



**Association of State  
Floodplain Managers**



# **Cooperating Technical Partner (CTP) Information Exchange**

## **Elevation Data Collection using LiDAR**

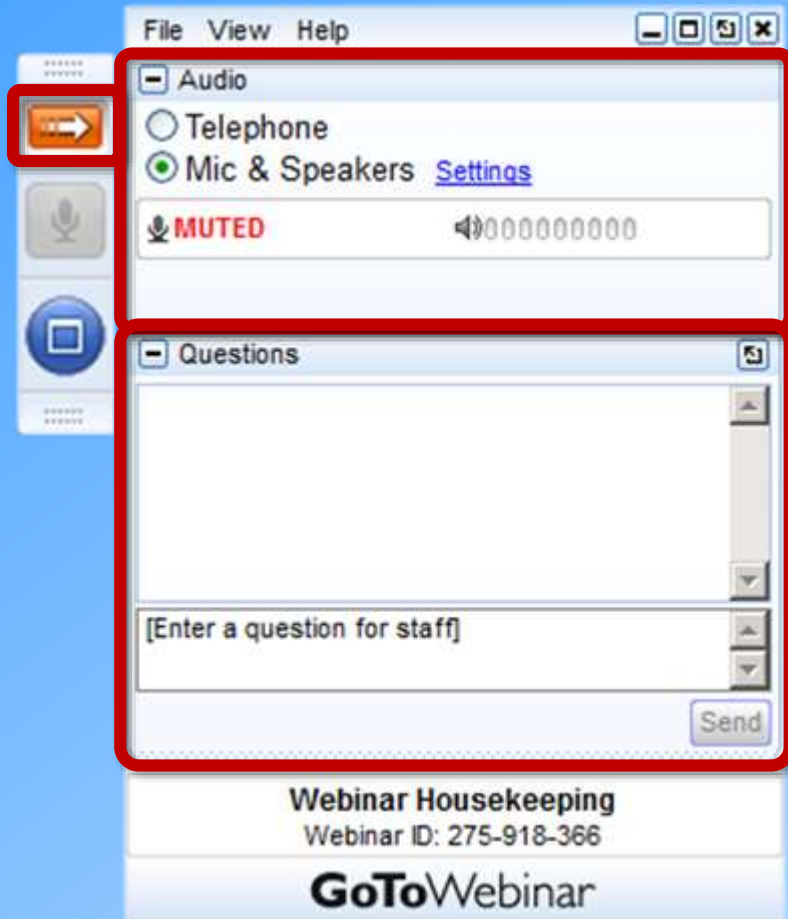
May 19, 2016  
2:00-3:30 Eastern Time



**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



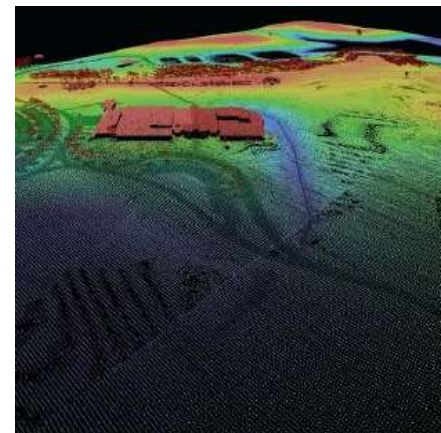
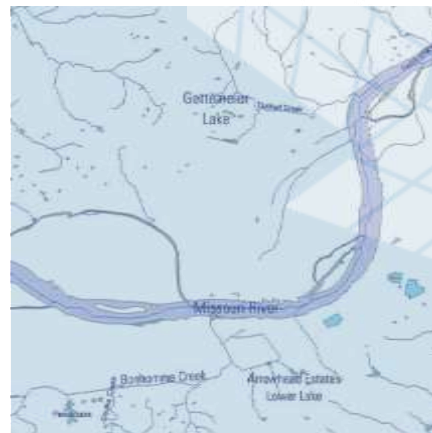


# Agenda

- 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***



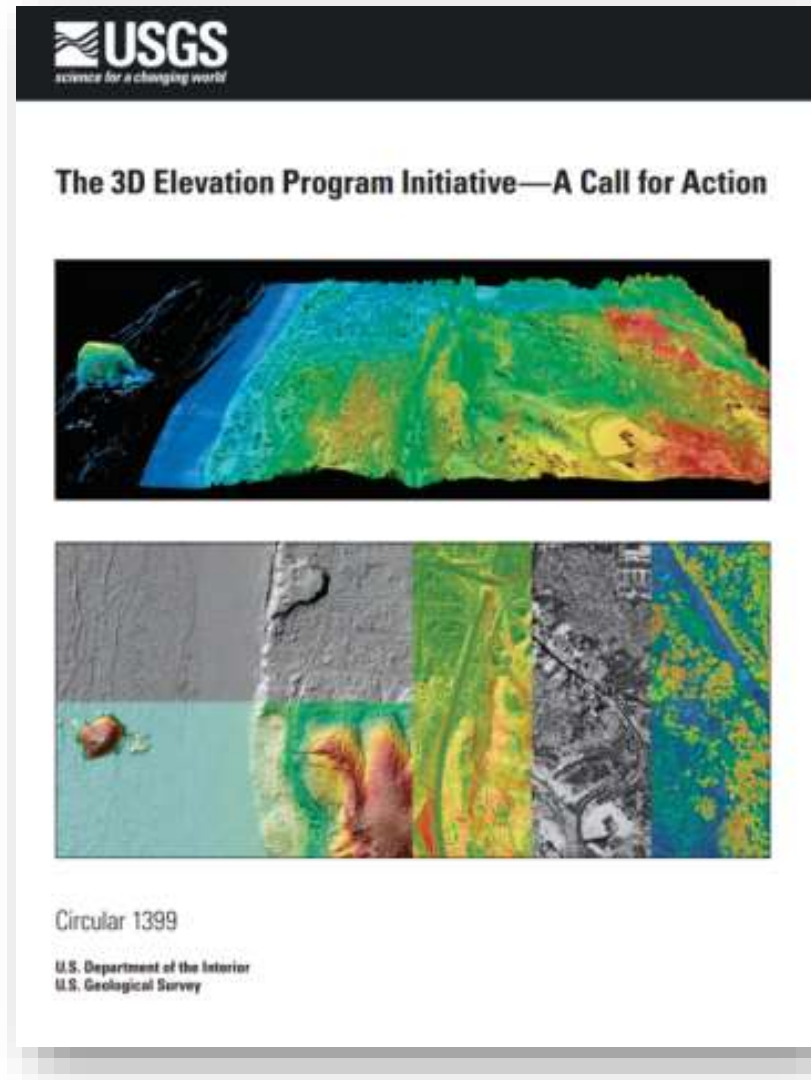
May 18, 2016



# + 3D Elevation Program (3DEP)

## Overview

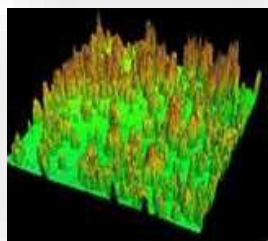
- 3DEP Overview
- 3DEP feeds The National Map
  - Elevation
  - Hydrography
- 3DEP
  - Data Acquisition
    - Specifications
    - Contracts / SOW
    - QA/QC
  - Products and Services



# + The National Map

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Geospatial products and services support key priorities



**The National Map**  
Your Source for Topographic Information

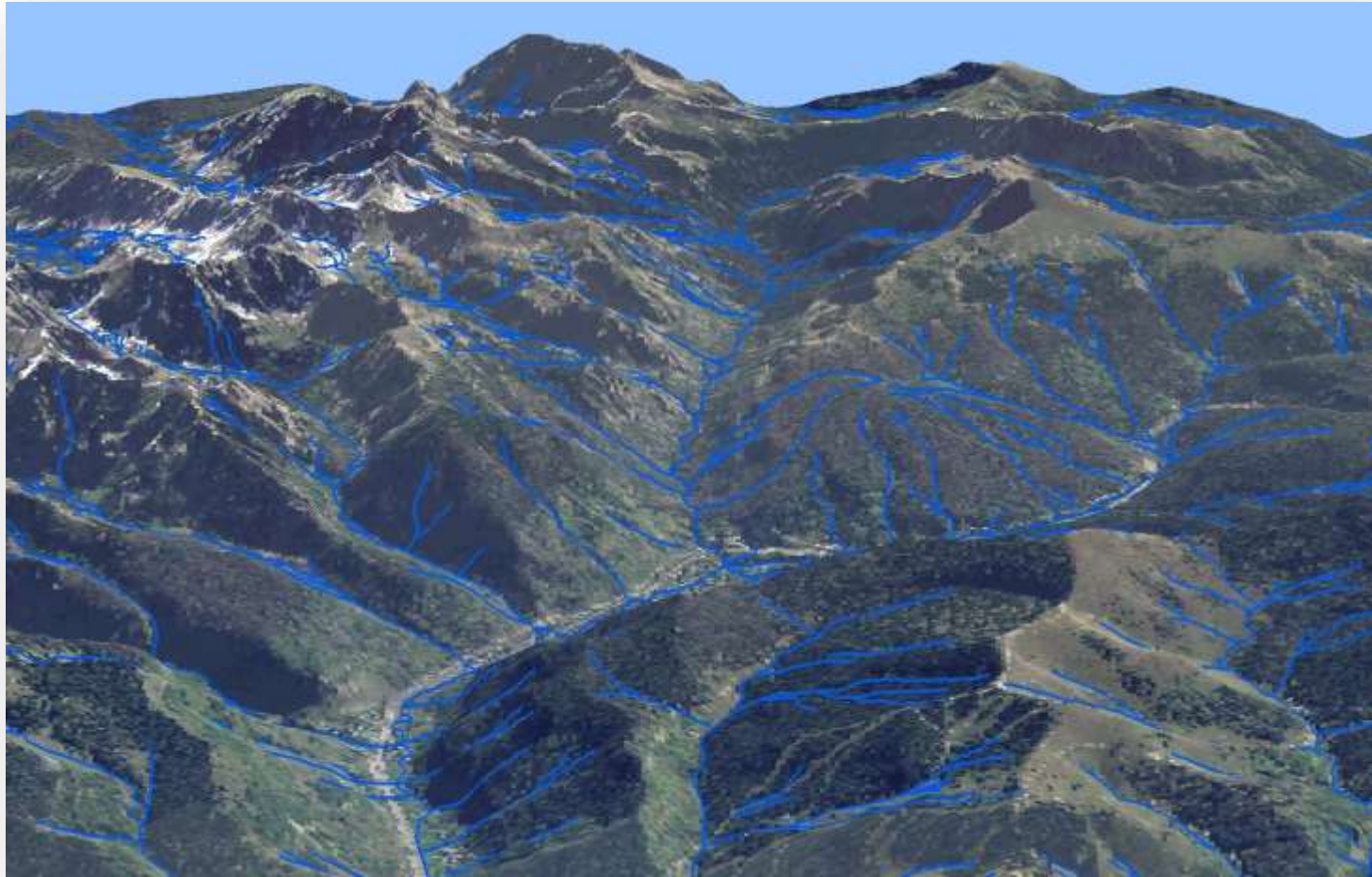
Area of National Leadership	Program Emphasis	DOI/Administration Priorities Supported
A-16 Lead for Terrestrial Elevation	3D Elevation Program (3DEP)	<ul style="list-style-type: none"> <li>• Climate Resilience</li> <li>• Building a Landscape-Level Understanding of our Resources</li> <li>• Ensuring Healthy Watersheds and Sustainable, Secure Water Supplies</li> <li>• Powering Our Future and Responsible Use of Our Resources</li> <li>• Enhancing America's Great Outdoors</li> </ul>
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

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# 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

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

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

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

### 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

2016

2017

2018

2019

FUTURE STATE



# + 3D Elevation Program (3DEP)

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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



# + 3D Elevation Program (3DEP)

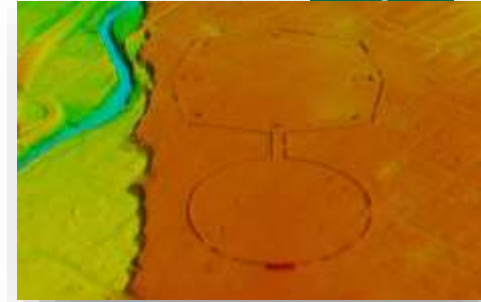
## Mission Critical Applications



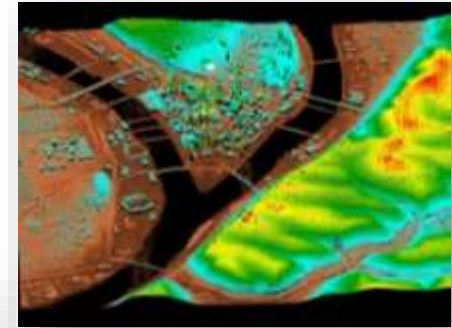
**Flood Risk Management**



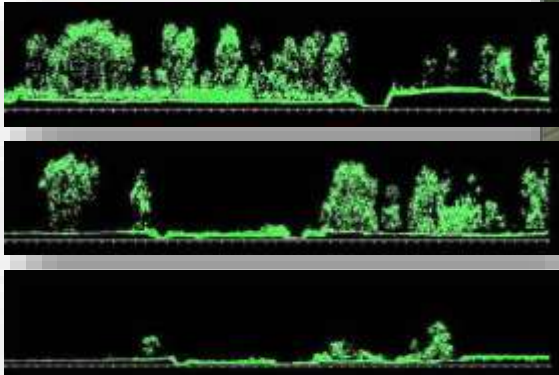
**Alternative Energy**



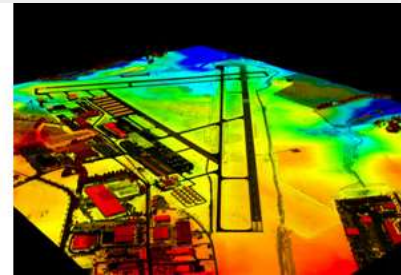
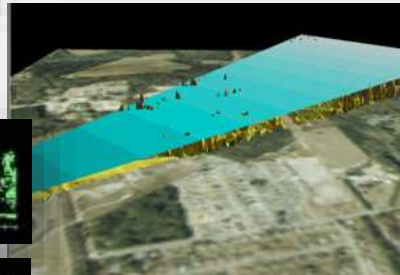
**Archaeology**



