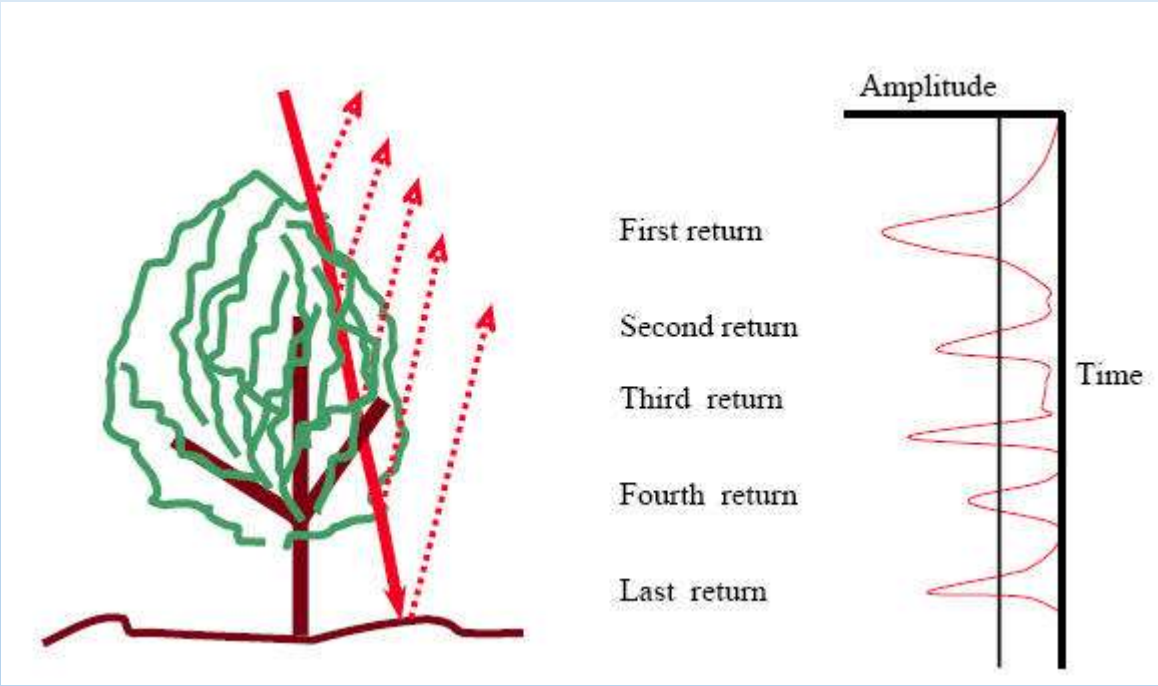
- The laser's precise position and orientation is known via a "Positioning and Orientation System (POS)." These supplemental data are used to derive the object space position

How Does It Work?

- Compact, rugged instrument installed on a small aircraft
- Laser pulses scanned across the path of the aircraft measuring range to surface
- 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



LIDARs detect Multi-Returns



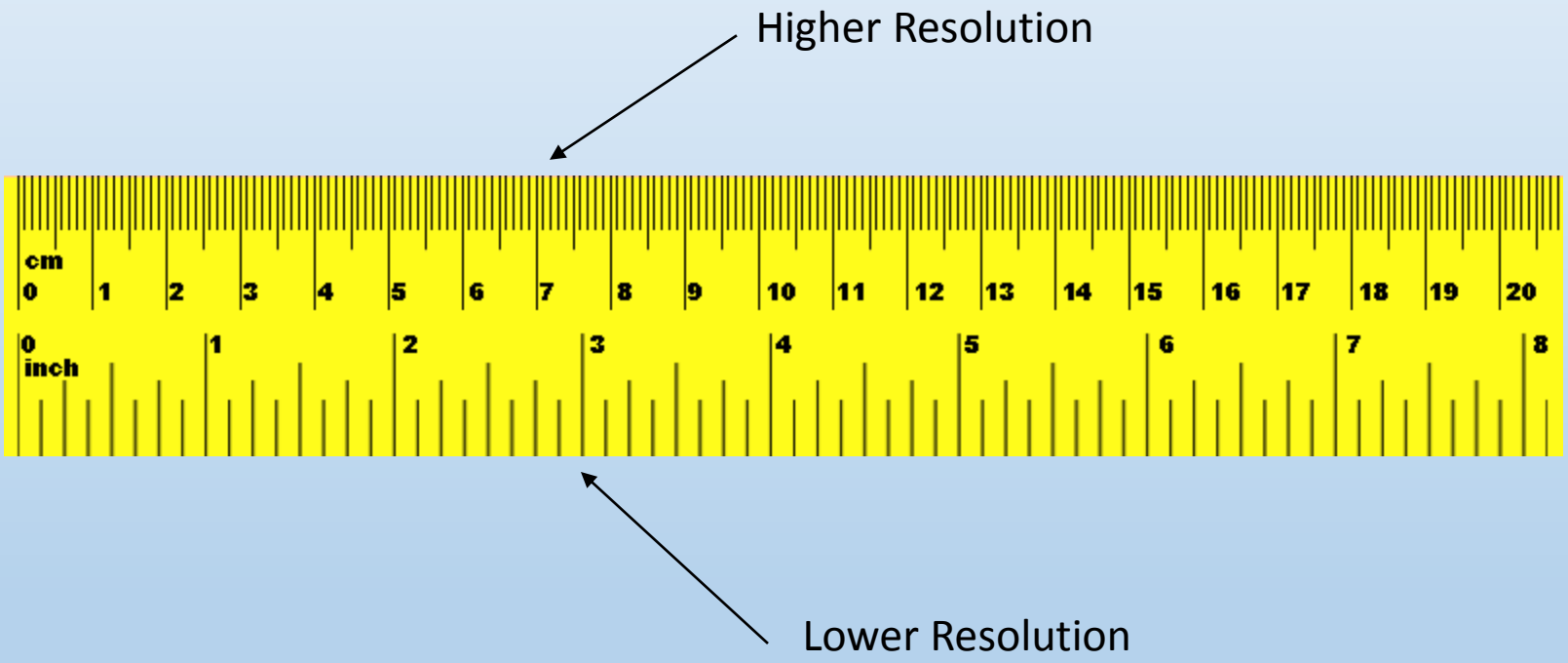
The notion of Return is extremely useful for automated algorithms. For example, only a last return (e.g. Return 3 of 3) can be a bare earth return.

Important Point Attributes

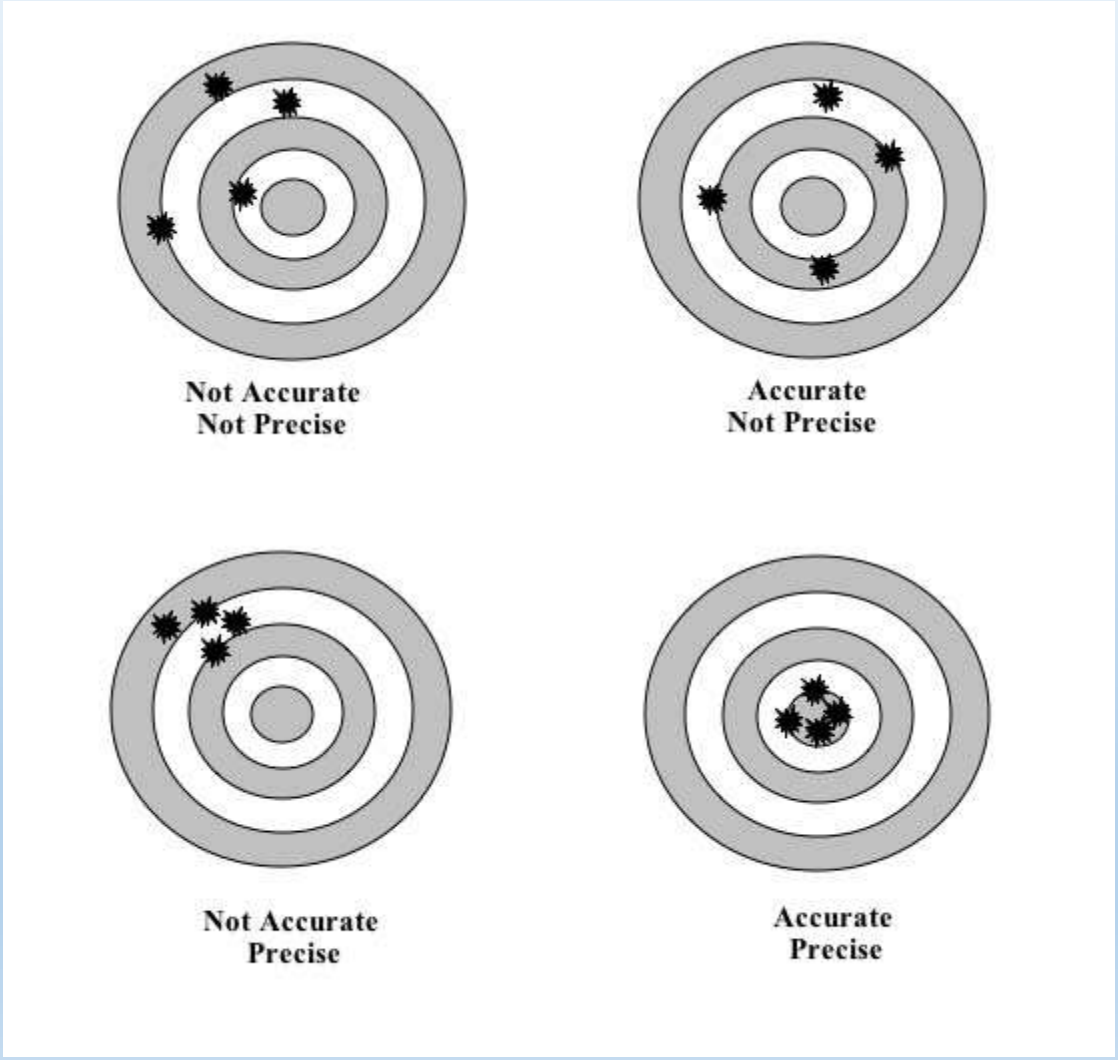
- Major attributes produced by the laser scanner:
  - Absolute time of pulse
  - Position (X, Y, Z)
  - Intensity
  - Return number (e.g. return “n of m”)
  - Edge of flight line
  - Scan angle
- All of the above are very important to advanced processing algorithms

