Airborne Laser Mapping

Uses & Benefits of LiDAR & Imagery

* Presented by:
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Discussion Agenda

I. Personal & company overview
II. LiDAR technology overview
III. SOM specification (LiDAR / Imagery)
IV. Resulting products and services from spec
V. Applications / uses: Environmental, Natural Resource, Transportation & other
VI. General overview of LiDAR advantages
VII. Return on investment?

Professional Bio

- Degrees in Business and Remote Sensing (Photogrammetry)
- 30+ years in Remote Sensing & mapping
- Introduced airborne / terrestrial LiDAR in 1992
- Assisted with many of the first LiDAR / Image applications, specifications & standards
- Consultant with first raster image “web portal”
- SME (RS) – Insurance, University, Elect. Utility,
  Oil Gas - E/P & Pipeline
- Past SME with MSU – assisted w/
  creation of this LiDAR specification
- Current SME w/ State of Michigan
  - General education on LiDAR
  - Answer vendor technical questions
  - Helped with proposal evaluation process
  - Discussing data compliance evaluation

Company Overview

- Spatial Intel, Inc. Corporation. Established January 2009
- Consulting & Services focus
- Local & International reach
- Why Spatial Intel?
  1. Unparalleled experience
  2. Represent client interests – MSA / SME
  3. Every available capture technology – (acquisition network 45 plus)
  4. Denver based sensor centric processing
  5. Scalable resources (capture & processing)
  6. Offer custom solutions to project challenges (time, budget, accuracy, etc.)
- Future of the industry – Cloud*MAP* Services!!!

Basic Terminology

- LiDAR – Light Detection and Ranging
- Point cloud – All lidar returns displayed in 3-D
- Break line – manually placed XYZ line string to enforce change
- DEM – digital elevation model (mass points or even grid spacing of ground points)
- DSM – digital surface model (first return canopy)
- DTM - digital terrain model (added break-lines)
- NPS – nominal “lateral” point spacing
- GSD – Ground sample distance
- Orthophoto – aerial image corrected for relief displacement (map accurate image)

Technology Overview

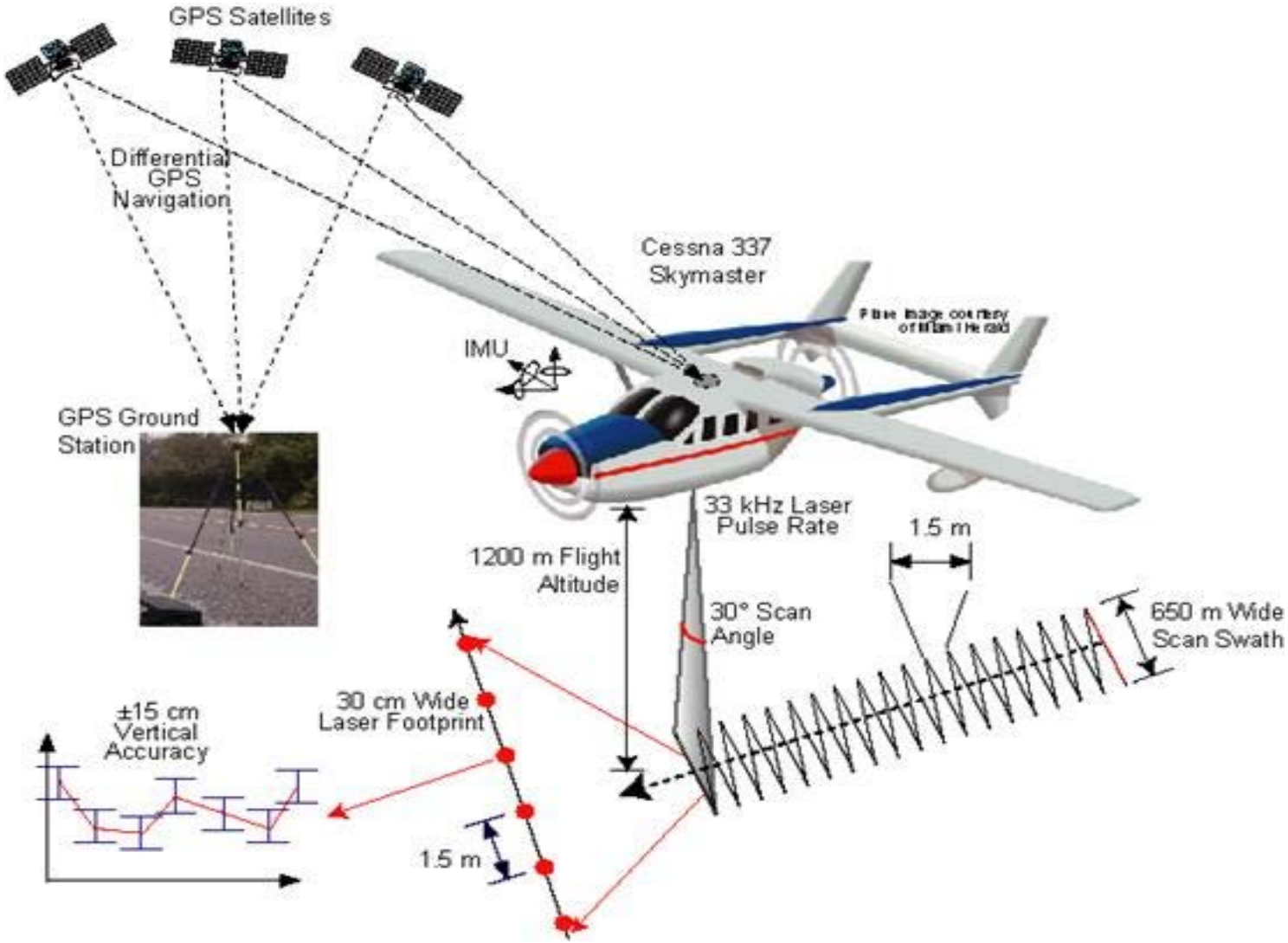
* Light Detection And Ranging - aka "**LiDAR**"