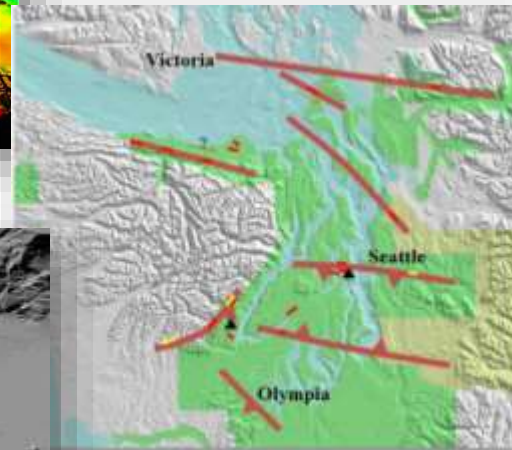
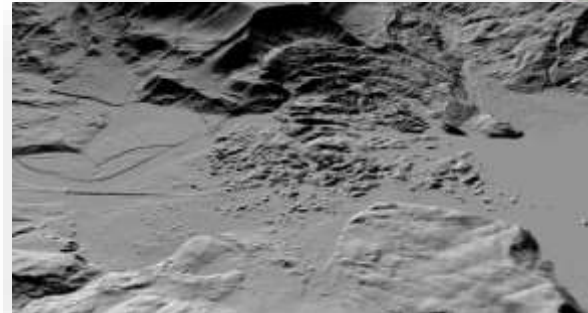
**Infrastructure Management**



**Precision Forestry**



**Aviation Safety**



Holocene Tectonics: Pt. Ralph Augerod, USGS

**Geologic Hazards**

# + 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



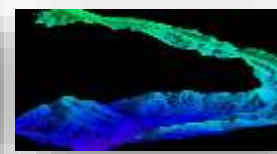
Infrastructure  
Management



Flood Risk Mitigation



Precision Farming



Land Navigation  
and Safety

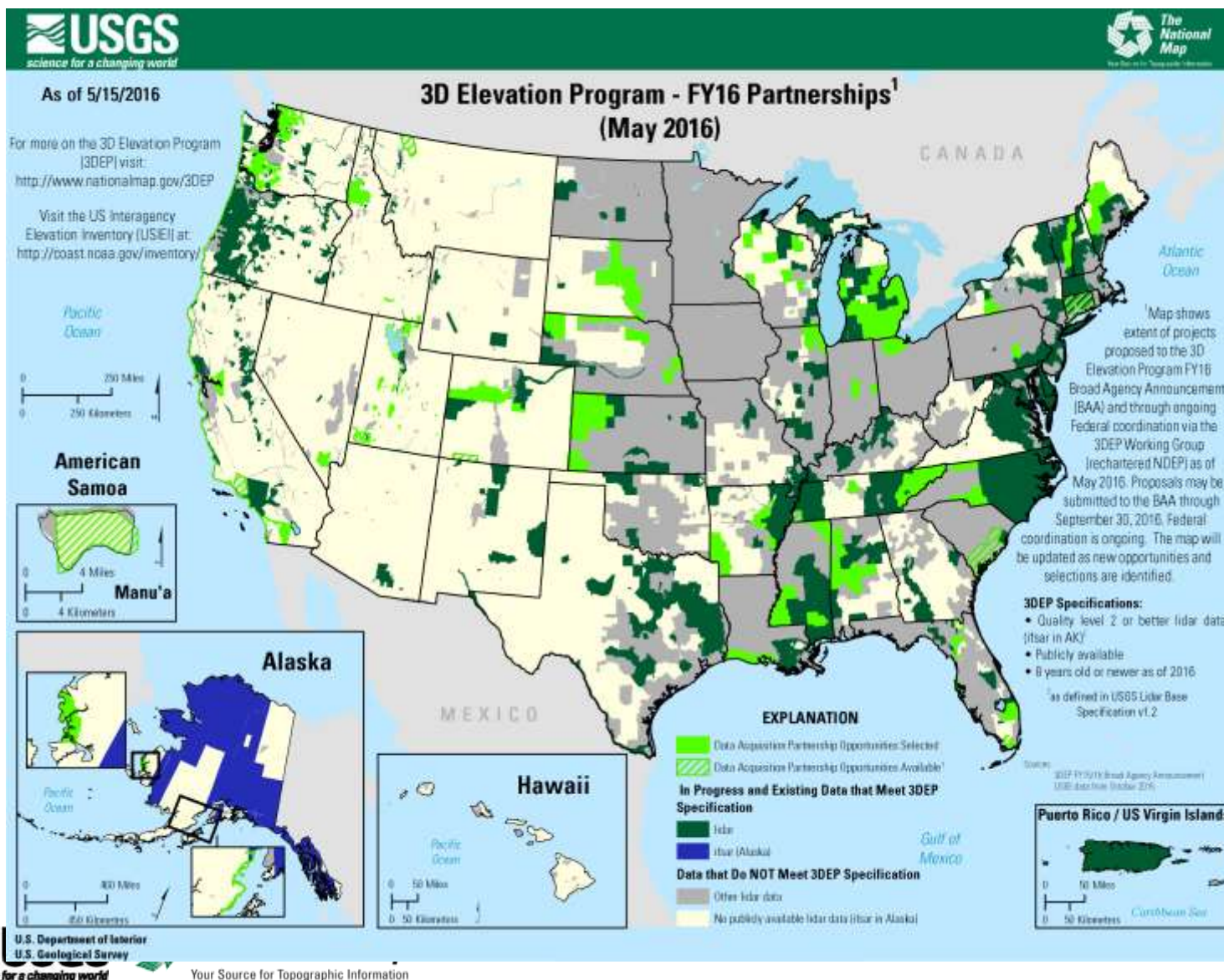


Geologic Resources and  
Hazards Mitigation



# + 3DEP Status

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# + 3DEP Data Acquisition

## Contracting Mechanisms

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**GPSC**  
Geospatial  
Products and  
Services  
Contracts

Financial  
Assistance  
(State or  
Local  
Contracts)

Contributed  
Data (State  
or Local  
Contracts)

**3DEP Source Data**

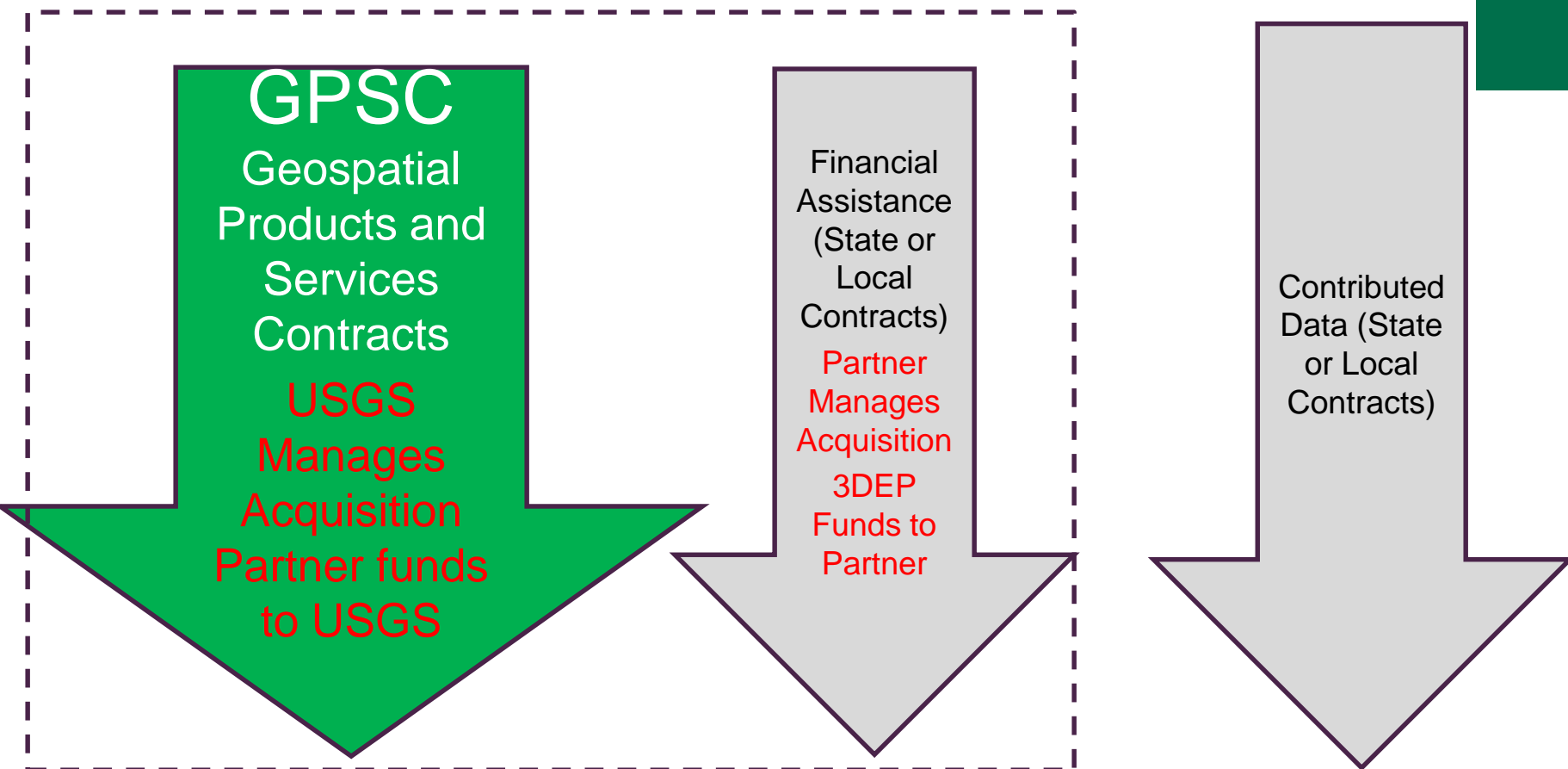
(Metadata, Raw Point Cloud, Classified Point Cloud, Bare Earth Surface, Breaklines)



# + 3DEP Data Acquisition \$

## Partnership Opportunities

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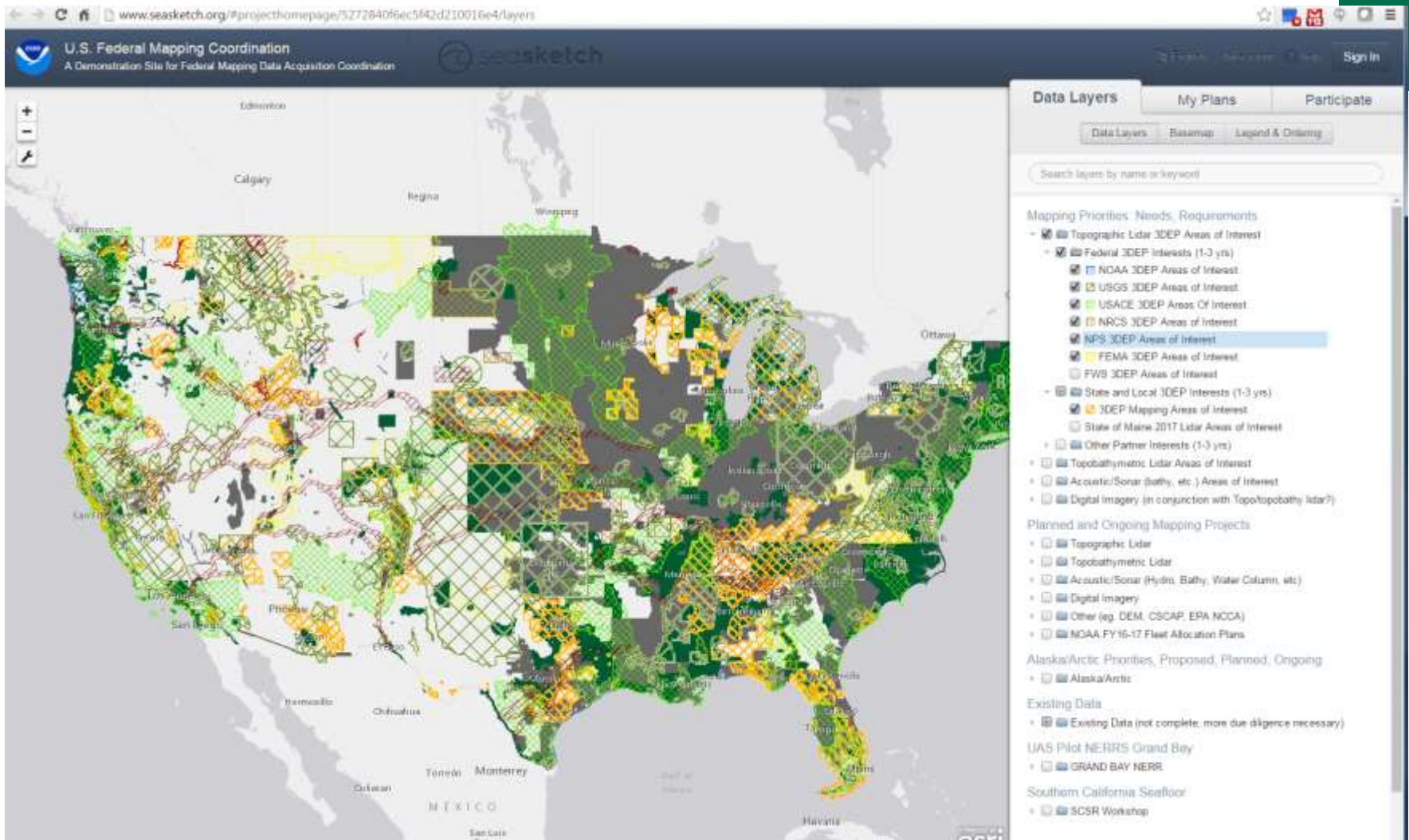