Accuracy

Resolution


Higher Resolution
cm
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 inch 1 2 3 4 5 6 7 8
Lower Resolution

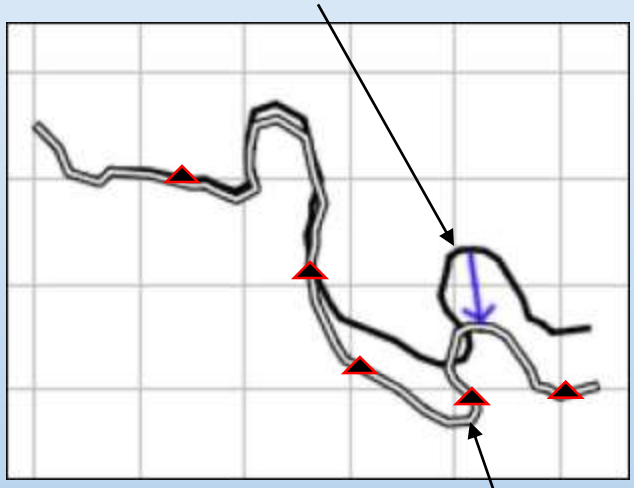
Resolution, Accuracy and Precision



- Resolution is the spacing of circles in the target
- Accuracy is related to μ
- Precision is related to σ
- Knowing σ is only useful if you are given the type of distribution (e.g. Gaussian, Poisson, etc.)

Network and Local Accuracy

Poor Network Accuracy, Good Local Accuracy



(▲= Network Control)

Good Network Accuracy, Good Local Accuracy

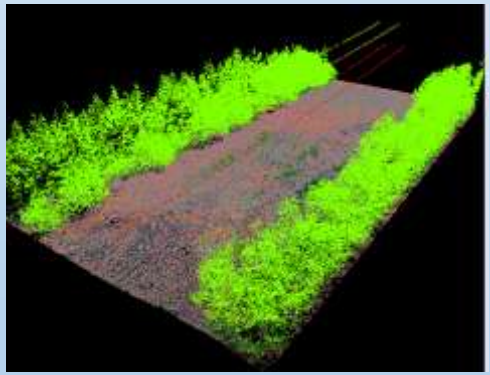
Network Accuracy – The degree to which positions agree with a reference network

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

Specifying, Buying LIDAR

Write a Data Use Plan!!

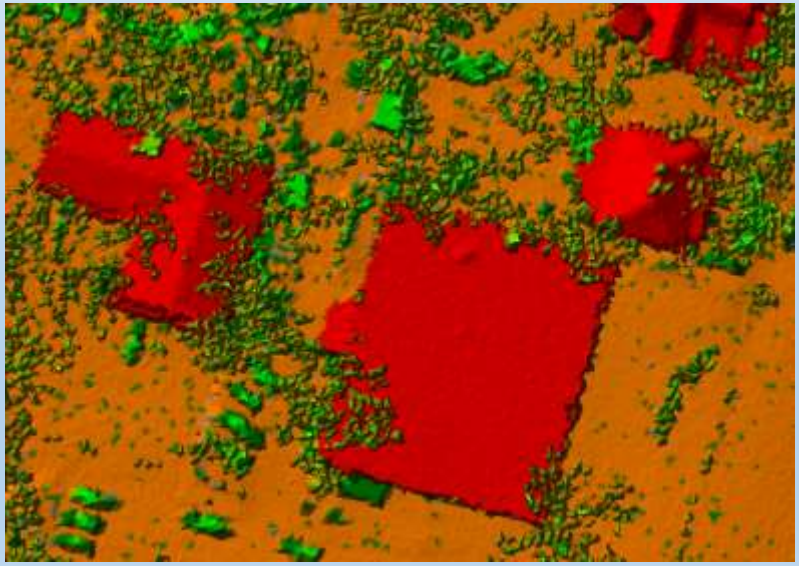
- Educate Stakeholders on LIDAR characteristics
- Capture basic requirements:
  - DEM, Contours, etc.
- Think outside the box about Just-In-Time use of LAS data:
  - Building footprints
  - Electric Distribution vegetation analysis
  - Tree Management
  - …..
- Use all of the above to decide on specifications



Evaluating Buy-ups

- Write a Pie-in-the-sky Data Use Plan
- Price via base and buy-ups
- Do a category-based Return on Investment (ROI) analysis

- Remove options until you meet the cost target



(A Vegetation and Building Classification Buy-up)

QC is an absolute must

"LIDAR data are very detailed and technical and require professional QA/QC…."

"Approximately 10-20% of the project cost is required for a separate QA/QC contract. "

– State of Kansas, LIDAR Implementation Plan

Specifying Data

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, …..

Notes on an Example Specification from a State LIDAR Procurement

Deferral to a Higher Authority…

All processes and deliverables shall be completed in accordance with the Federal Emergency Management Agency (FEMA)'s Standards for Flood Risk Analysis and Mapping, dated July 31, 2015, located on FEMA's website at www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping. These guidelines and standards (www.fema.gov/media-library/assets/documents/35313) define the specific implementation of the statutory and regulatory requirements for NFIP flood risk analysis and mapping, and address the performance of flood risk projects, processing of letters of map change and related Risk MAP activities. Standards and guidance which may apply to this project may include, but are not necessarily limited to, the following: "Standard" numbers 40 – 49, 152, 158, and 547; FEMA Procedure Memorandum No. 61 – Standards for Lidar and Other High Quality Digital Topography; and FEMA Appendix A: Guidance for Aerial Mapping and Surveying. **Documentation of compliance, along with the required certifications (per Standards 42 and 49) shall be included within the project report deliverable. DNRC has notified Contractor of FEMA's anticipated Fall 2015 Maintenance Cycle revisions to Standards 40, 43, 46, 47, and 48 as relevant to the work being performed under this contract.**

Density/Accuracy Specs …

attitude. The system will be flown in a fixed wing aircraft. The LiDAR will be collected at 8 points per square meter to ensure at a minimum 8 ppsm first return. All overlapping flight lines will be flown in opposing directions to maximize detection of swath-to-swath inconsistencies and to minimize any off-NADIR shadowing from vegetation or terrain. LiDAR data accuracy will be 9.25 cm RMSEz (18.2 cm Accuracyz) and suitable for 1 foot contour generation.

LIDAR Data Spec

LiDAR

Point Cloud:

- Raw Point Cloud All Returns, LAS v1.2,
  Calibrated and adjusted to ground by swath.
- Classified All returns, Las 1.2 format
  Point files will include the following fields: X,Y,Z, Return Intensity, Return Number, Point Classifications (0,1,2, 7,9,10,11), Scan Angle, GPS Time and intensity. Tiles provided without overlap.

FEMA CRS Requirement

41	For areas within the Continental United States field surveys and aerial data acquisition must be referenced to the North American Vertical Datum of 1988 (NAVD88) and the North American Datum 1983 (NAD83) and connected to the NSRS.	• Base Map & FIRM Panel Layout

- Have a horizontal datum of North American Datum of 1983 (NAD83), National Spatial Reference System 2007 (NSRS 2007).

But USGS says…

USGS LIDAR Spec 1.2 says a horizontal NAD 83, realization of "most recently published" (currently 2010.00). Most recently published is

FEMA specifications say NAVD88 for the vertical but never mention ellipsoid/geoid or specify the realization of the geoid (USGS is "latest NGS Geoid" which is 12B)