- **Reflector-less laser rangefinder that emits intense NIR laser light and detects travel time, beam angle and intensity of the reflected energy from the target object.**
- **Lasers mounted on:**
  - **Fixed wing aircraft**
    - **Single, twin, turbo**
  - **Helicopter**
  - **Lear Jet**
  - **UAV's**
  - **Tethered balloons**

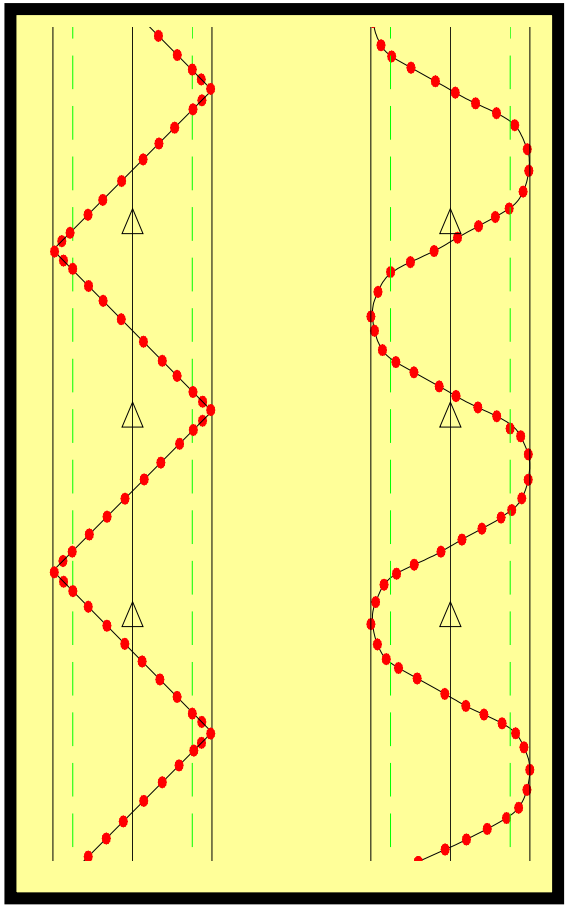
- **Positioning survey platform - GPS / IMU (or INU / INS)**

*Often accompanied with image or other sensor!