## Broad Agency Announcement (BAA)



# FY16 3DEP Partnerships

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



# FY16 3DEP Partnerships

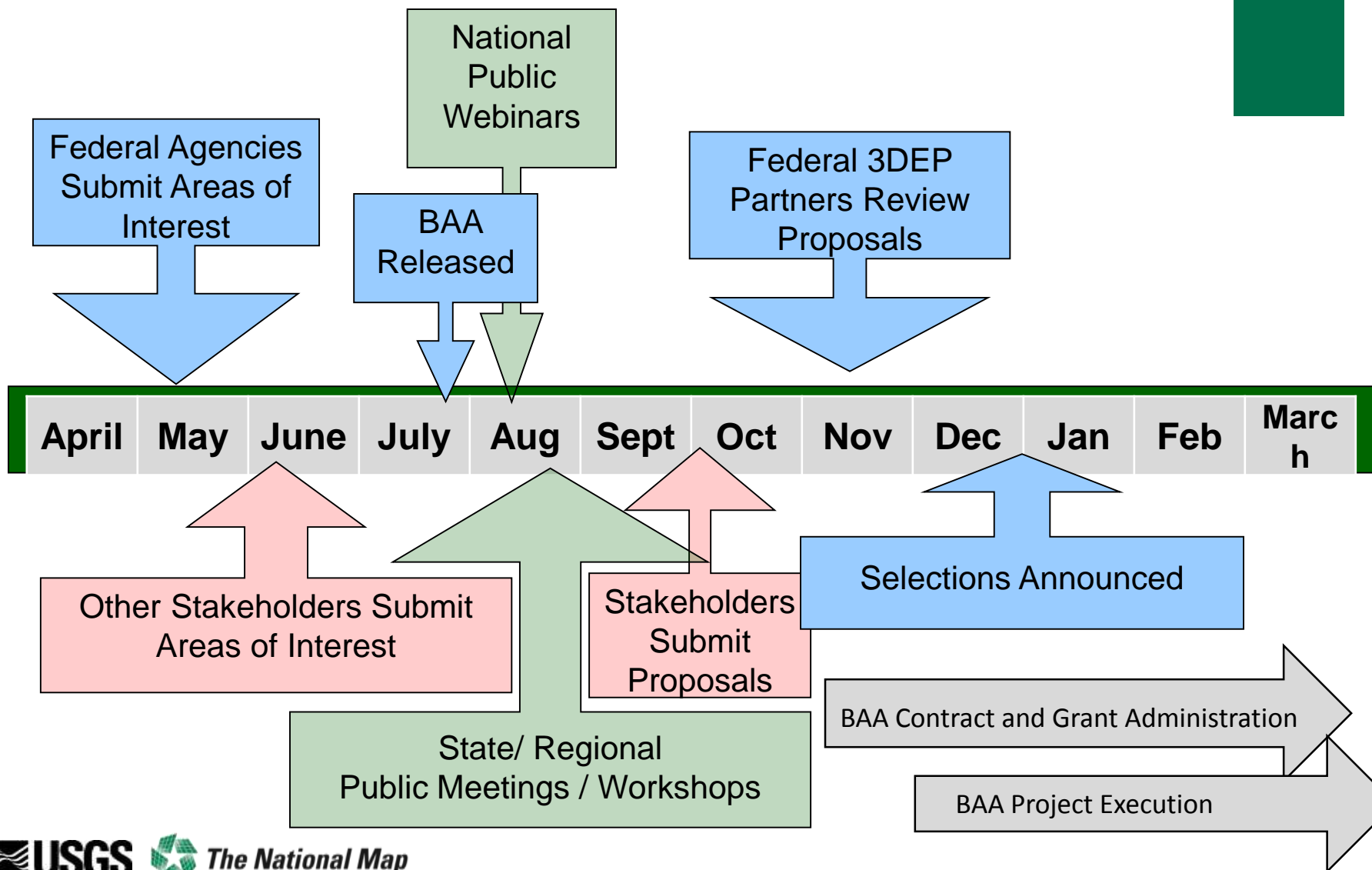
## BAA

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

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# + 3DEP Data Acquisition

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## GPSC



GPSC  
Geospatial  
Products and  
Services  
Contracts

- 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)

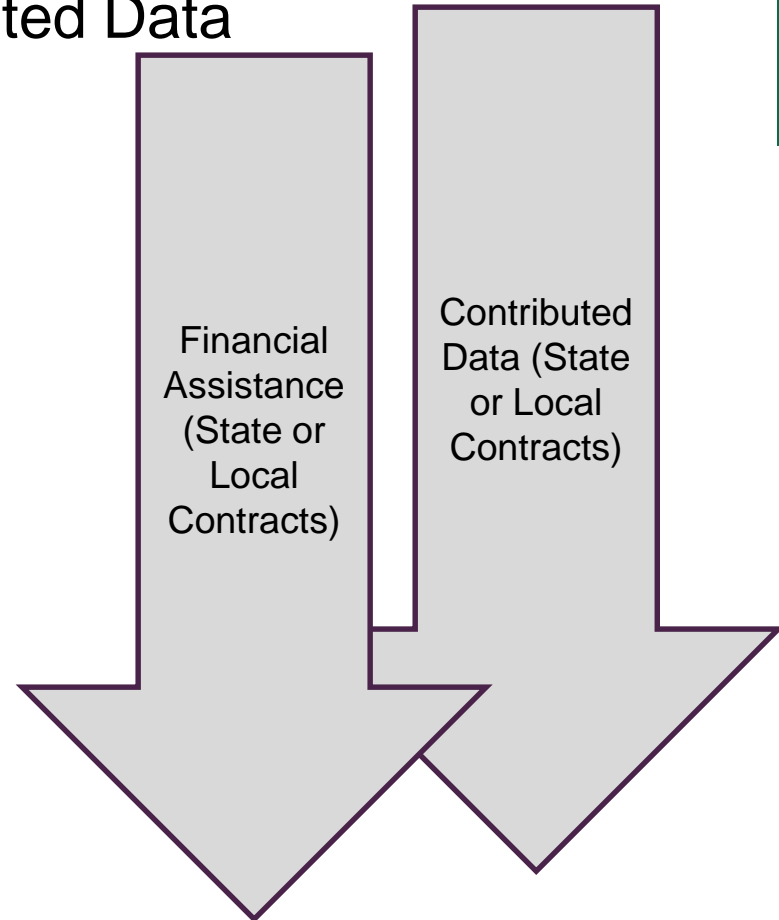


# + 3DEP Data Acquisition

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## 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

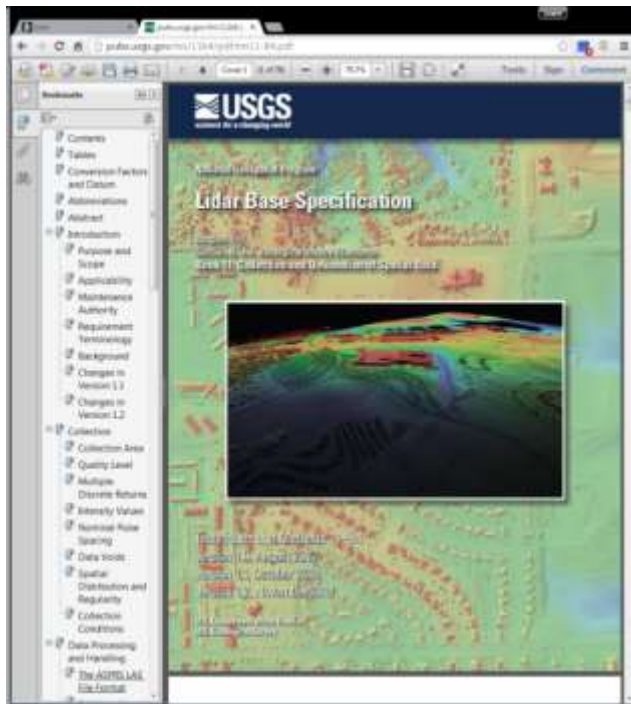


## 3DEP Source Data

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

# + 3DEP Data Acquisition

## Specifications, Contract Language, Scope of Work

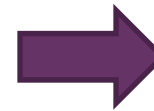


### C.3 Final Data Delivery

#### 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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#### Appendix A. Municipality of Big Mountain LIDAR Topographic Surveying Services Scope of Work

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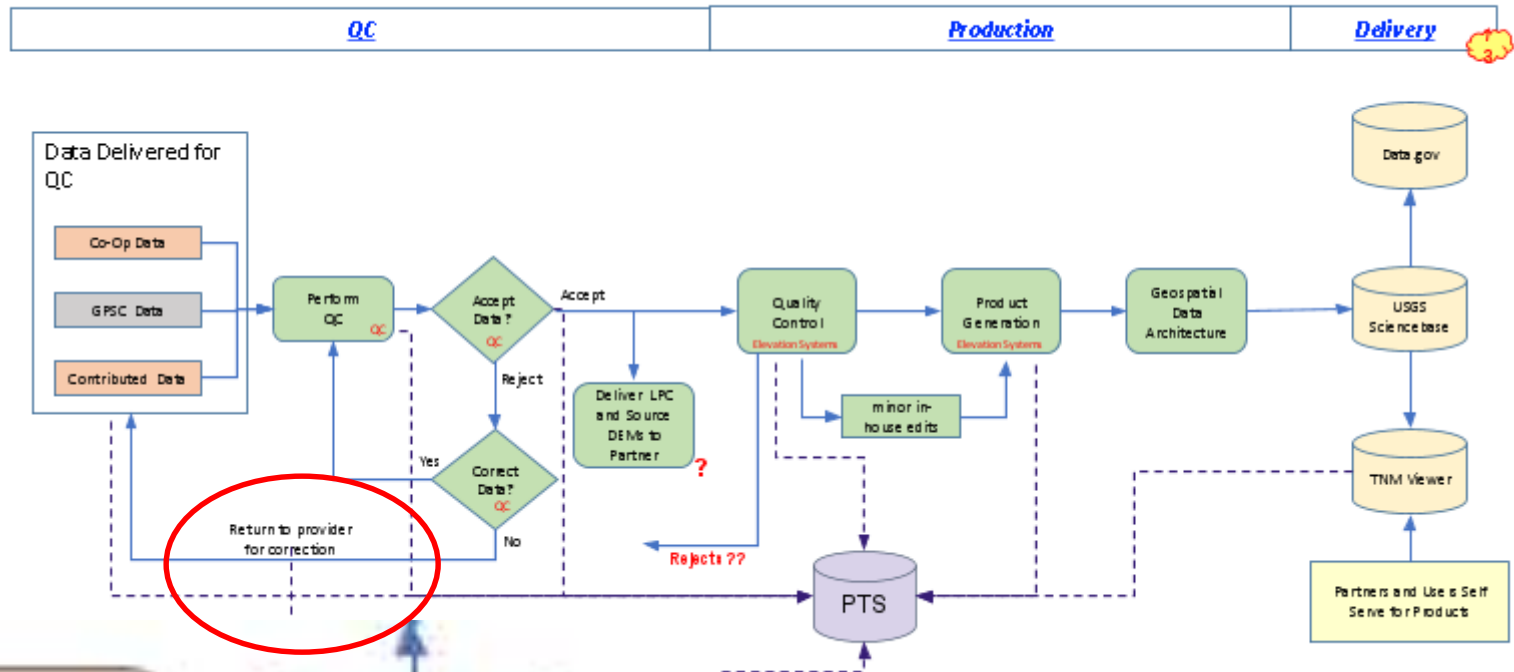
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Collection Conditions	3
Project Tasks	3
1.0 Project Initiation	3
2.0 LIDAR Acquisition	4
3.0 Processing	4
Schedule	5
Deliverables	6
Project Management	7
Pricing	9

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

# + 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

## 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

**3D Elevation Program (3DEP)**

[The National Map home](#) [The National Map 3DEP](#) [About 3DEP Products & Services](#)

**About** [News](#) [Get Data](#) [Data Partnership Opportunities](#) [Benefits](#) [Resources](#) [Contact Us](#)

**About 3DEP Products and Services**

The 3DEP products and services available through The National Map consist of standard digital elevation models (DEMs) at various horizontal resolutions, elevation source and associated datasets, an elevation point query service and bulk point query service. All 3DEP products are available, free of charge and without use restrictions. To download 3DEP products visit: <http://viewer.nationalmap.gov/basic/>

For the latest information on 3DEP Products and Services, visit our [3DEP Product News](#) page.

**Standard DEMs** represent the topographic surface of the earth and contain flattened water surfaces. Each DEM dataset is identified by its horizontal resolution and is produced to a consistent set of specifications. Standard DEMs are characterized either as project-based or seamless. Project-based DEMs are available for the full areal extents of projects when produced from light detection and ranging (lidar), or as one-degree blocks with overedge when produced from IFSAR. Seamless DEMs are produced by blending only the highest quality project data into a continuous terrain surface for the U.S. These data are distributed in files that can be merged to support analysis across large geographic areas.

**Project-based**

- **1-meter** - This dataset was introduced in 2015 with limited coverage of the U.S., but will be expanding as new DEMs from 3DEP quality level 2 or better lidar data are acquired. Horizontal coordinates are referenced to the Universal Transverse Mercator projection.
- **1/9 arc-second** - This dataset covers about 25 percent of the conterminous U.S. and is produced from 3-meter or higher resolution DEMs acquired by the USGS prior to January 2015. Horizontal coordinates are referenced to geographic coordinates (longitude, latitude). The 1/9 arc-second dataset will no longer be updated with newly acquired DEMs; however, it will continue to be distributed.
- **5 meter** - This dataset is comprised of 5-meter IFSAR-derived DEMs (3DEP quality level 5) over Alaska only. Horizontal coordinates are referenced to Albers Equal Area Conical projection.

**Seamless\***

- **1/3 arc-second** - This is the highest resolution seamless DEM dataset for the U.S. with full coverage of the 48 conterminous states, Hawaii, and U.S. territories. Alaska coverage is partially available now and is being expanded to statewide coverage as part of the Alaska Mapping Initiative. Ground spacing is approximately 10 meters north/south, but variable east/west due to convergence of meridians with latitude.
- **1 arc-second** - This is a lower resolution seamless dataset providing complete coverage over the conterminous U.S. and partial coverage of Alaska. Most of Canada and Mexico are also covered by the 1 arc-second dataset. Ground spacing is approximately 30 meters north/south, but variable east/west depending on latitude.
- **2 arc-second** - This seamless dataset is the lowest resolution seamless dataset available and covers only Alaska. Although ground spacing is approximately 60 meters north-south, east-west spacing can vary from 35 meters in southern Alaska to 20 meters on the North Shore.

**Source Data Products** include lidar point clouds, source (original) resolution DEMs from which the 3DEP standard DEM datasets were produced, and additional data types produced from IFSAR collections.

- **Lidar point cloud** - These data are the foundational data for 3DEP in the conterminous U.S., and contain the original three-dimensional information from which the DEM products are derived. Most of the data collected in 2014 and later meet 3DEP specifications for quality level 2 nominal pulse spacing and vertical accuracy, and data collected prior to 2014 often do not meet the quality level 2 specification. Distinctions in nominal pulse spacing are provided in the lidar point cloud status graphics and in the download platform; however, other qualities such as vertical accuracy must be examined to determine if the data meet particular 3DEP quality level specifications.
- **IFSAR digital surface model (DSM)** - These 5 meter rasters, available only in Alaska, are the initial IFSAR product, before bare-earth filtering is done to create the DEMs. Man-made structures and vegetation are modeled in the DSM.
- **IFSAR orthorectified radar intensity image (ORI)** - These rasters (resolutions vary), available only in Alaska, are radar reflectance intensity recordings detected by the IFSAR sensor.
- **Source resolution DEMs** - these data are the original bare earth DEMs derived from lidar point cloud source. Source DEMs processed by the USGS after January 2015 are provided where the original DEM horizontal resolution or projection differ from the 3DEP standard DEM datasets.