Spec Recommendation

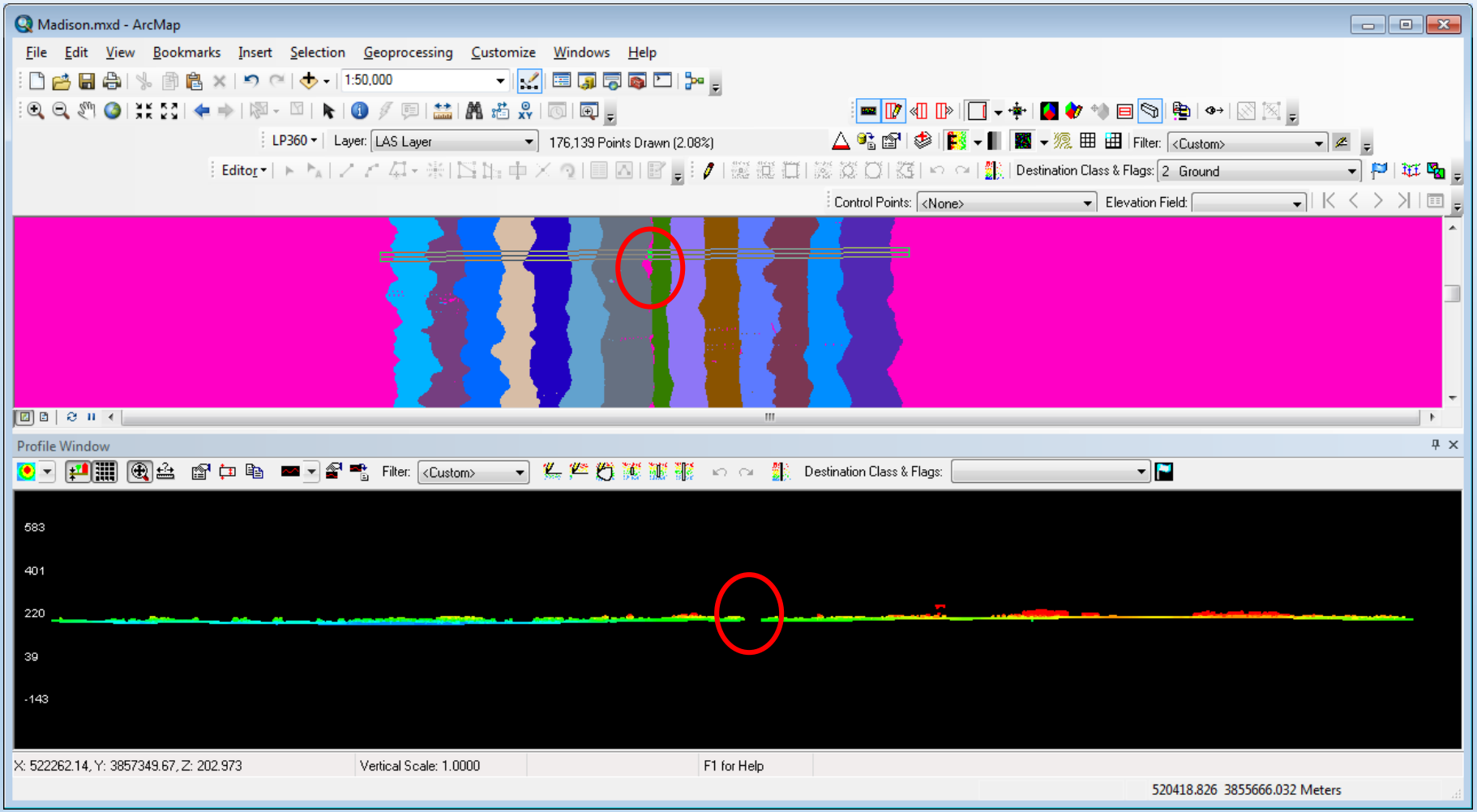
- Reference FEMA and USGS specs but….
- Clearly specify at least at a summary level what you expect:
  - Format (full, all returns, LAS 1.4, …), tiling, Horizontal and Vertical Coordinate Reference Systems (CRS), fully specified including realization!!
  - Vertical Accuracy
  - Density and in what classes, maximum void
    - Can separately specify density of ground in bare earth areas
  - Noise treatment
  - Water body treatment (nulls, hydro constraints, …)
  - ….
- Require incremental delivery

Thoughts on QC

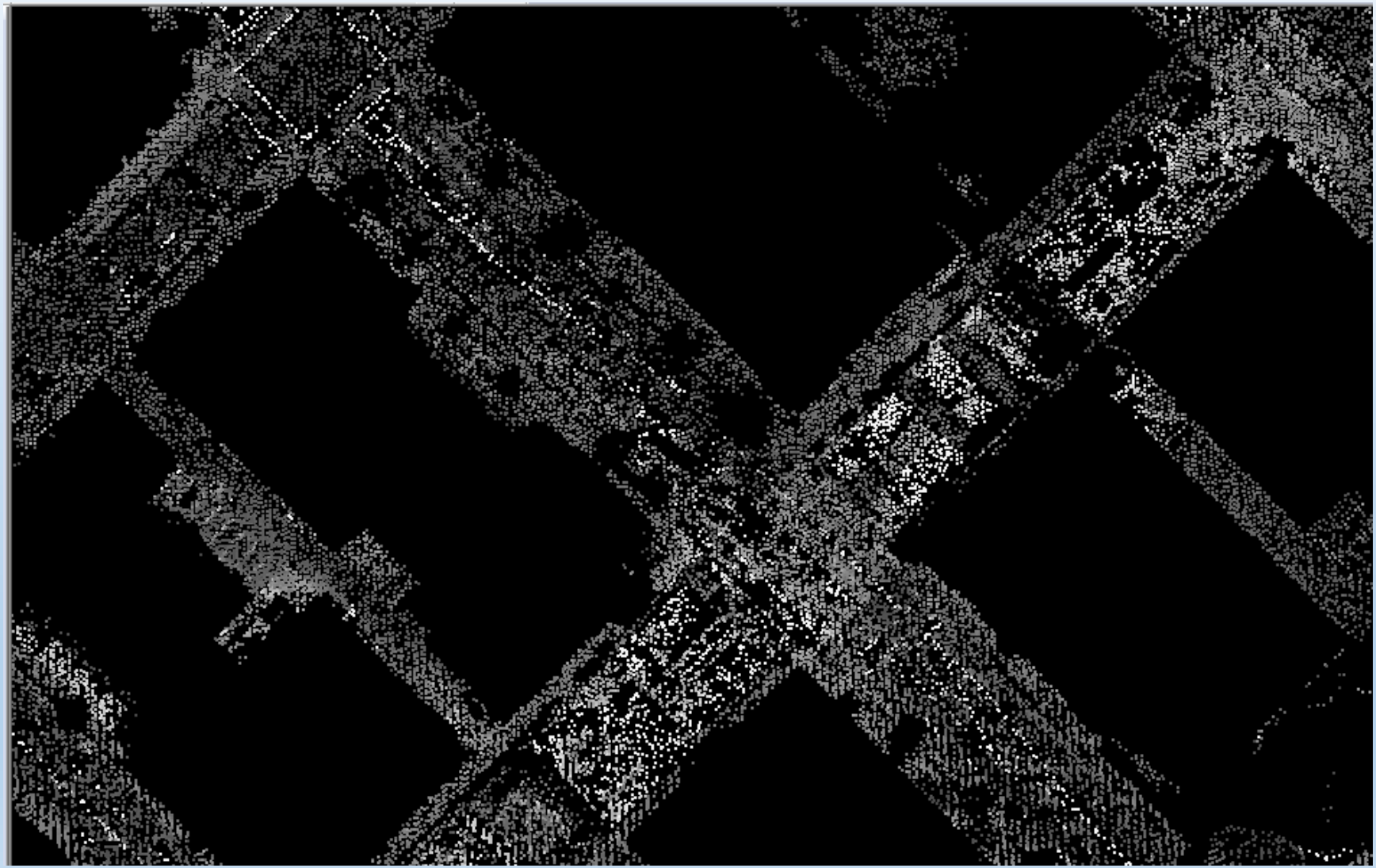
Ignoring QC

- With LIDAR, you typically find the issues months or years after the fact
- Secondary product derivation may be impossible
- Stakeholders lose some percentage of their investment
- Persons involved in the procurement lose credibility
- Often the technology (LIDAR), rather than the process, is blamed.