Sensor Operation

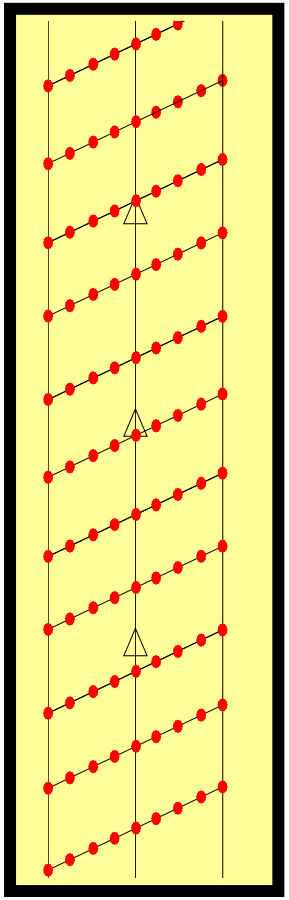


Laser Scan Patterns



Zig-zag Elliptical

(higher altitude scanners)



Parallel

(low – medium altitude)

Benefits

- Regular parallel lines
- Adjustment of scan rate and pulse rate lead to a regular point spacing
- Point density, point spacing along and across track can be calculated precisely
- Point spacing constant
  - In flight
  - Across track
- Full usage of swath width

LiDAR "Network" Overview

Provider / sensor statistics

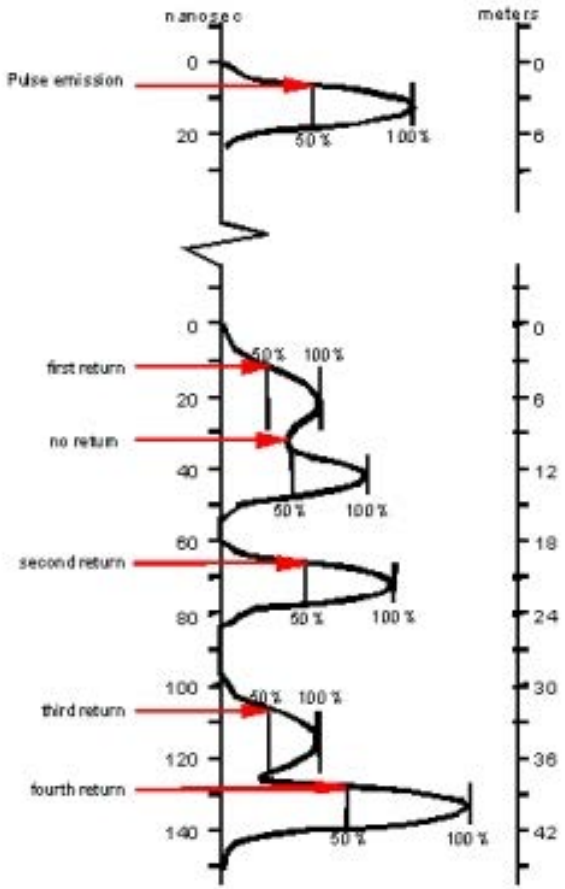
- 45 + LiDAR company's (US / CA)
- 5 Emerging company's (install phase)
- 90+ Sensors in operation
- 12 models / capabilities (33-**500**kHtz)
- 4 major system classifications:

1. Single pulse / single return (dated technology)
2. Single pulse / multiple return (most common)
3. Multi Pulse In Air (MPIA) (significant)
4. Wave Form (evolving)