[http://nationalmap.gov/3DEP/3dep\\_prodserv.html](http://nationalmap.gov/3DEP/3dep_prodserv.html)

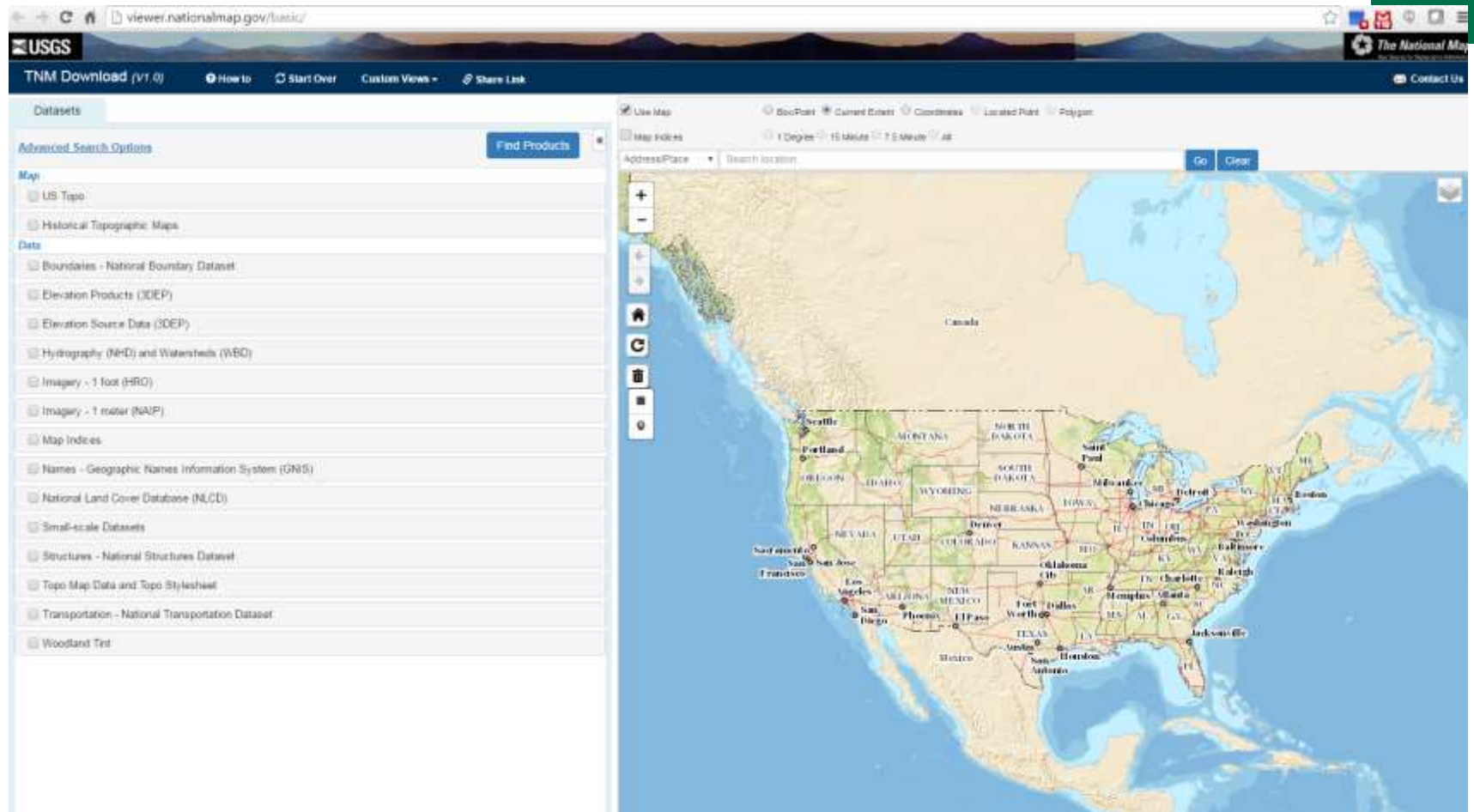




# 3DEP Products and Services

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## The National Map



# + 3DEP Products and Services

## The National Map

☒ Elevation Products (3DEP)

### Product Search Filter

☐ All Subcategories

- ☐ 1 arc-second DEM  
[Show Availability](#)
- ☐ 1 meter DEM  
[Show Availability](#)
- ☒ 1/3 arc-second DEM  
[Show Availability](#)
- ☐ 1/9 arc-second DEM  
[Show Availability](#)
- ☐ 2 arc-second DEM - Alaska  
[Show Availability](#)
- ☐ 5 meter DEM (Alaska only)  
[Show Availability](#)
- ☐ Contours (1:24,000-scale)  
[Show Preview](#)

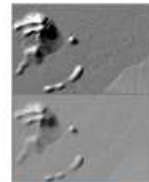
#### File Format

- ☒ ArcGrid
- ☐ GridFloat
- ☐ IMG

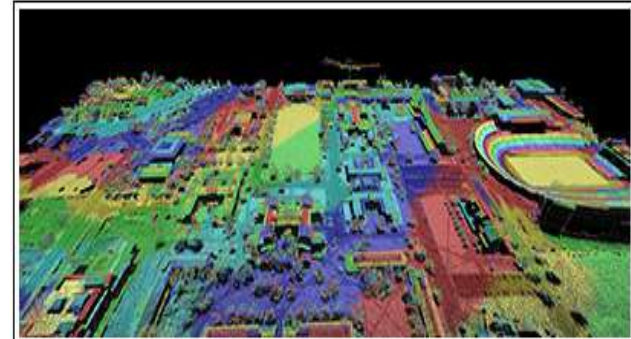
#### Data Extent

1 x 1 degree

[Availability legend](#)



Description



☒ Elevation Source Data (3DEP)

### Product Search Filter

☐ All Subcategories

- ☐ DEM Source (OPR)  
[Show Availability](#)
- ☐ Ifsar Digital Surface Model (DSM)  
[Show Availability](#)
- ☐ Ifsar Orthorectified Radar Image (ORI)  
[Show Availability](#)
- ☒ Lidar Point Cloud (LPC)  
[Show Availability](#)

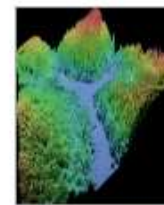
#### File Format

LAS

#### Data Extent

Varies

[Availability legend](#)



Description



# 3DEP Resources

31

## Resources [3DEP@usgs.gov](mailto:3DEP@usgs.gov)

### 3DEP Data Acquisition

[http://nationalmap.gov/3DEP/3dep\\_about.html](http://nationalmap.gov/3DEP/3dep_about.html)

Diane Eldridge

[deldridge@usgs.gov](mailto:deldridge@usgs.gov)

### 3DEP Products and Services

#### Integration of New Technologies

[http://nationalmap.gov/3DEP/3dep\\_prodserv.html](http://nationalmap.gov/3DEP/3dep_prodserv.html)

Jason Stoker

[jstoker@usgs.gov](mailto:jstoker@usgs.gov)

### Geospatial Products and Services Contract (GPSC)

[http://geodatacontracts.er.usgs.gov/gpsc\\_information\\_sheet.html](http://geodatacontracts.er.usgs.gov/gpsc_information_sheet.html)

Tim Saultz

[tsalutz@usgs.gov](mailto:tsalutz@usgs.gov)

### Lidar Base Specifications

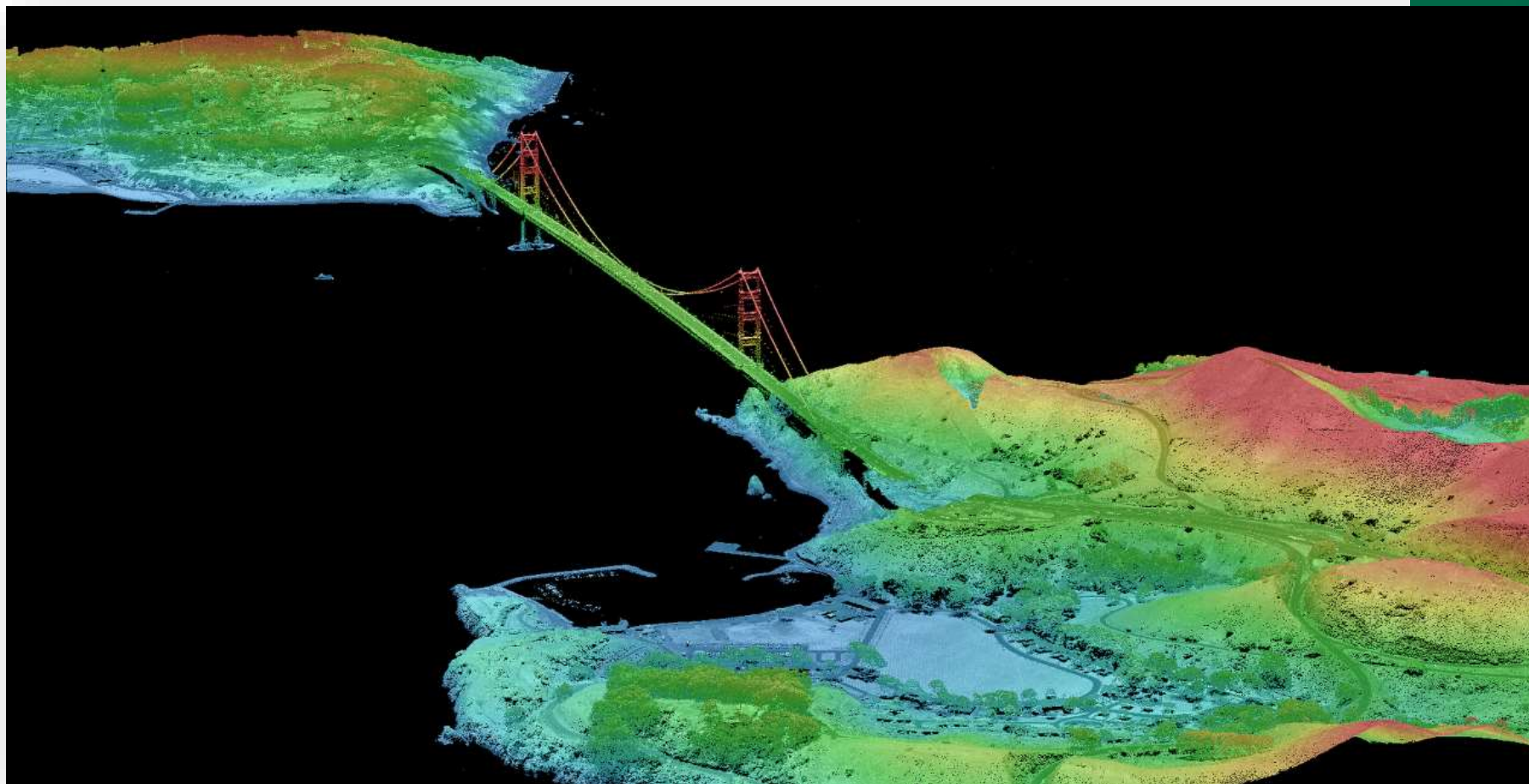
<http://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf>

Karl Heidemann

[kheidemann@usgs.gov](mailto:kheidemann@usgs.gov)

+ Thank you!

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# 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

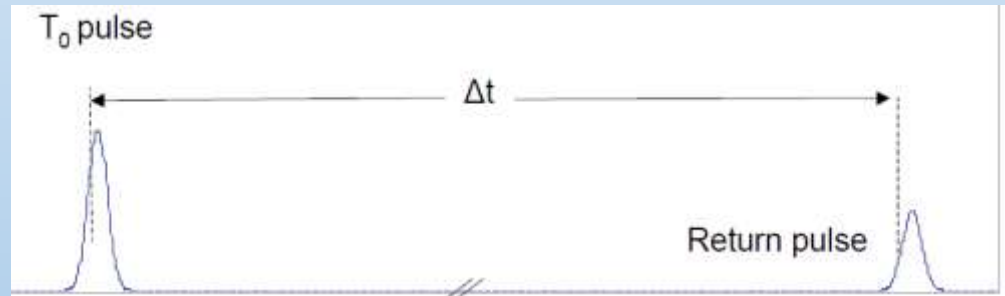
GeoCue Group, Inc.

[www.geocue.com](http://www.geocue.com)

# LIDAR Overview

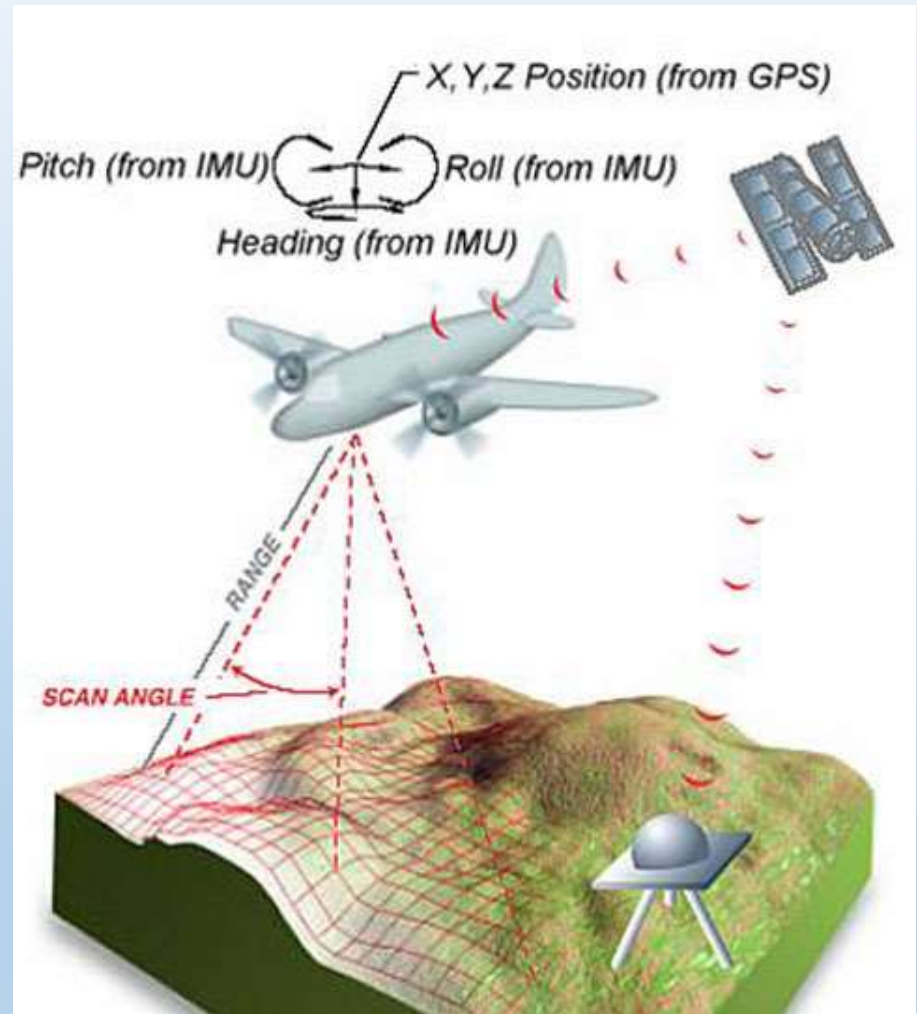
# What Is LIDAR?