Gross Void Checks

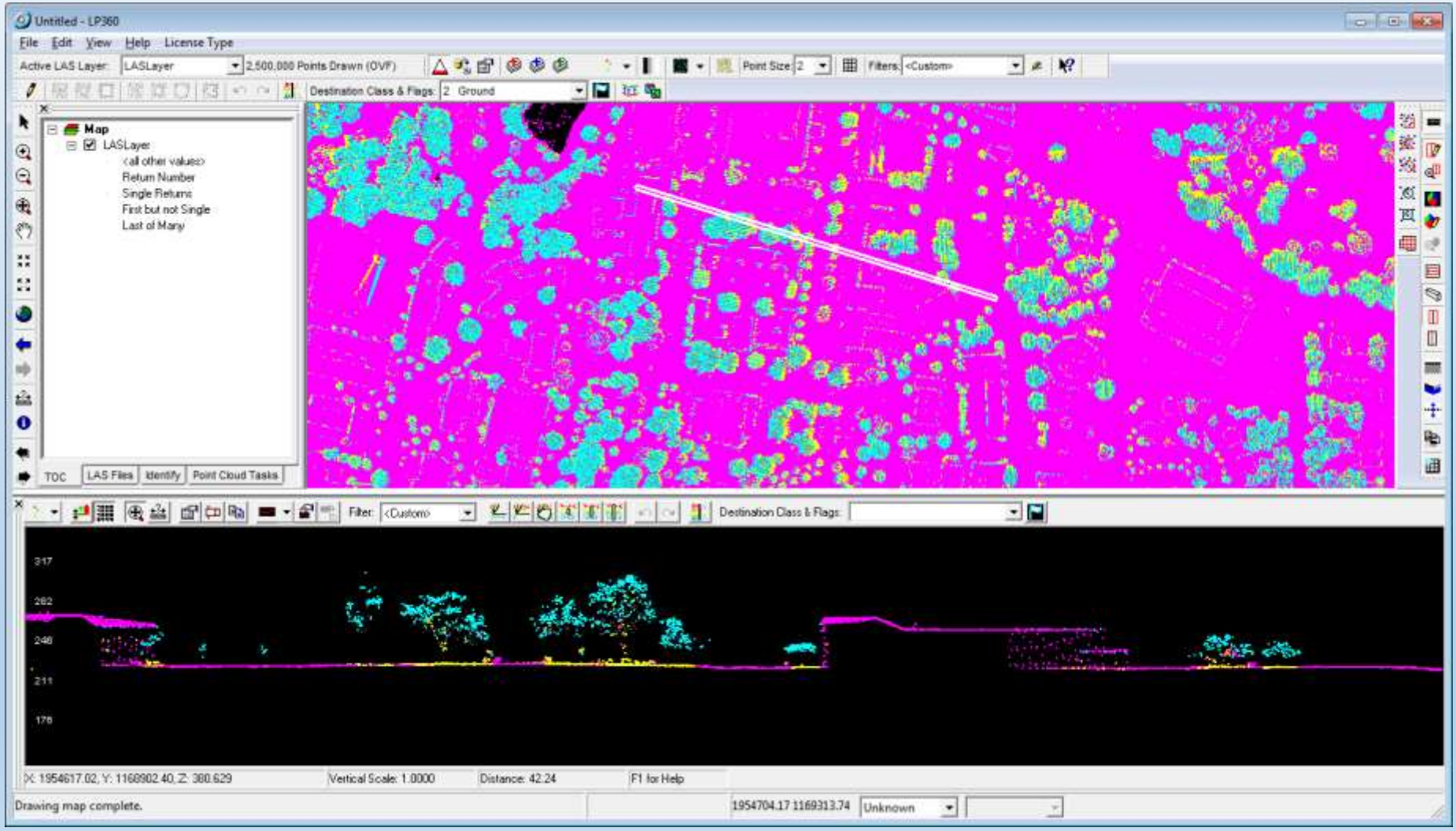


Poor Radiometry

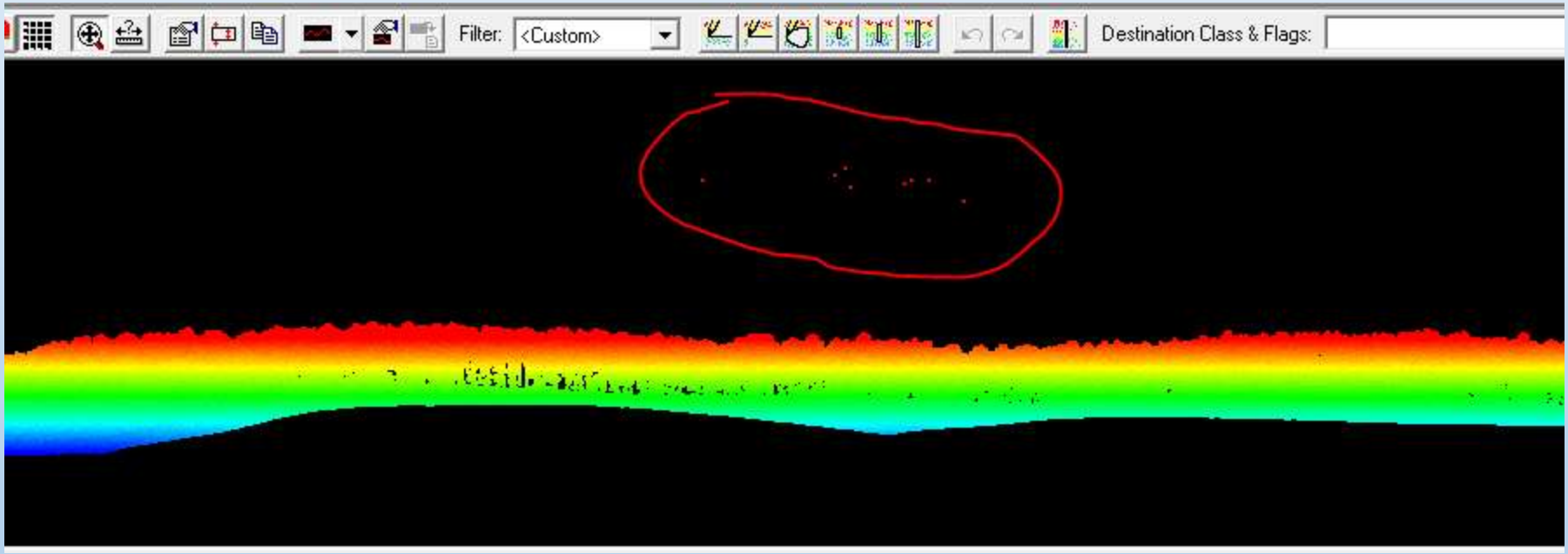


Good Radiometry

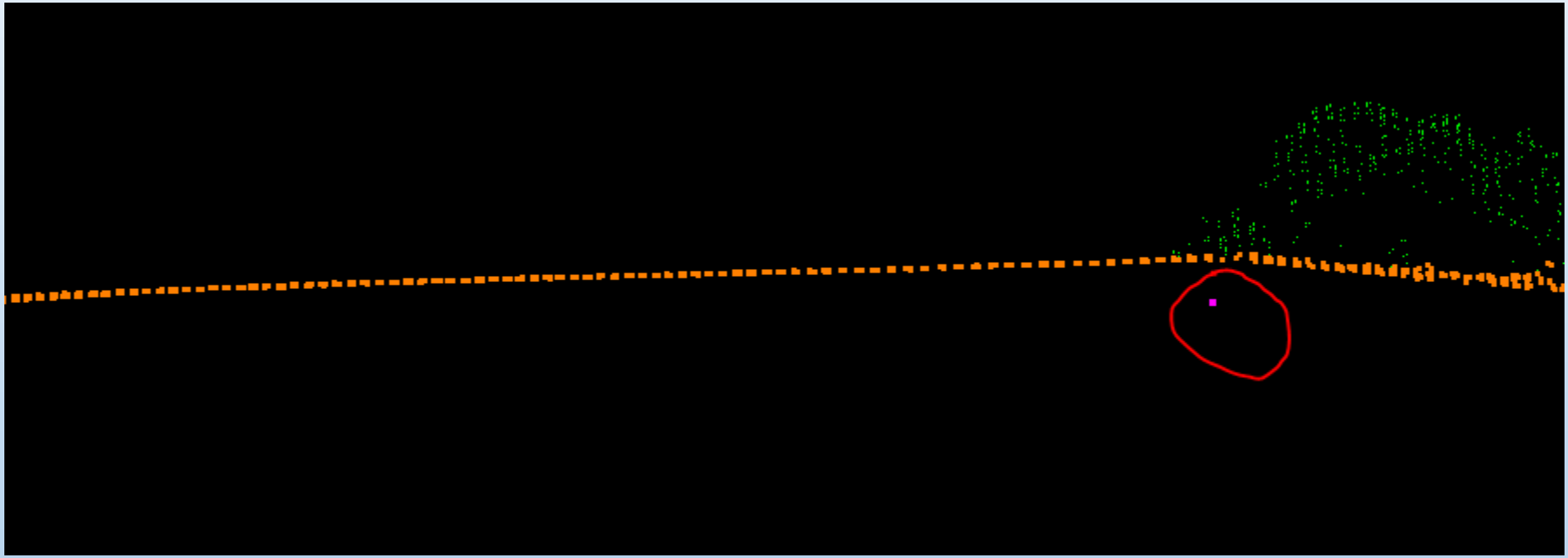
Returns


Untitled - LP360
File Edit View Help License Type
Active LAS Layer: LASLayer
2,500,000 Points Drawn (OVF)
Point Size: 2
Filters: <Custom>
Destination Class & Flags: 2 Ground
Map
LASLayer
<all other values>
Return Number
Single Returns
First but not Single
Last of Many
TOC
LAS Files
Identify
Point Cloud Tasks
Filter: <Custom>
Destination Class & Flags:
317
282
246
211
176
X: 1954617.02, Y: 1168902.40, Z: 380.629
Vertical Scale: 1.0000
Distance: 42.24
F1 for Help
Drawing map complete.
1954704.17 1169313.74
Unknown

High Noise

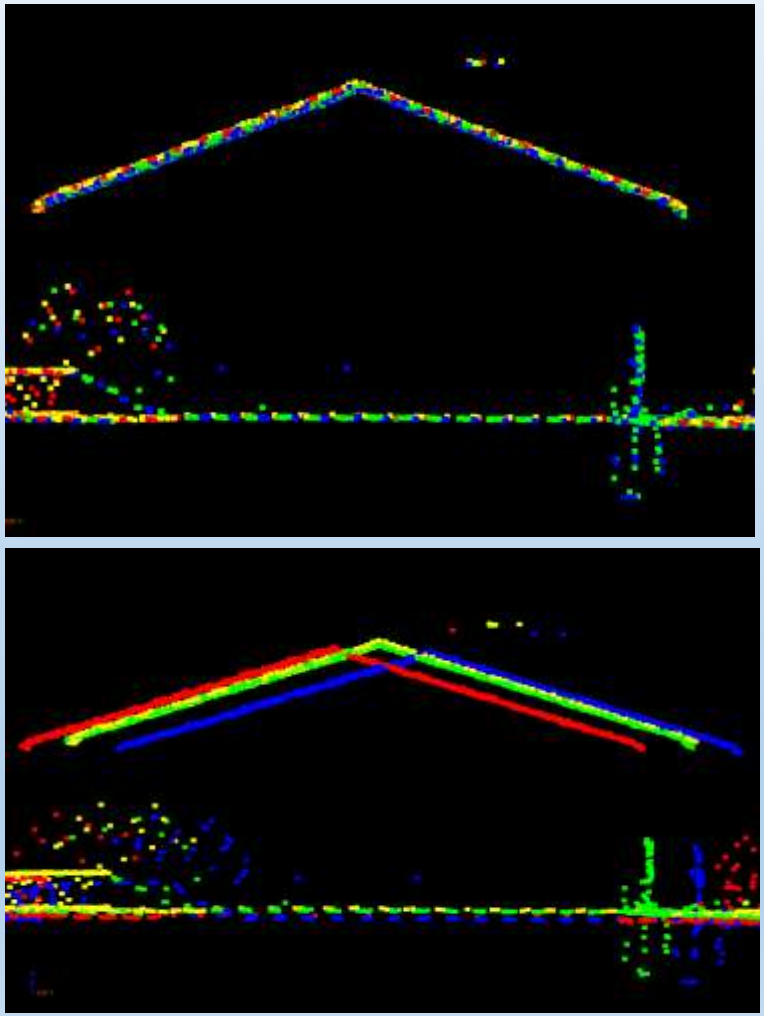


Low Noise



Local Accuracy

- Poor Alignment
  - Image Swaths
- Look at Flight Overlap
- Examine Surface
- Examine Cross-Sections
  - Buildings in Overlap
  - Roads
  - Parking Lots



Overlap Analysis

Table

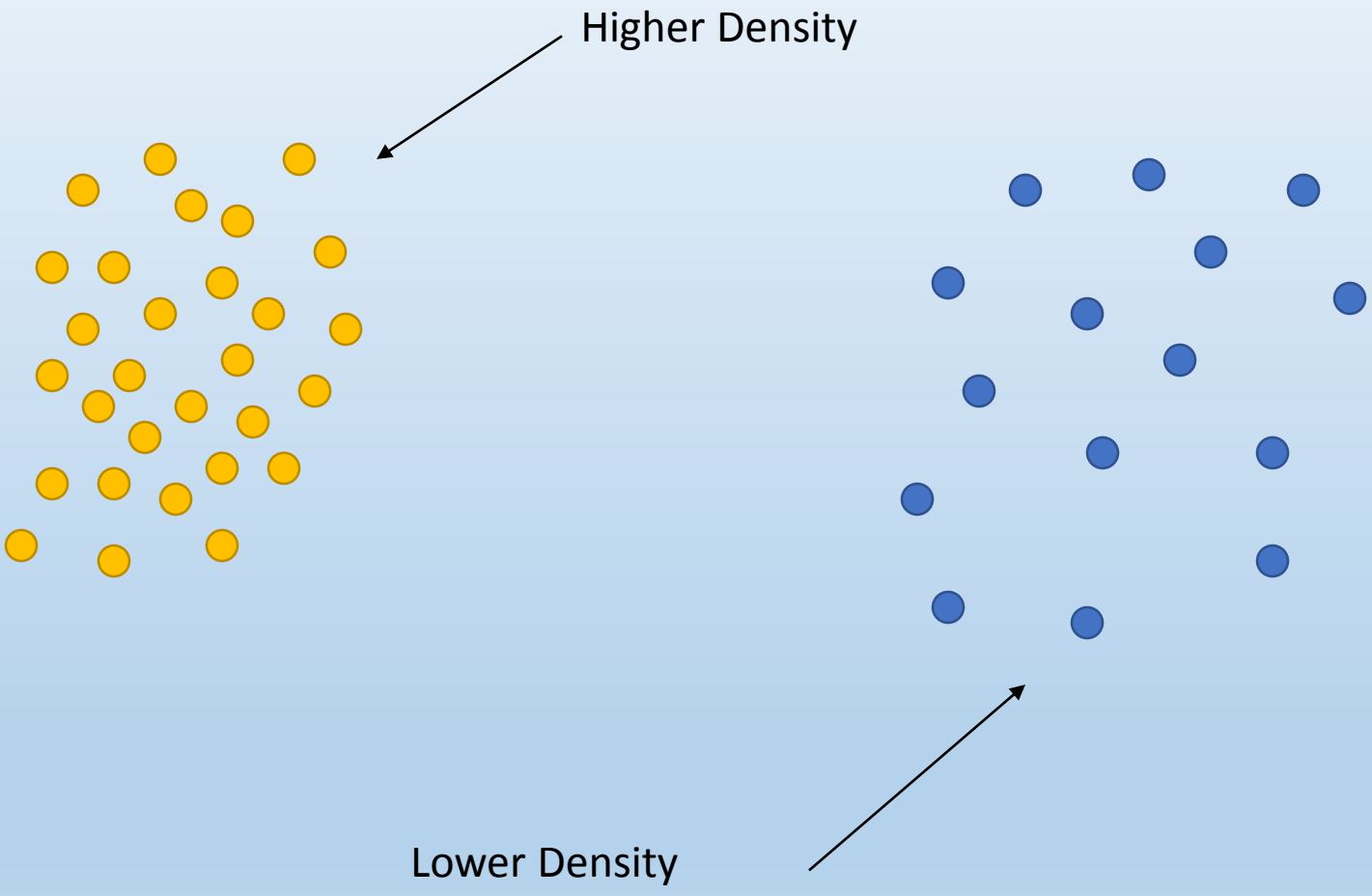
Ground_Relative_Analysis_samples

FID	Shape	ID	IDSrc1	IDSrc2	dZ2_1
0	Point ZM	0	79	81	-0.35
1	Point ZM	0	79	81	0.03
2	Point ZM	0	79	81	0
3	Point ZM	0	79	81	-0.06
4	Point ZM	0	79	81	-0.01
5	Point ZM	0	79	81	0.0433
6	Point ZM	1	79	81	0.19
7	Point ZM	1	79	81	-0.35
8	Point ZM	1	79	81	-0.075

(0 out of 83 Selected)

Ground_Relative_Analysis_s... Ground_Relative_Analysis_s...

Density



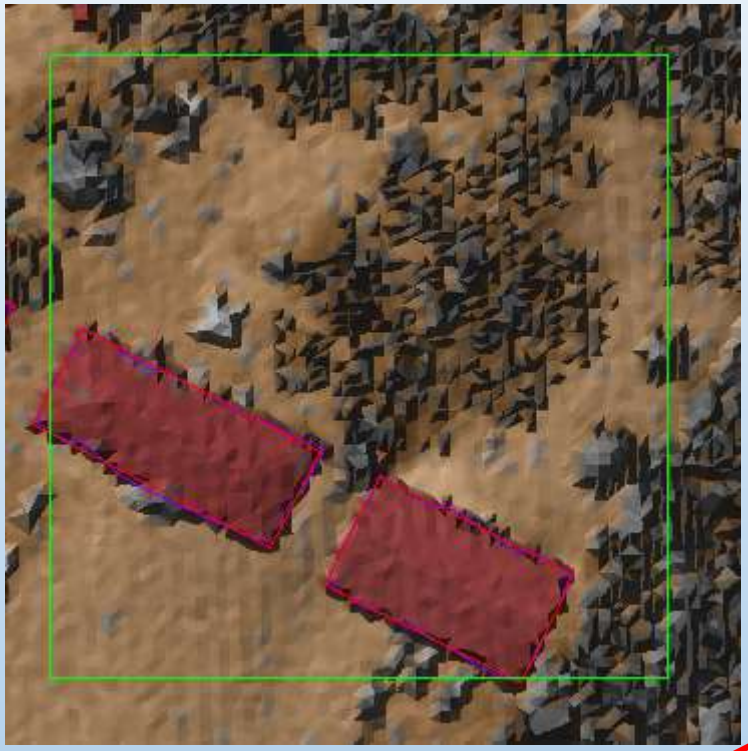
Point Spacing/Density Measurement

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

$$NPS = \frac{1}{\sqrt{Density}}$$

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

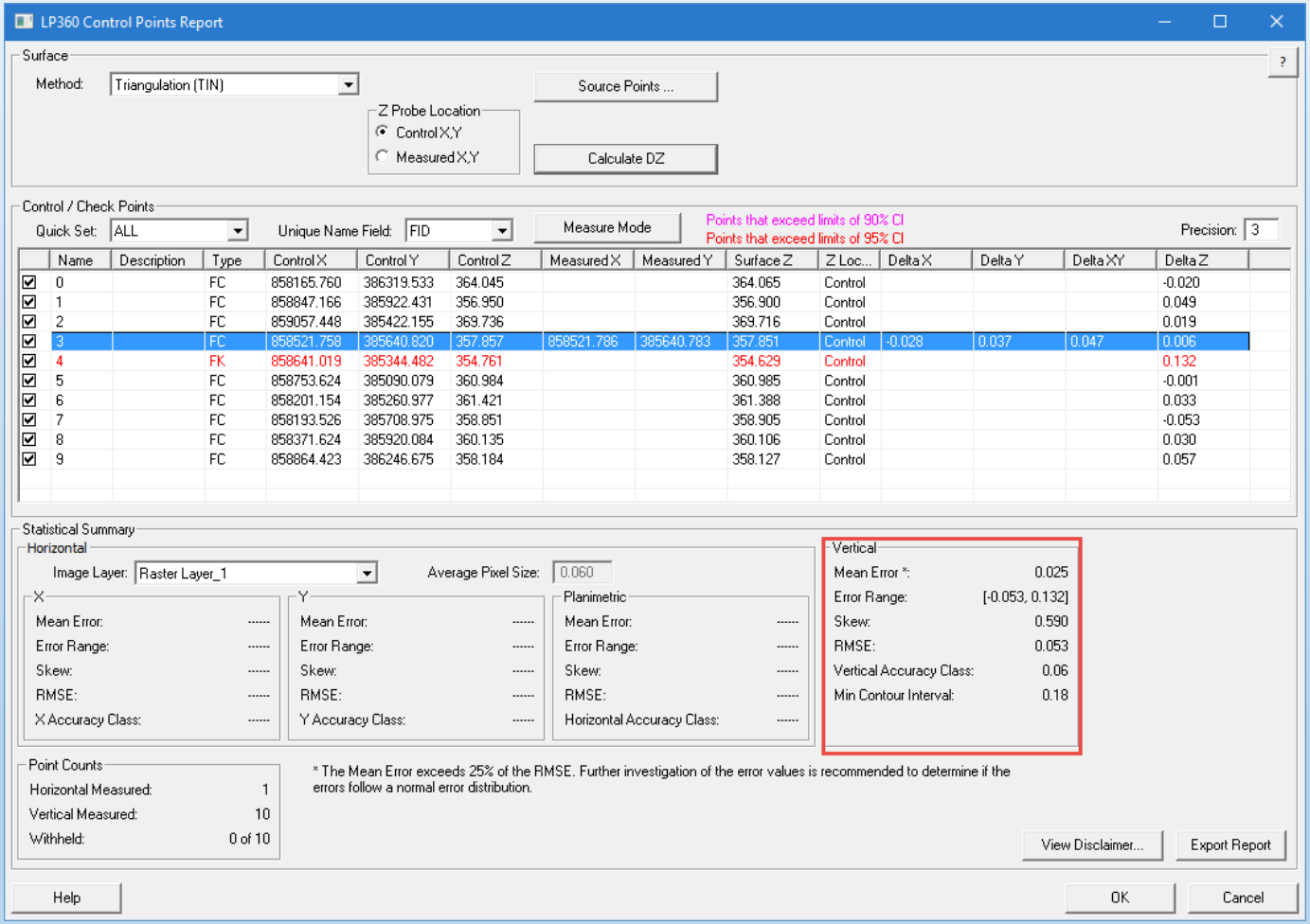
Density Test



PntCnt	3,404
NumCLUsed	4
CLCnt_1	1,010
CLCnt_2	1,949
CLCnt_6	444
CLCnt_11	1
SumArea	2,446.8992
PntDen	1.3911
CLDen_1	0.4128
CLDen_2	0.7965
CLDen_6	0.1815
CLDen_11	0.0004
NPS	0.8478