- 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



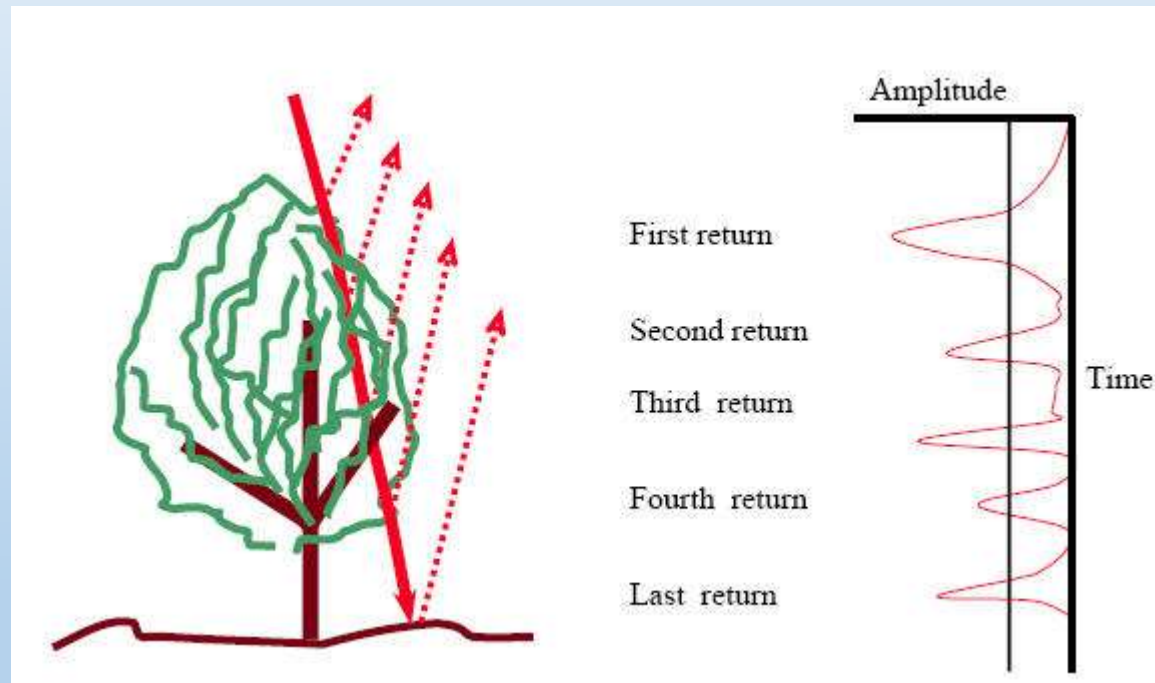
# How Does It Work?

- 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



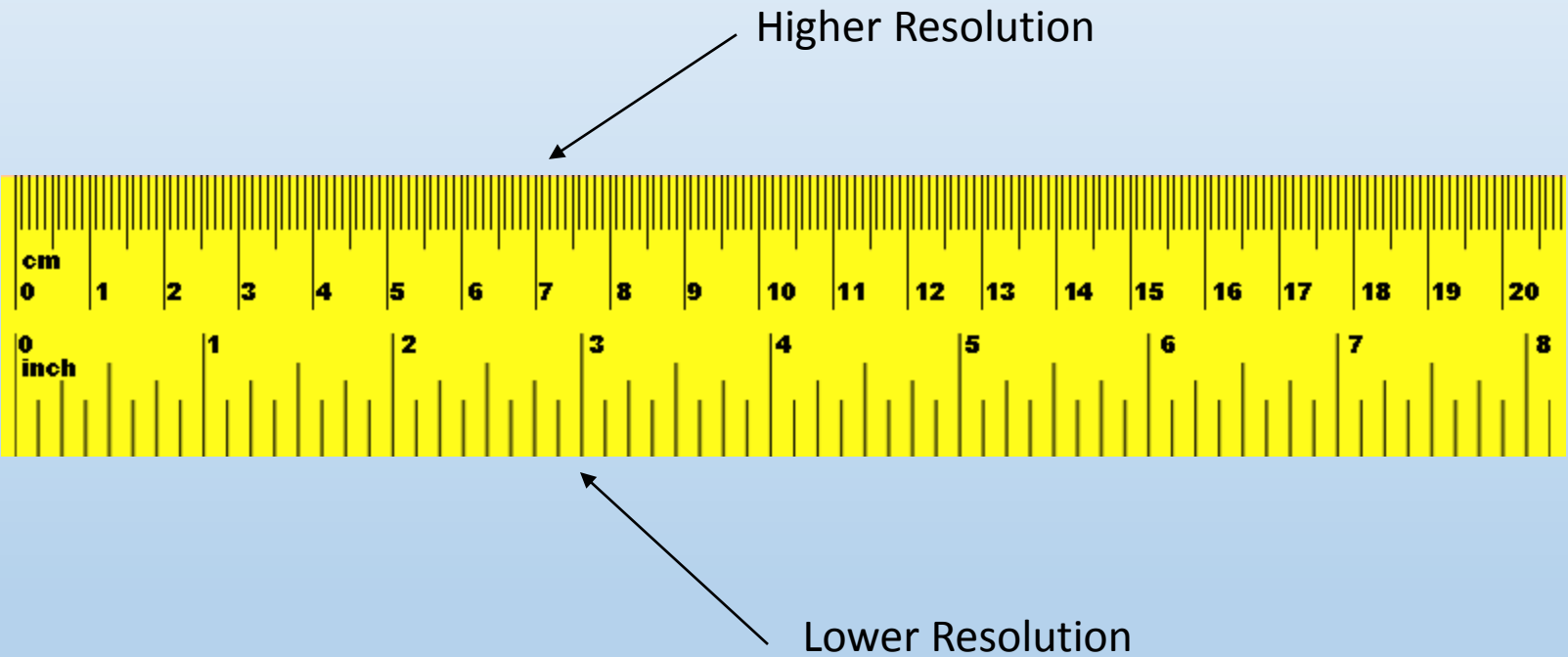
The notion of Return is extremely useful for automated algorithms. For example, only a last return (e.g. Return 3 of 3) can be a bare earth return.

# Important Point Attributes

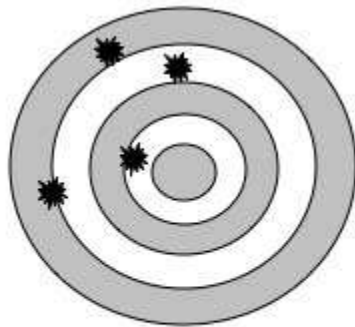
- Major attributes produced by the laser scanner:
  - Absolute time of pulse
  - Position (X, Y, Z)
  - Intensity
  - Return number (e.g. return “n of m”)
  - Edge of flight line
  - Scan angle
- All of the above are very important to advanced processing algorithms

Accuracy

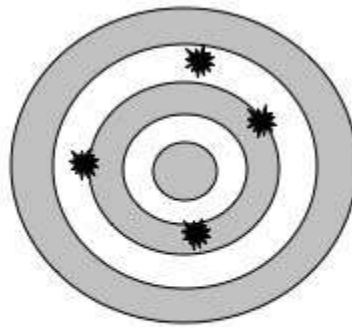
# Resolution



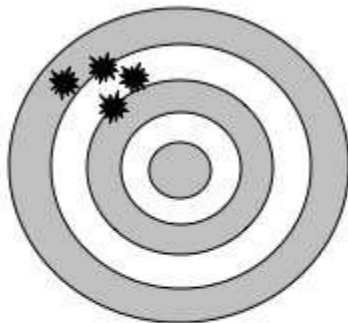
# Resolution, Accuracy and Precision



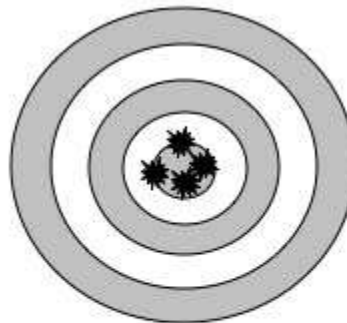
**Not Accurate  
Not Precise**



**Accurate  
Not Precise**



**Not Accurate  
Precise**



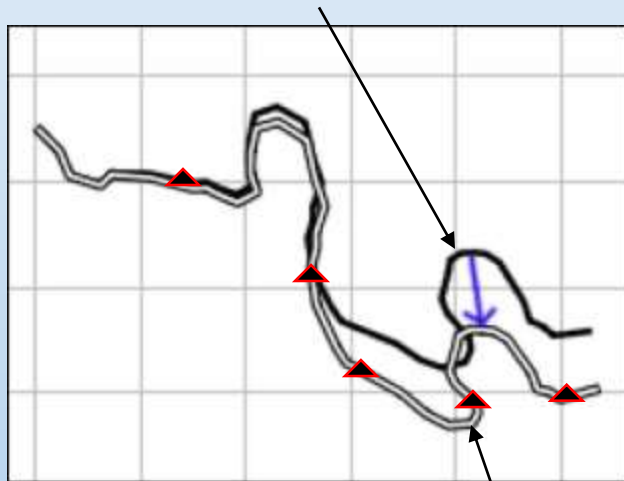
**Accurate  
Precise**

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



# Network and Local Accuracy

Poor Network Accuracy, Good Local Accuracy



(▲ = Network Control)

Good Network Accuracy, Good Local Accuracy

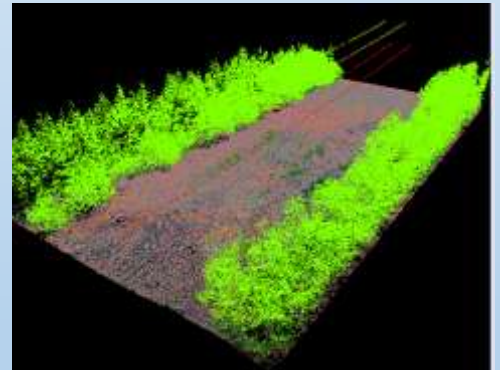
Network Accuracy – The degree to which positions agree with a reference network

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

# Specifying, Buying LIDAR

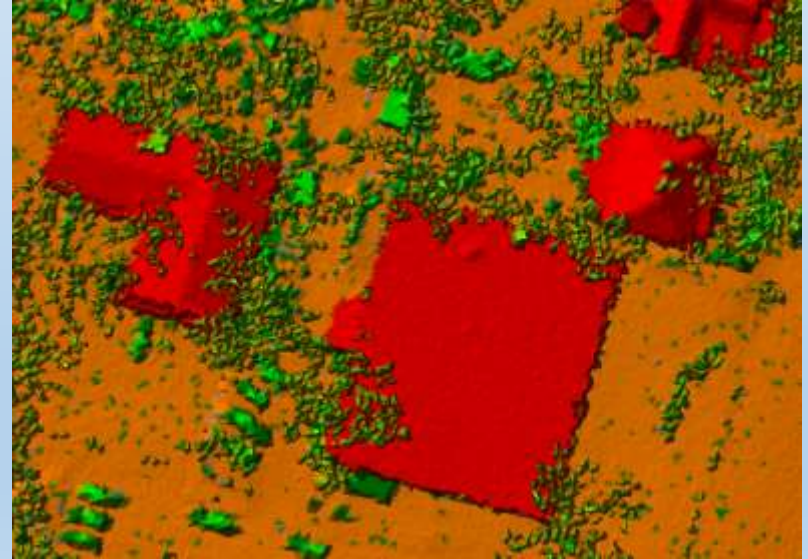
# Write a Data Use Plan!!

- 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](http://www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping). These guidelines and standards ([www.fema.gov/media-library/assets/documents/35313](http://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

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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