$$NPS = \frac{1}{\sqrt{Density}}$$

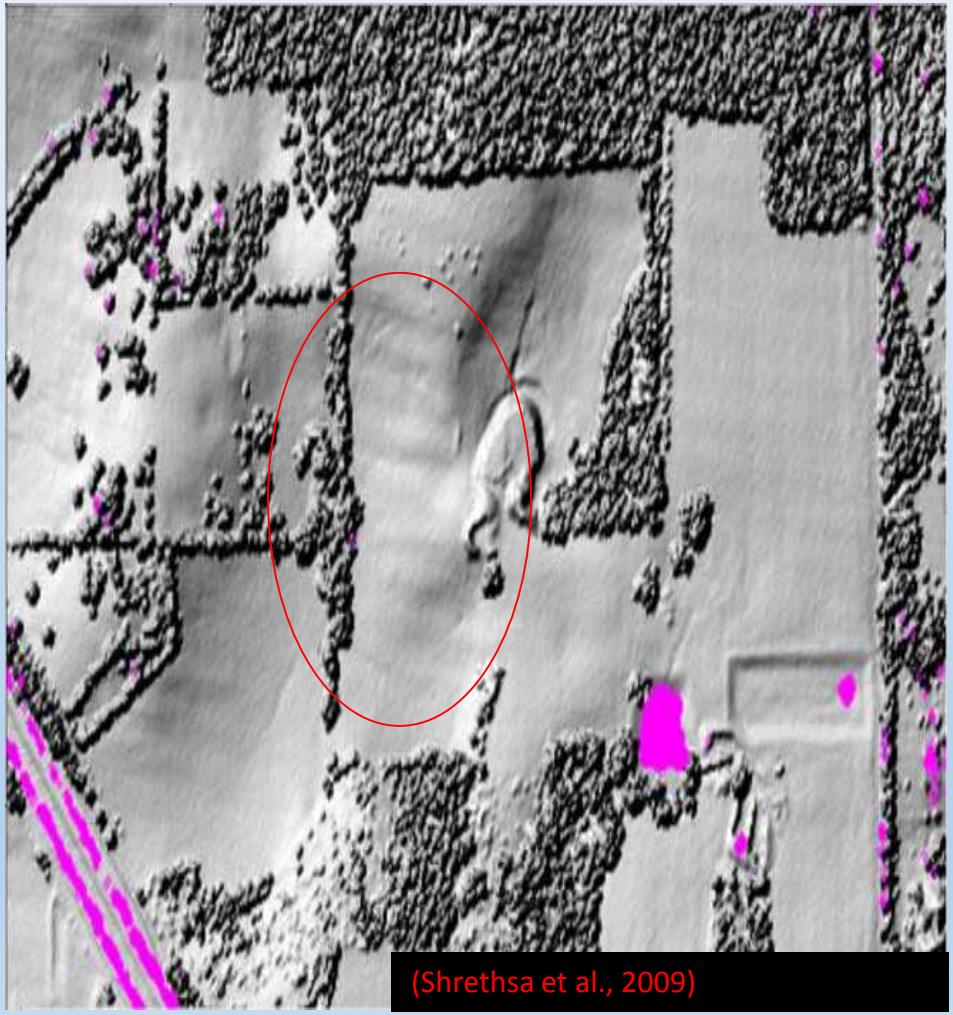
Network Metric Accuracy



* These data are actually from a high resolution sUAS point cloud

Error Identification: Pits, Spikes &Undulations

- Pits
  - Anomalies
- Spikes
  - Atmospheric Particles
  - Anomalies
- Undulations
  - IMU Measurement/Calibration Error



Classifications Errors

- Missed Ground Points
  - Earthen Berms
  - Boulders
  - Cliffs
  - Under Trees
- Missed Building Points
  - Near vegetation
- Multiple classification errors
  - Vegetation
  - Bridges
  - Roads
  - Etc.

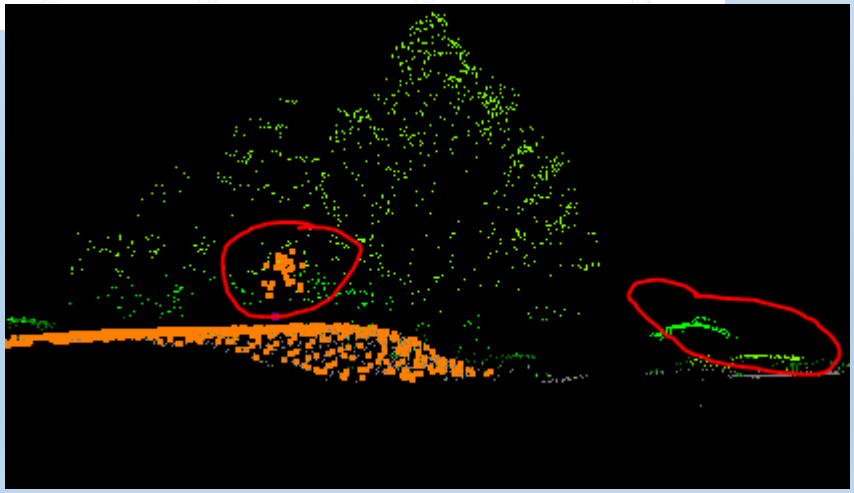
Building misclassified as vegetation

Quantifying 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



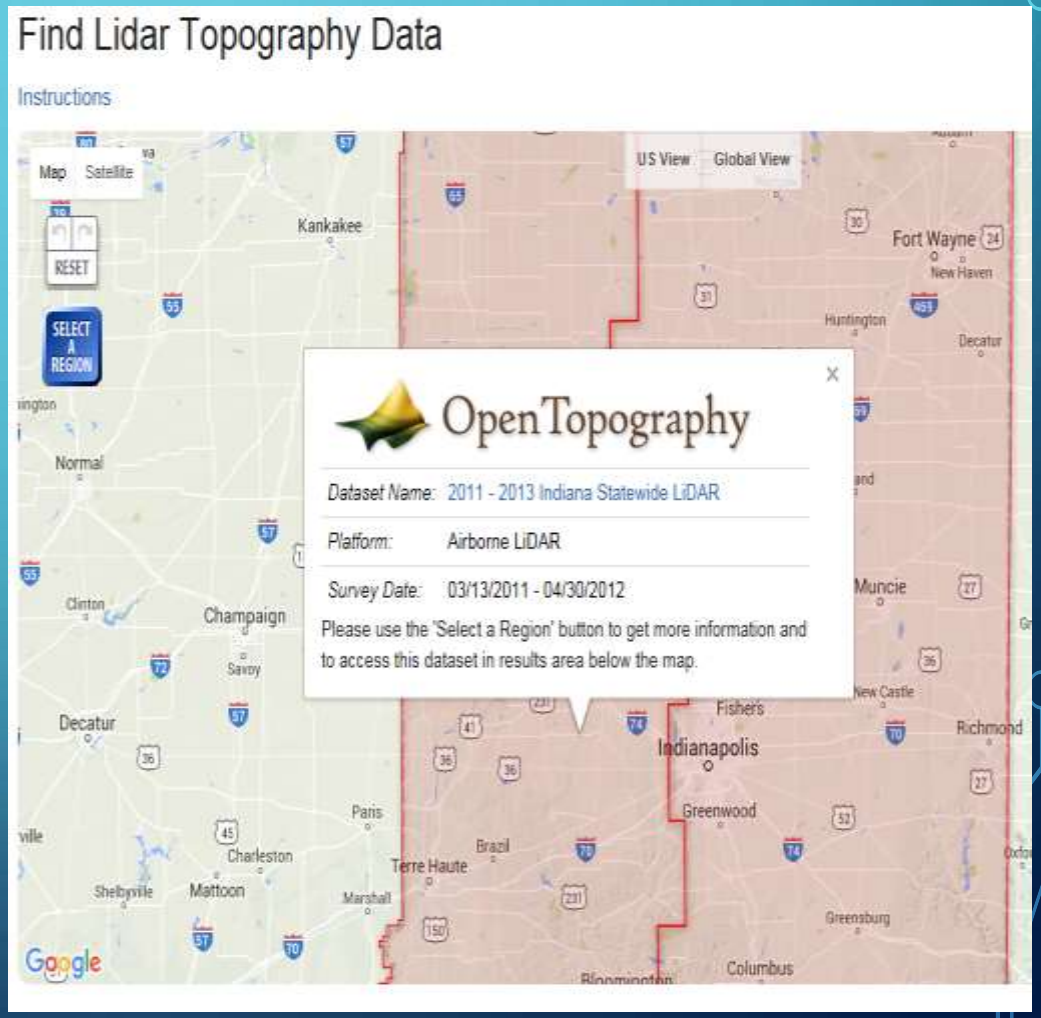
(misclassified Ground and Building

OPEN TOPOGRAPHY

- www.opentopography.org
- Stores all of Indiana's LiDAR and related DEM files for free download
- Map browser allows you to draw an area of interest to download
- OT Processing will merge multiple source files into one download for each selected product
  - Tiles of original delivery files are spliced together for you by OT processing
  - Note: TauDEM generated files will be split into new strips by the processing
- Bulk download options are available. See help links on the OT site for more info.