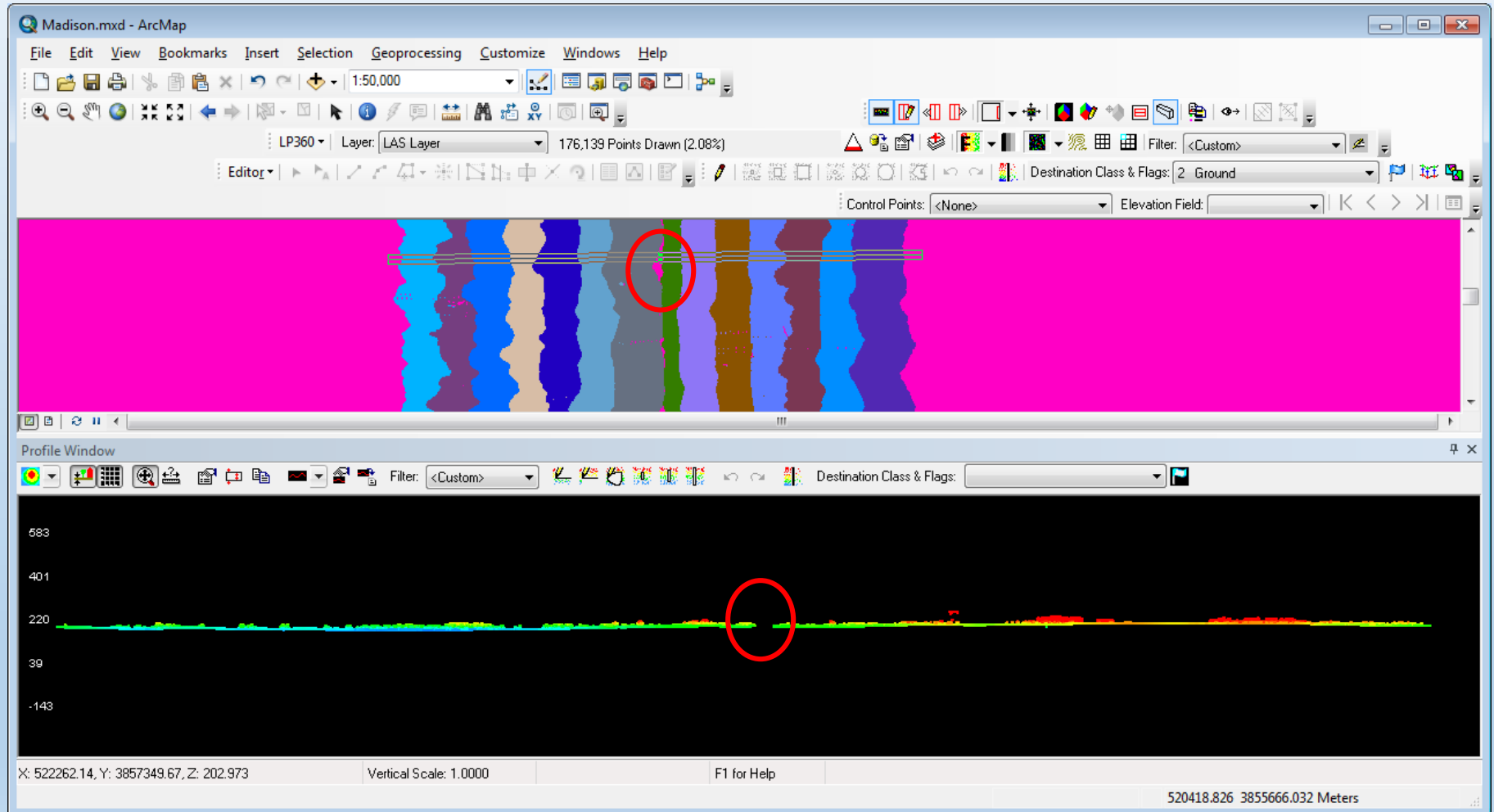


Thoughts on QC

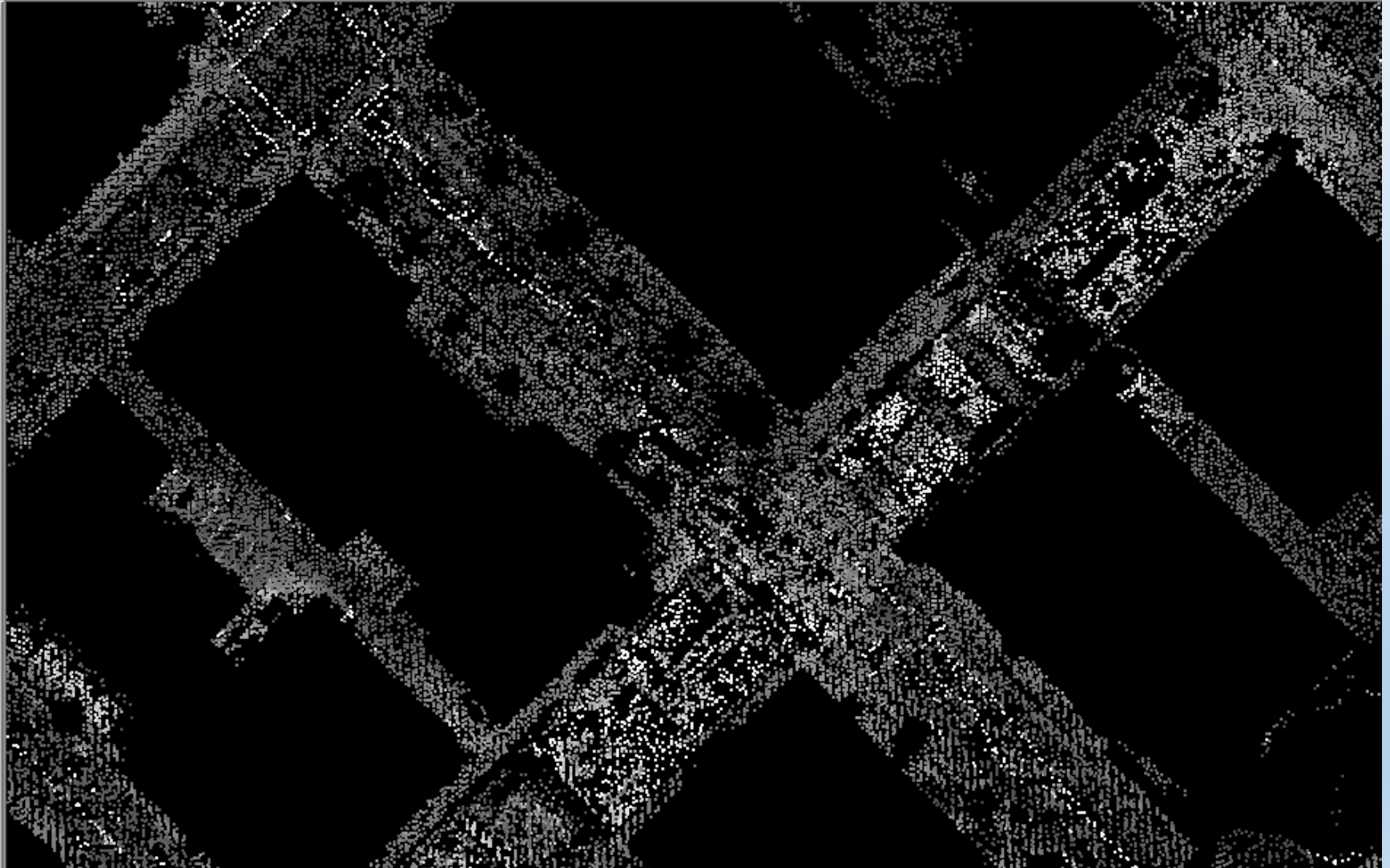
# Ignoring QC

- 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

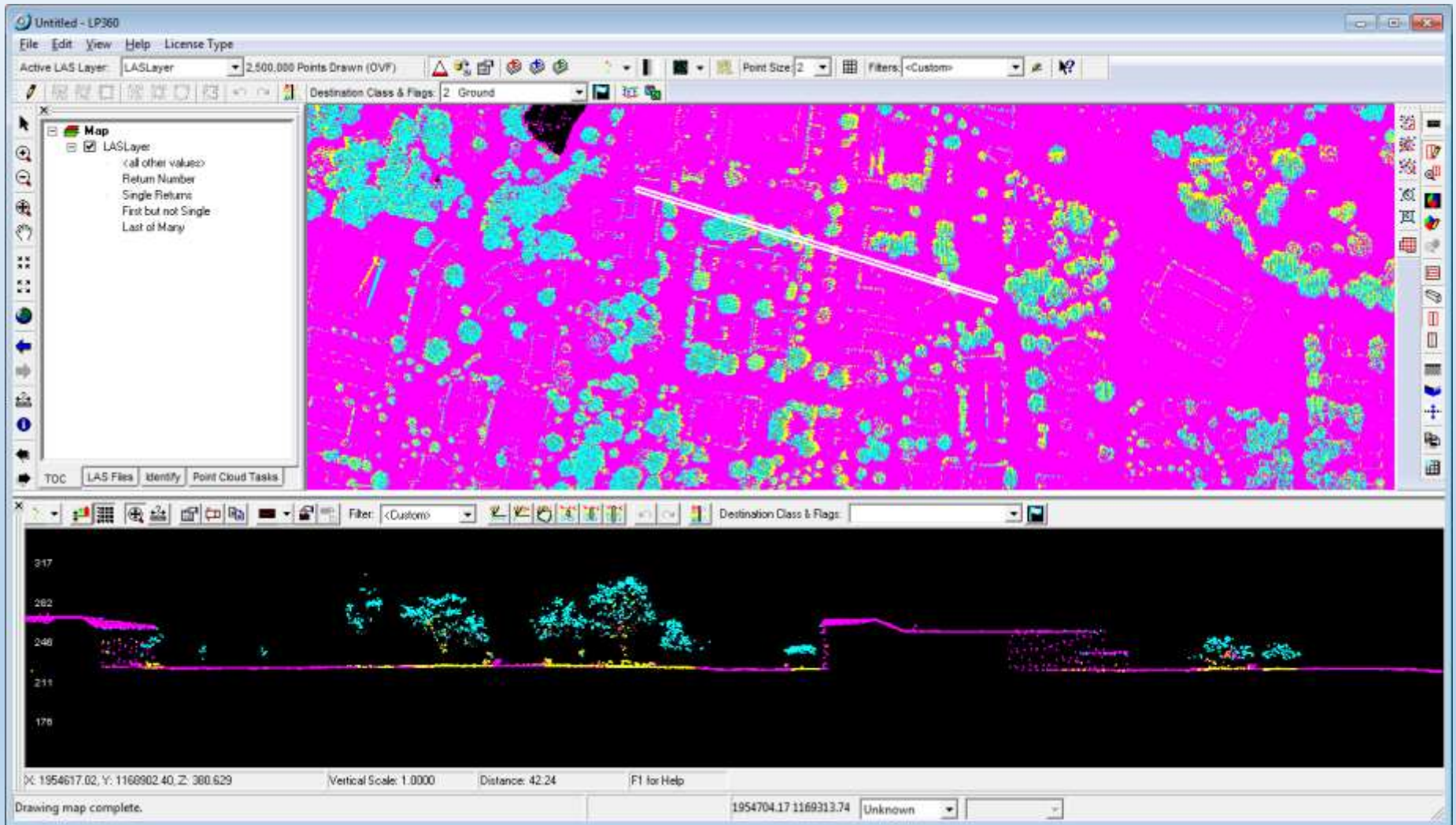


# Good Radiometry



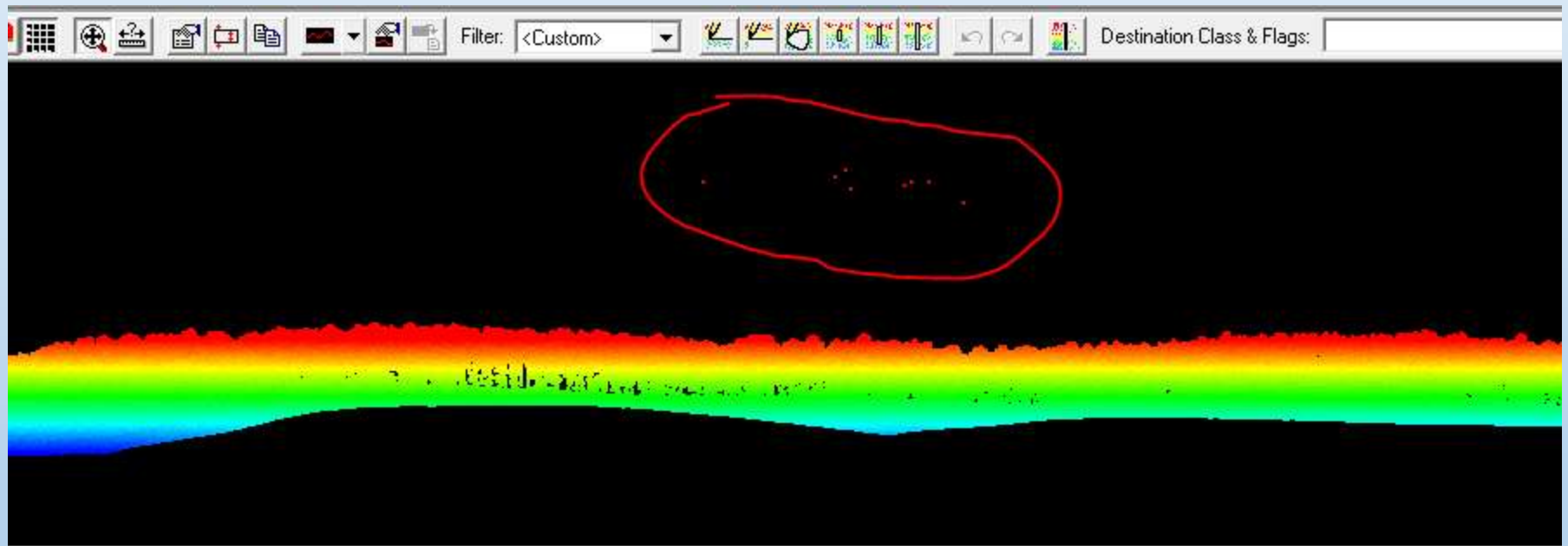


# Returns

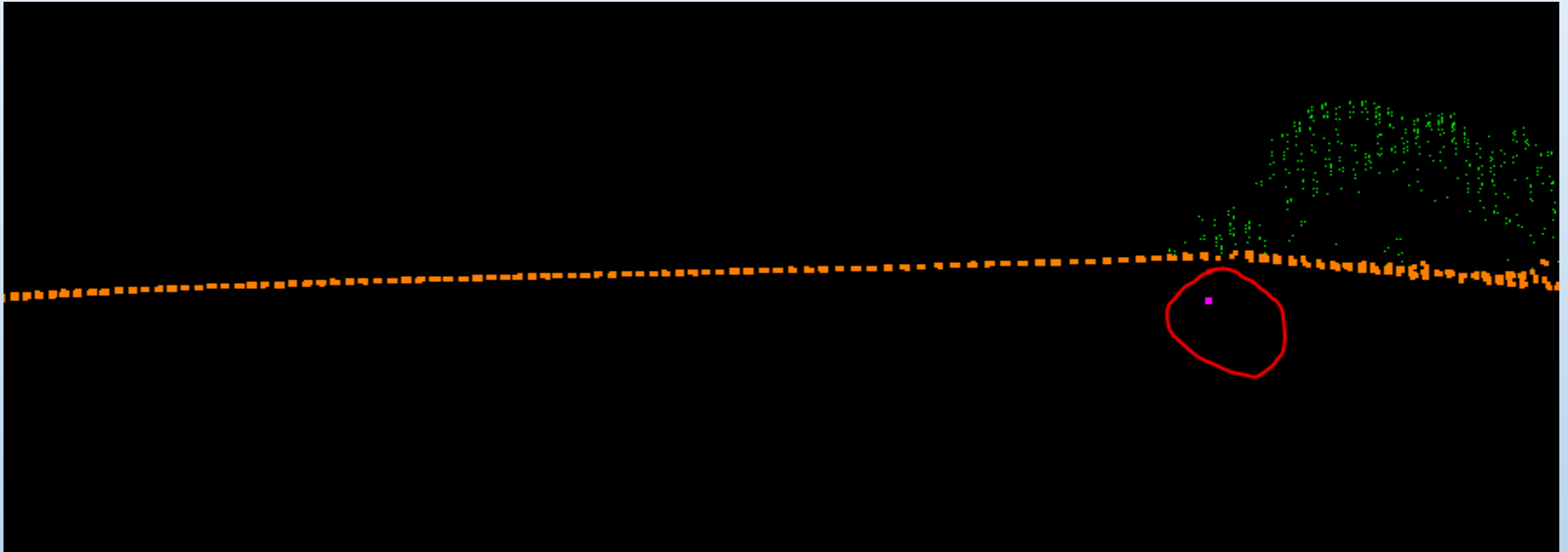




# High Noise

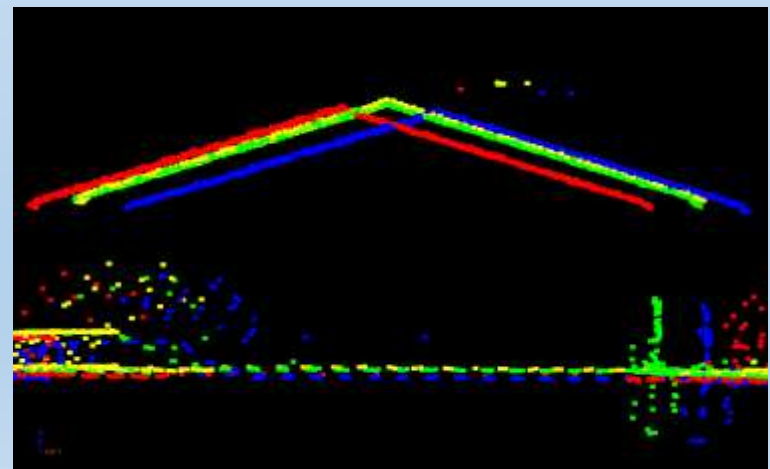
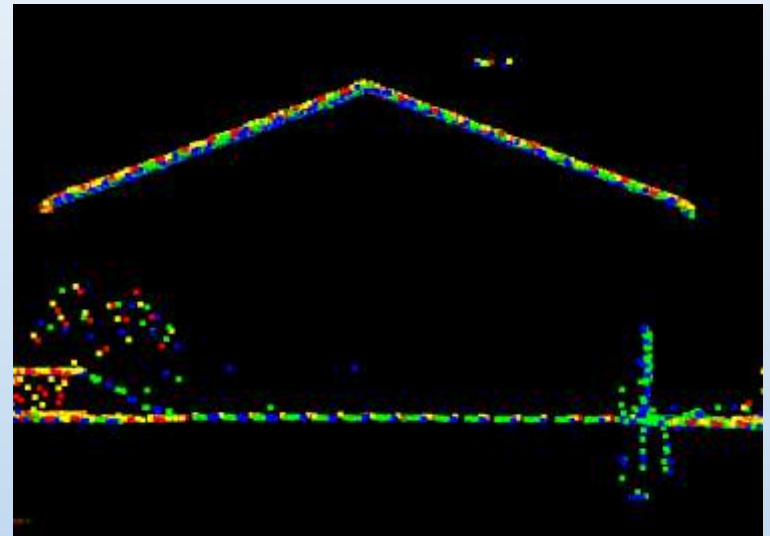