DOWNLOADING DEMS FROM OPEN TOPOGRAPHY

- From the home page, click *Data*
- Zoom in to Indiana
- Click the east or west zone on map
- Click the 2011-2013 Indiana Statewide LiDAR link in the pop-up

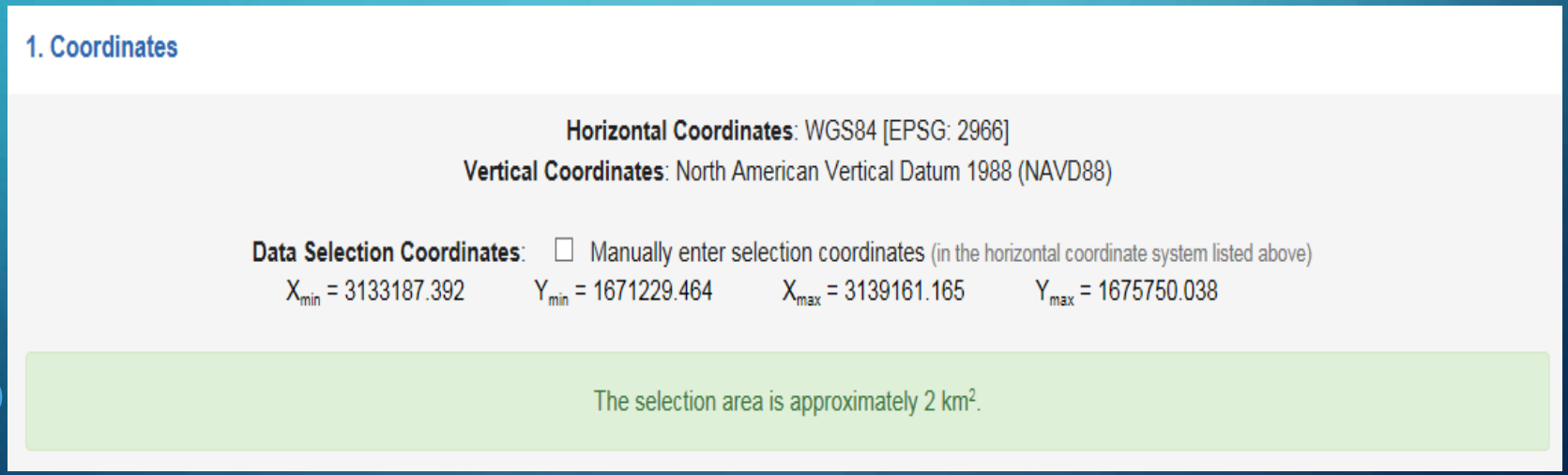


DOWNLOADING DEMS FROM OPEN TOPOGRAPHY

- Click the Raster link for area needed (IN West or IN East)
- Note: Point Cloud Data is raw lidar in .LAS format
- Zoom in to your desired project area
- Click *Select A Region* button.
- Draw a rectangle around project area

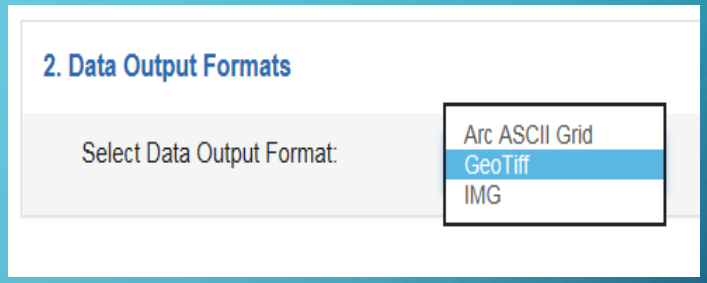
DOWNLOADING DEMS FROM OPEN TOPOGRAPHY

- Coordinates: X,Y for extent drawn are listed in State Plane Feet
  - Values have option to be edited if you have coordinates for desired extent
  - Note: EPSG code indicates NAD83 based system despite onscreen text



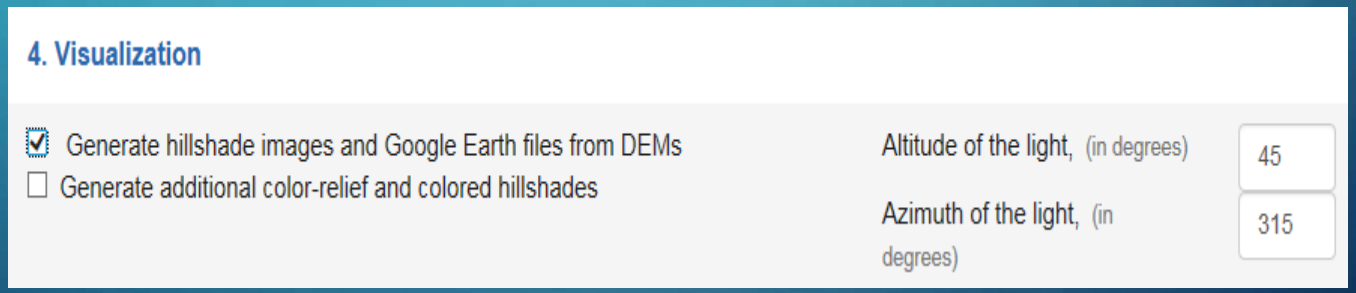
DOWNLOADING DEMS FROM OPEN TOPOGRAPHY

- Data Output Formats: GeoTiff
  - Required if using TauDEM
  - Embedded x,y coordinates
  - Relatively large file format; no compression thus no data loss
- Layer Types: Bare Earth



DOWNLOADING DEMS FROM OPEN TOPOGRAPHY

- Visualization (Optional):
  - Not needed if not using Google Earth.
  - We can generate our own visualization surfaces and control the algorithms using GIS if we want to create these layers.
  - If used, accept default Altitude (45) & Azimuth (315).

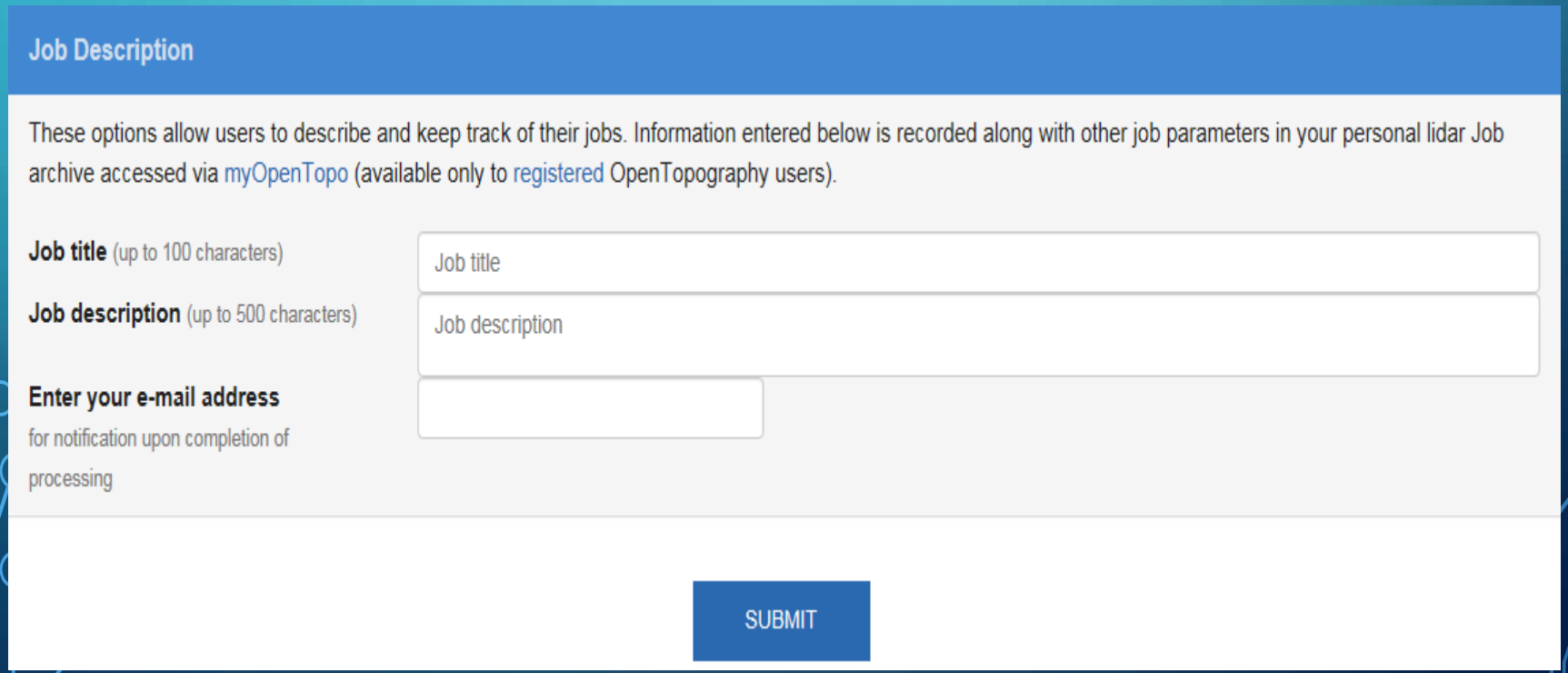


TAUDEM

- TauDEM options process the Bare Earth to prep various layers for use in hydrologic modeling
- The original Bare Earth DEM will be processed and slightly smoothed
- Low lying areas will “fill up” until water can “runoff” the area
- Am I doing hydrography related analyses in dendritic terrain?
  - Yes: Run TauDEM
  - No: Stick to the Bare Earth and post-process it yourself