# Low Noise



# 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

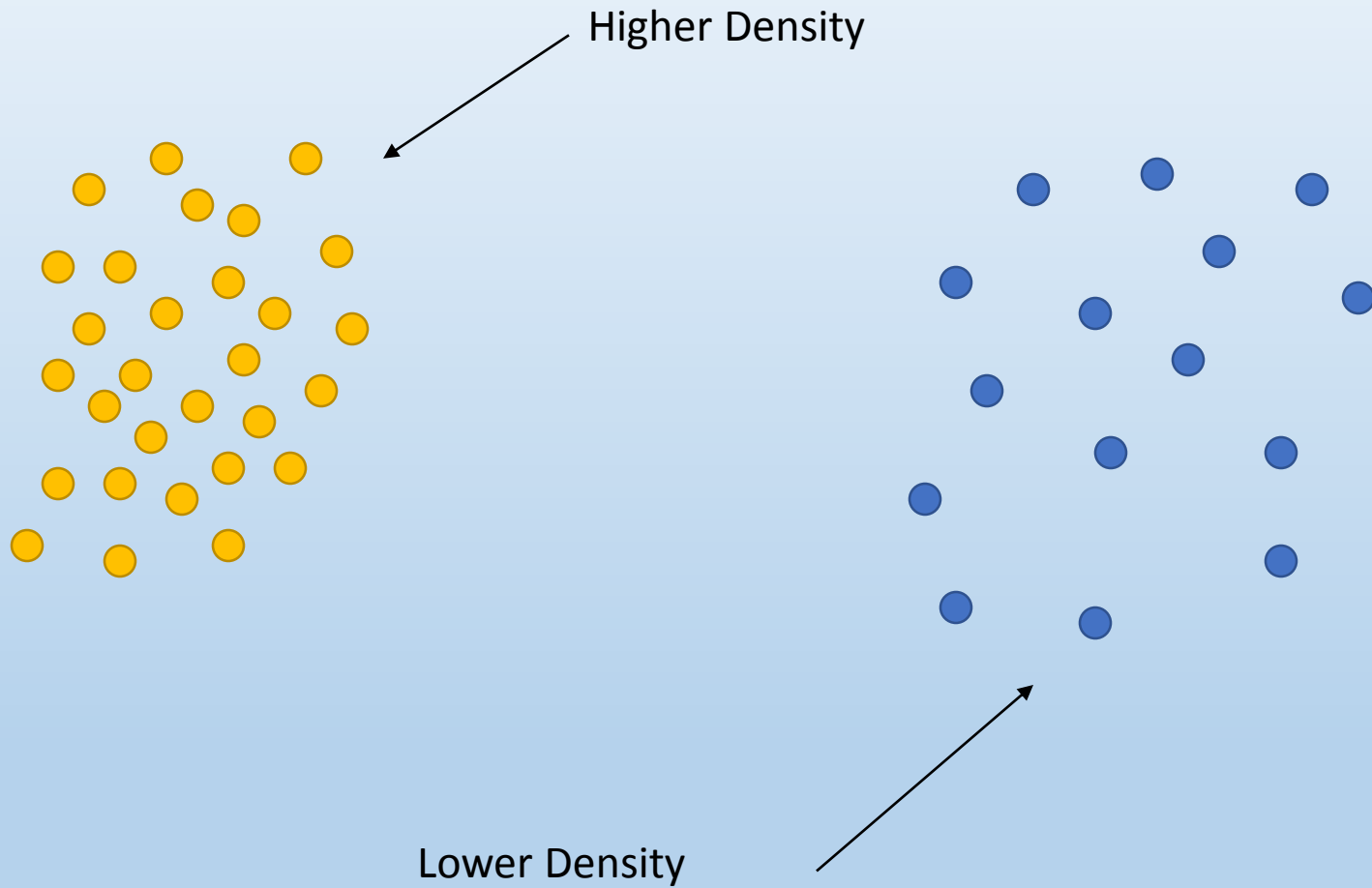
	FID	Shape	ID	IDSrc1	IDSrc2	dZ2_1
▶	0	Point ZM	0	79	81	-0.35
	1	Point ZM	0	79	81	0.03
	2	Point ZM	0	79	81	0
	3	Point ZM	0	79	81	-0.06
	4	Point ZM	0	79	81	-0.01
	5	Point ZM	0	79	81	0.0433
	6	Point ZM	1	79	81	0.19
	7	Point ZM	1	79	81	-0.35
	8	Point ZM	1	79	81	-0.075

Navigation icons: First, Previous, Next, Last, Find, Print, Close

(0 out of 83 Selected)

Ground\_Relative\_Analysis\_s... Ground\_Relative\_Analysis\_s...

# Density



# Point Spacing/Density Measurement

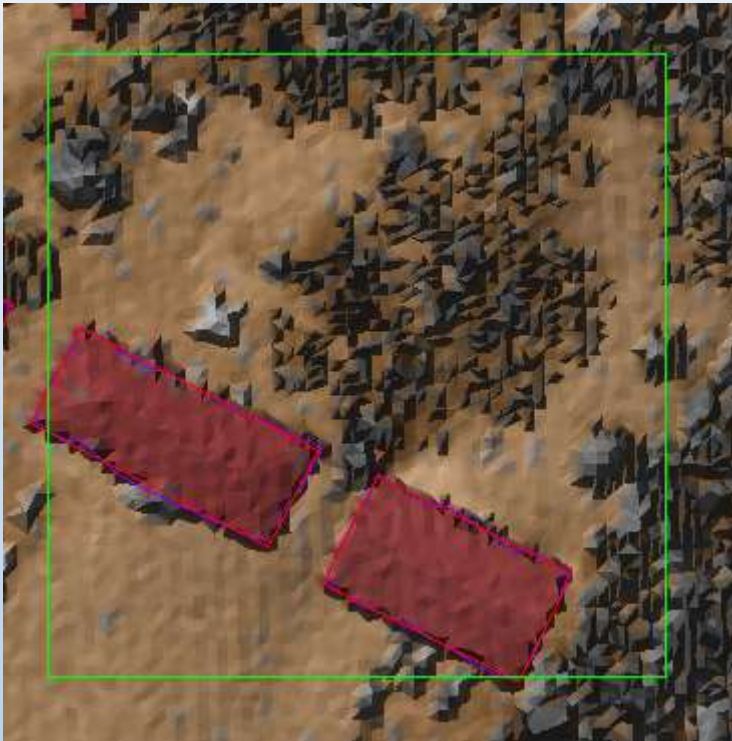
- Measured as:
  - Density - Points per unit area (e.g. points per square meter, ppm)
  - Nominal Point Spacing (NPS) – average distance between points
  - Ground Sample Distance (GSD) – same as NPS

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

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



# Density Test



PntCnt	3,404
NumCLUUsed	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

LP360 Control Points Report

Surface  
Method: Triangulation (TIN) Source Points ...

☒ Z Probe Location  
☒ Control X,Y  
☐ Measured X,Y Calculate DZ

Control / Check Points  
Quick Set: ALL Unique Name Field: FID Measure Mode Points that exceed limits of 90% CI Points that exceed limits of 95% CI Precision: 3

	Name	Description	Type	Control X	Control Y	Control Z	Measured X	Measured Y	Surface Z	Z Loc...	Delta X	Delta Y	Delta X,Y	Delta Z
<input checked="" type="checkbox"/>	0		FC	858165.760	386319.533	364.045			364.065	Control				-0.020
<input checked="" type="checkbox"/>	1		FC	858847.166	385922.431	356.950			356.900	Control				0.049
<input checked="" type="checkbox"/>	2		FC	859057.448	385422.155	369.736			369.716	Control				0.019
<input checked="" type="checkbox"/>	3		FC	858521.758	385640.820	357.857	858521.786	385640.783	357.851	Control	-0.028	0.037	0.047	0.006
<input checked="" type="checkbox"/>	4		FK	858641.019	385344.482	354.761			354.629	Control				0.132
<input checked="" type="checkbox"/>	5		FC	858753.624	385090.079	360.984			360.985	Control				-0.001
<input checked="" type="checkbox"/>	6		FC	858201.154	385260.977	361.421			361.388	Control				0.033
<input checked="" type="checkbox"/>	7		FC	858193.526	385708.975	358.851			358.905	Control				-0.053
<input checked="" type="checkbox"/>	8		FC	858371.624	385920.084	360.135			360.106	Control				0.030
<input checked="" type="checkbox"/>	9		FC	858864.423	386246.675	358.184			358.127	Control				0.057

Statistical Summary  
Horizontal  
Image Layer: Raster Layer\_1 Average Pixel Size: 0.060

X  
Mean Error: .....  
Error Range: .....  
Skew: .....  
RMSE: .....  
X Accuracy Class: .....

Y  
Mean Error: .....  
Error Range: .....  
Skew: .....  
RMSE: .....  
Y Accuracy Class: .....

Planimetric  
Mean Error: .....  
Error Range: .....  
Skew: .....  
RMSE: .....  
Horizontal Accuracy Class: .....

Vertical  
Mean Error \*: 0.025  
Error Range: [-0.053, 0.132]  
Skew: 0.590  
RMSE: 0.053  
Vertical Accuracy Class: 0.06  
Min Contour Interval: 0.18

Point Counts  
Horizontal Measured: 1  
Vertical Measured: 10  
Withheld: 0 of 10

\* The Mean Error exceeds 25% of the RMSE. Further investigation of the error values is recommended to determine if the errors follow a normal error distribution.

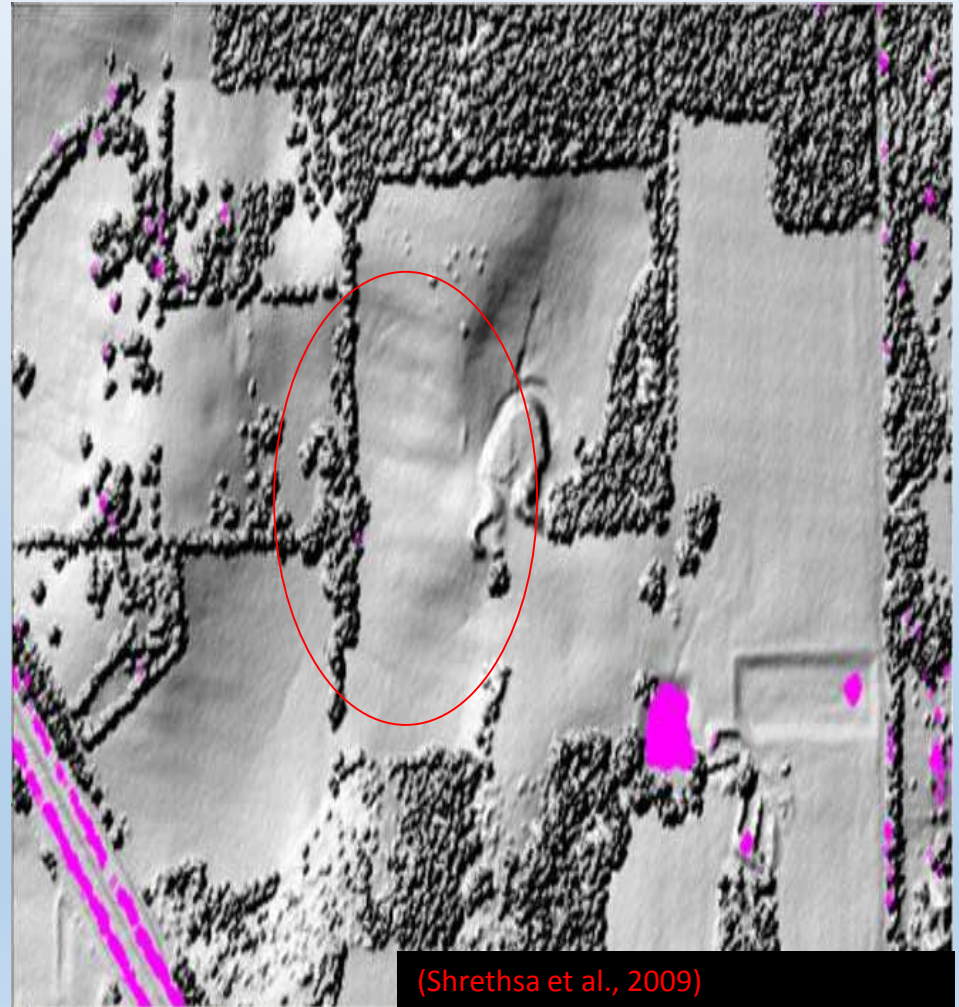
View Disclaimer... Export Report

Help OK Cancel

\* 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



(Shrethsa et al., 2009)

# 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

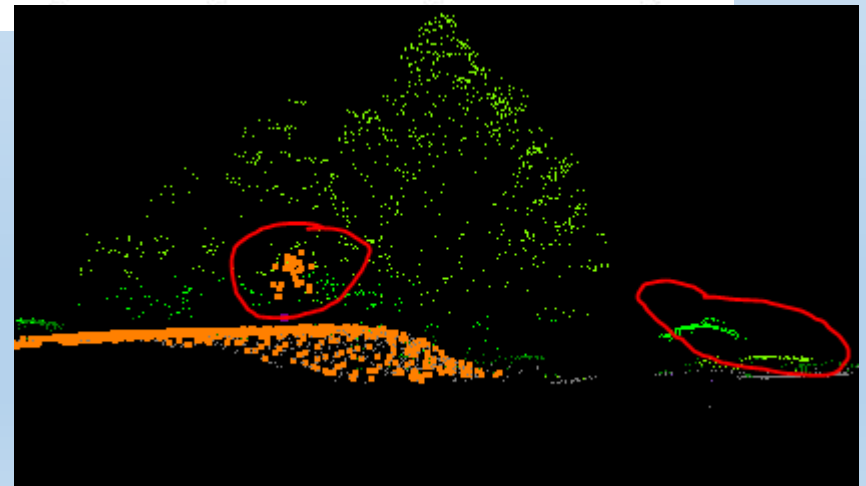
		Ground Truth				
		B	V	C	G	Total
Classified Data	B	<b>16326</b>	2178	224	1486	20214
	V	1709	<b>24635</b>	62	1535	27941
	C	111	252	<b>263</b>	327	953
	G	667	4827	257	<b>20257</b>	26008
	Total	18813	31892	806	23605	<b>75116</b>