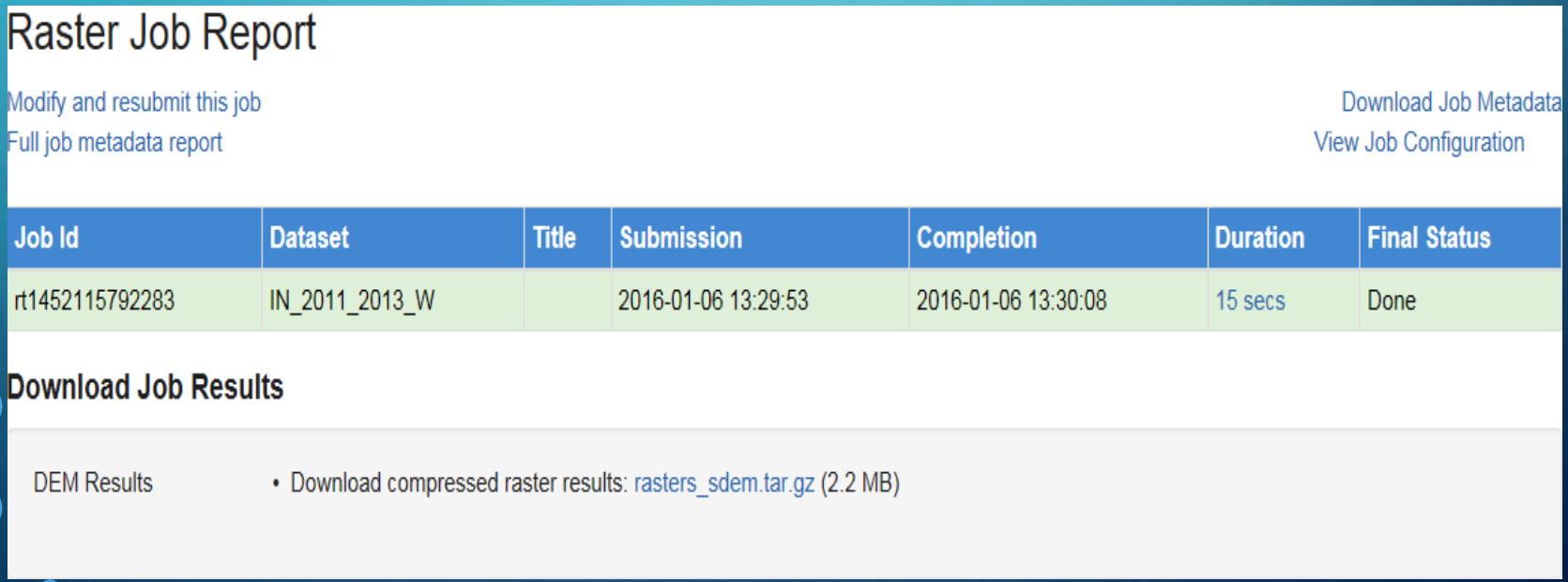
DOWNLOADING DEMS FROM OPEN TOPOGRAPHY

- Enter job title, description, and e-mail address
- Click Submit



DOWNLOADING DEMS FROM OPEN TOPOGRAPHY

- Job Status Window opens & has download links after processing finishes. A copy of a link to access the window



DATA FORMATS

- Compressed files (tar.gz)
- Extract downloaded OT files with 7-zip (free) or WinZip (commercial)

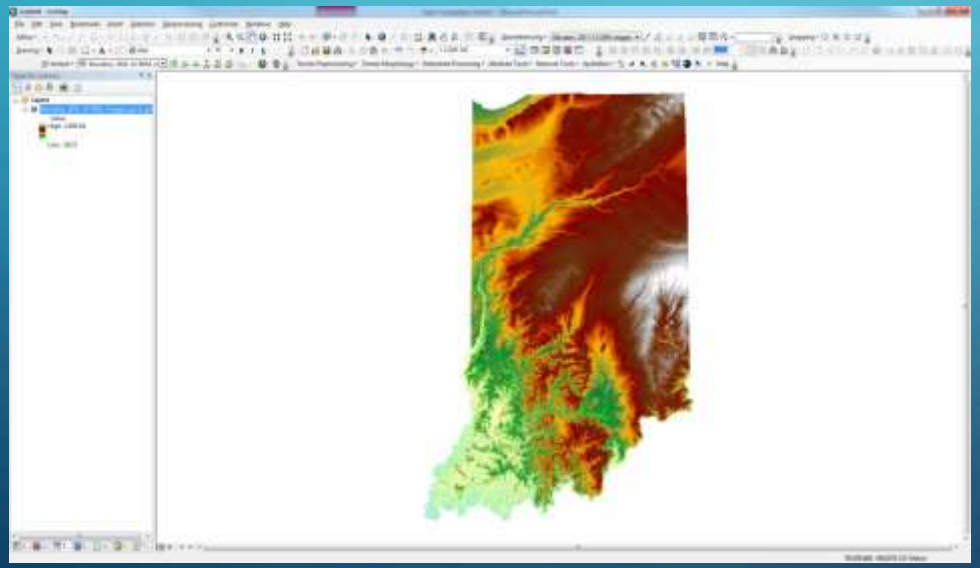
www.7-zip.org

INDIANA SPATIAL DATA PORTAL

- gis.iu.edu

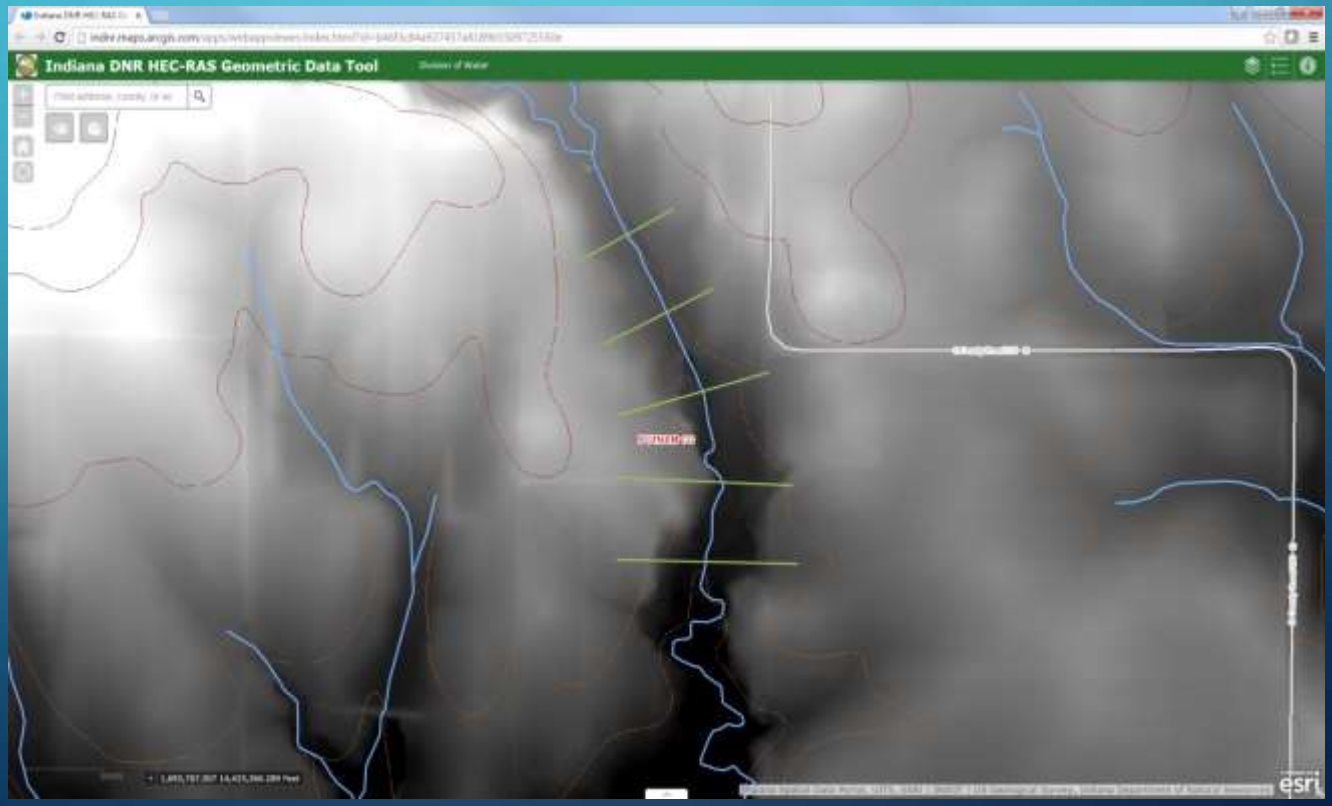
STATE OF INDIANA IMAGERY REST SERVICE

- https://imagery.gis.in.gov/arcgis/rest/services/Elevation/Statewide_DEM_11_13/ImageServer



INDIANA DNR HEC-RAS GEOMETRIC DATA TOOL

- http://dnrmaps.dnr.in.gov/apps/stepc.htm



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