B = Building

V = Vegetation

C = Car

G = Ground



(misclassified Ground and Building)

# OPEN TOPOGRAPHY



- [www.opentopography.org](http://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

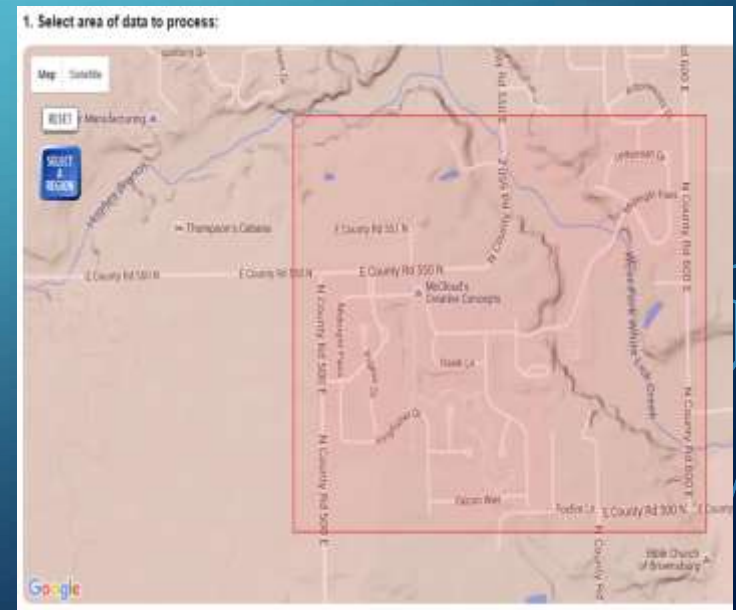
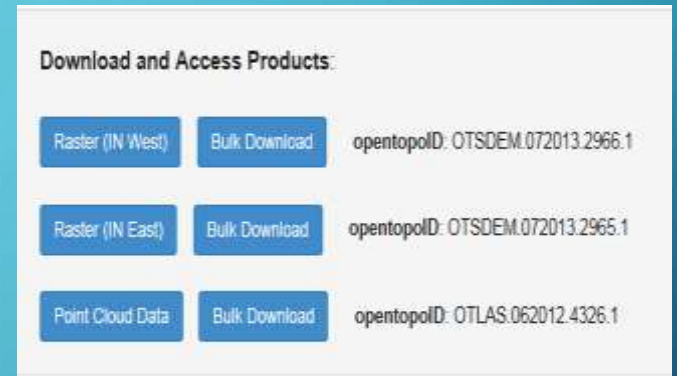
## Find Lidar Topography Data

Instructions



# 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

## 1. Coordinates

**Horizontal Coordinates:** WGS84 [EPSG: 2966]

**Vertical Coordinates:** North American Vertical Datum 1988 (NAVD88)

**Data Selection Coordinates:** ☐ Manually enter selection coordinates (in the horizontal coordinate system listed above)

$X_{\min} = 3133187.392$

$Y_{\min} = 1671229.464$

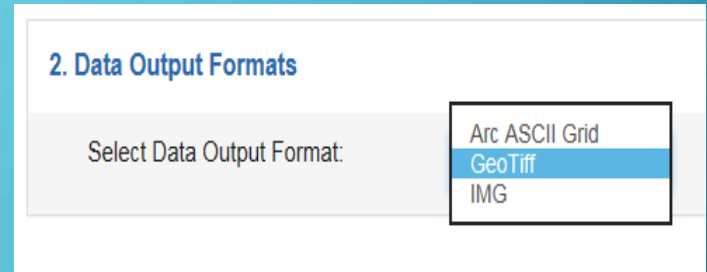
$X_{\max} = 3139161.165$

$Y_{\max} = 1675750.038$

The selection area is approximately 2 km<sup>2</sup>.

# 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



2. Data Output Formats

Select Data Output Format:

- Arc ASCII Grid
- GeoTiff
- IMG



3. Layer Types & Additional SRTM Data

Digital Elevation Models (DEMs) **Bare Earth:** ☒ Bare Earth

Include Global 30m SRTM Data ☐

# 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).

## 4. Visualization

- ☒ Generate hillshade images and Google Earth files from DEMs
- ☐ Generate additional color-relief and colored hillshades

Altitude of the light, (in degrees)

45

Azimuth of the light, (in degrees)

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

## 5. Hydrologic Terrain Analysis Products (tauDEM):

☐ Hydrologically correct DEM  
with pits filled

☐ D-Infinity Flow Direction  
☐ D8 Flow Direction:

☐ D-Infinity Specific Catchment  
Area  
☐ D8 Contributing Area

☐ Topographic Wetness Index

*This option is only available when Bare Earth layer type is selected and data output format is GeoTiff. [Click here](#) to select Bare earth layer and and geoTiff format to enable this TauDEM option*



# DOWNLOADING DEMS FROM OPEN TOPOGRAPHY

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

## Job Description

These options allow users to describe and keep track of their jobs. Information entered below is recorded along with other job parameters in your personal lidar Job archive accessed via [myOpenTopo](#) (available only to [registered](#) OpenTopography users).

**Job title** (up to 100 characters)

**Job description** (up to 500 characters)

**Enter your e-mail address**

for notification upon completion of  
processing

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

## Raster Job Report

[Modify and resubmit this job](#)  
[Full job metadata report](#)

[Download Job Metadata](#)  
[View Job Configuration](#)

Job Id	Dataset	Title	Submission	Completion	Duration	Final Status
rt1452115792283	IN_2011_2013_W		2016-01-06 13:29:53	2016-01-06 13:30:08	15 secs	Done

## Download Job Results

DEM Results

- Download compressed raster results: [rasters\\_sdem.tar.gz](#) (2.2 MB)

# DATA FORMATS

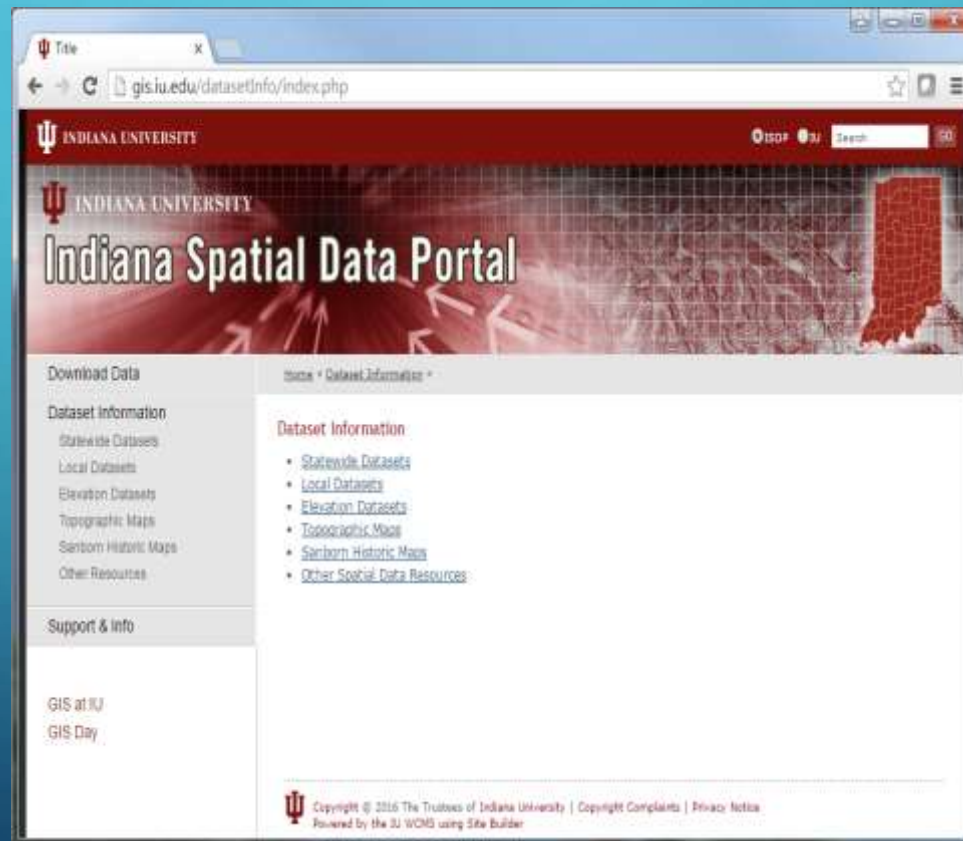
- Compressed files (tar.gz)
- Extract downloaded OT files with 7-zip (free) or WinZip (commercial)

[www.7-zip.org](http://www.7-zip.org)



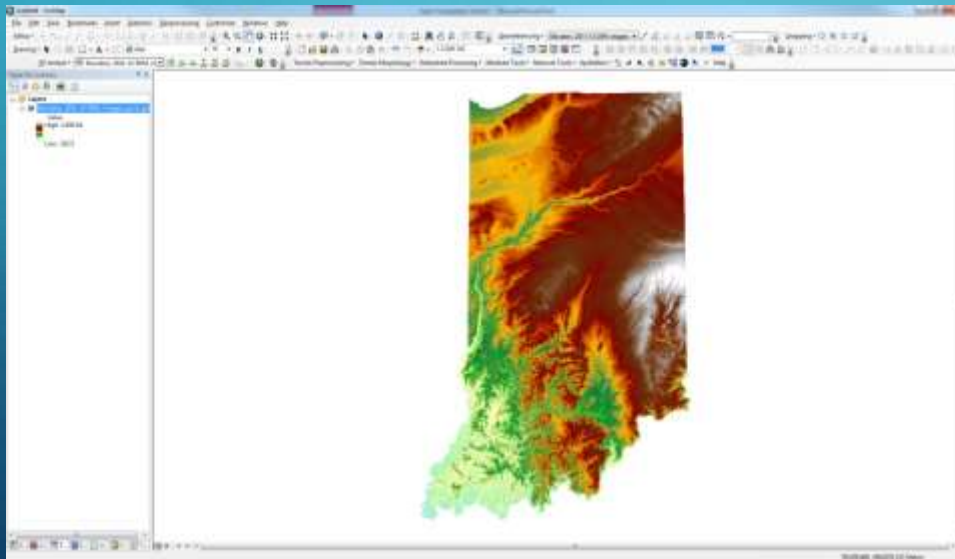
# INDIANA SPATIAL DATA PORTAL

- [gis.iu.edu](http://gis.iu.edu)



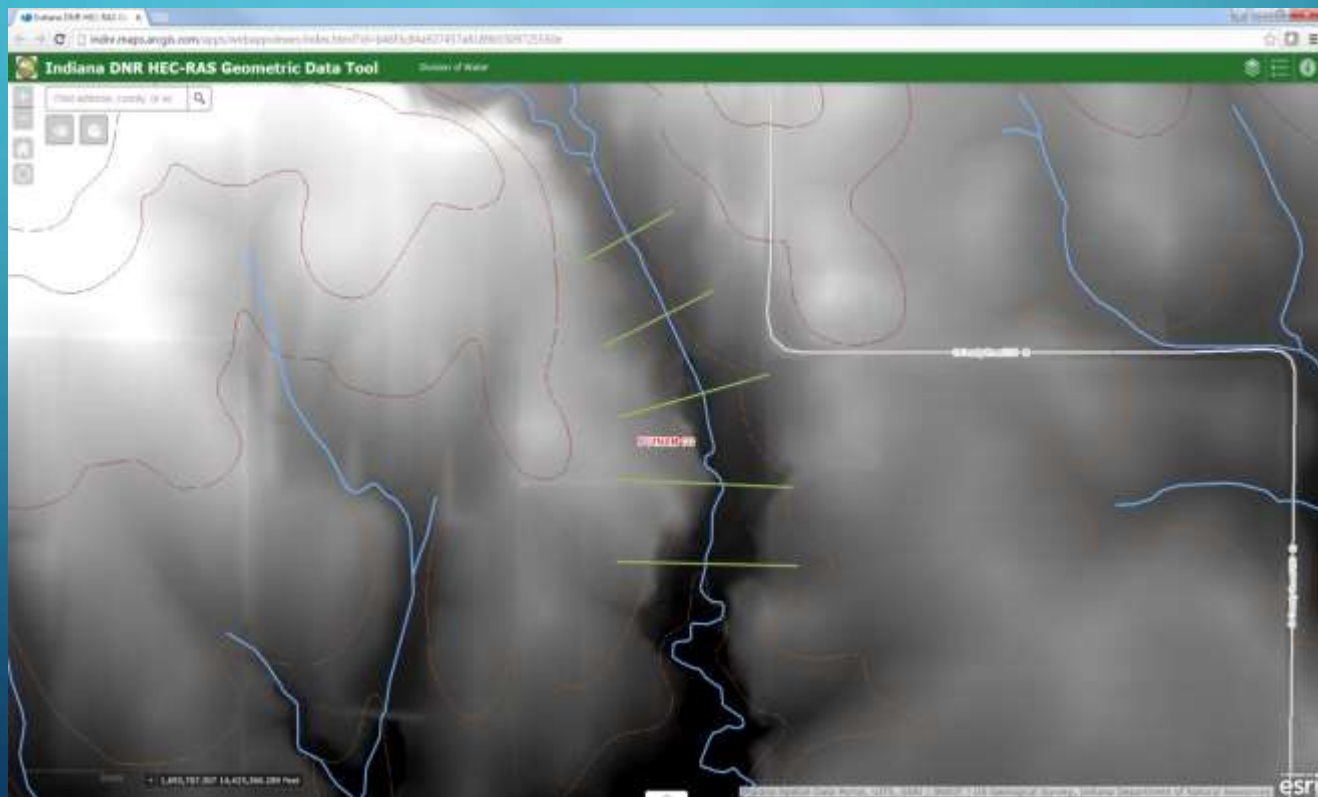
# STATE OF INDIANA IMAGERY REST SERVICE

- [https://imagery.gis.in.gov/arcgis/rest/services/Elevation/Statewide\\_DEM\\_11\\_13/ImageServer](https://imagery.gis.in.gov/arcgis/rest/services/Elevation/Statewide_DEM_11_13/ImageServer)



# INDIANA DNR HEC-RAS GEOMETRIC DATA TOOL

- <http://dnrmapping.dnr.in.gov/apps/stepc.htm>







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