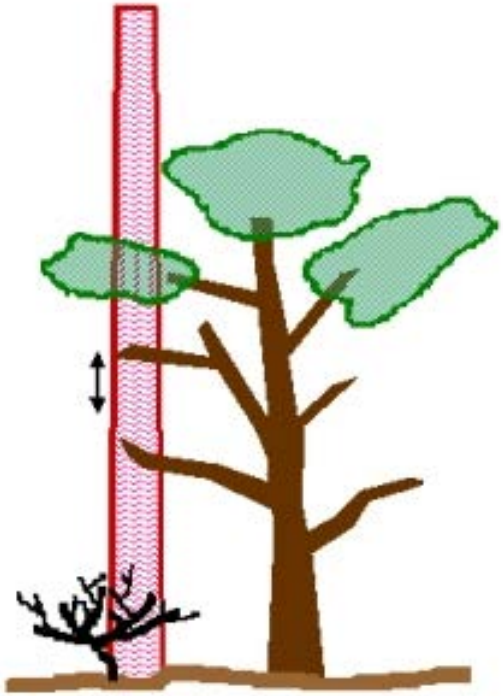
**All have associated costs / benefits*

Single Pulse Multi-Return

Up to 5 returns on average

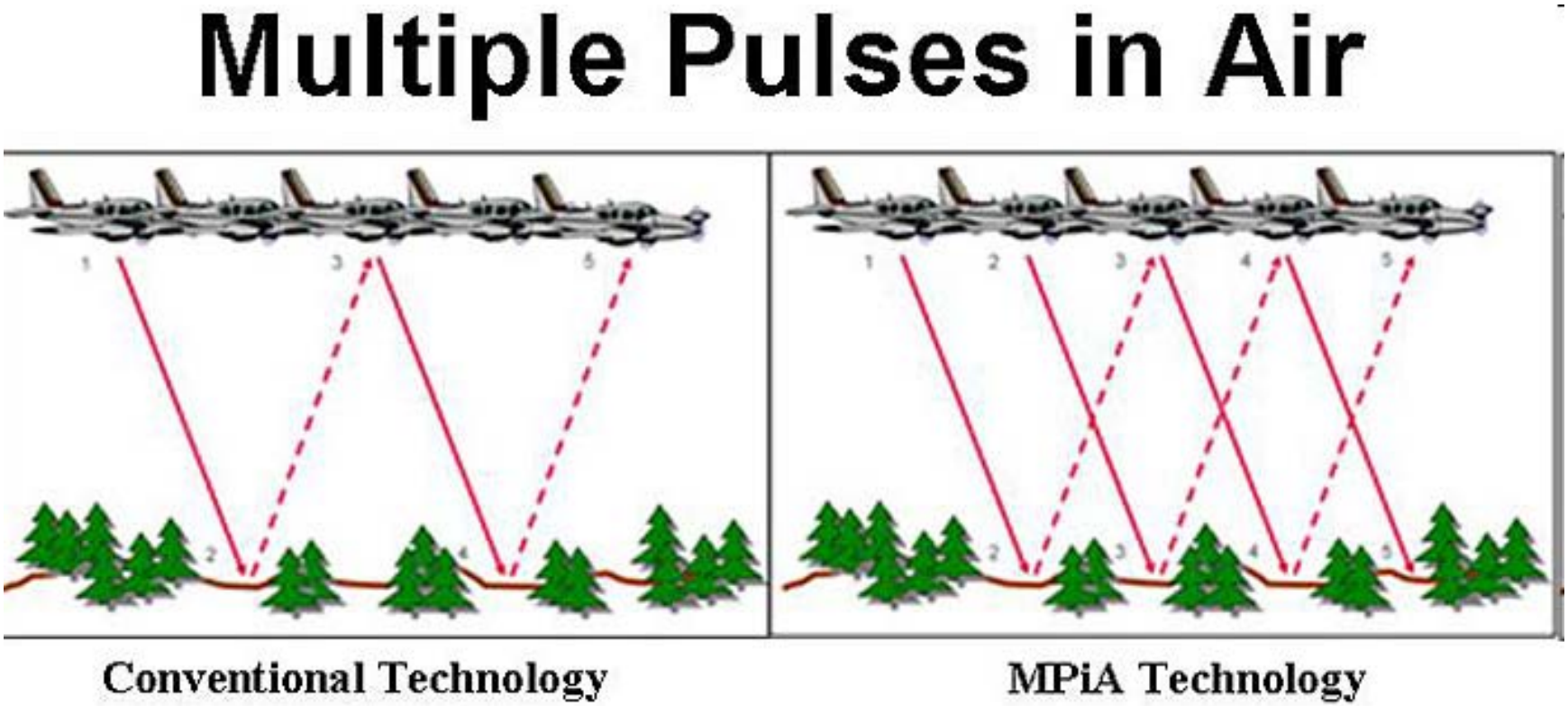


Beam width +/- yard stick



Sensor Technology

MPIA

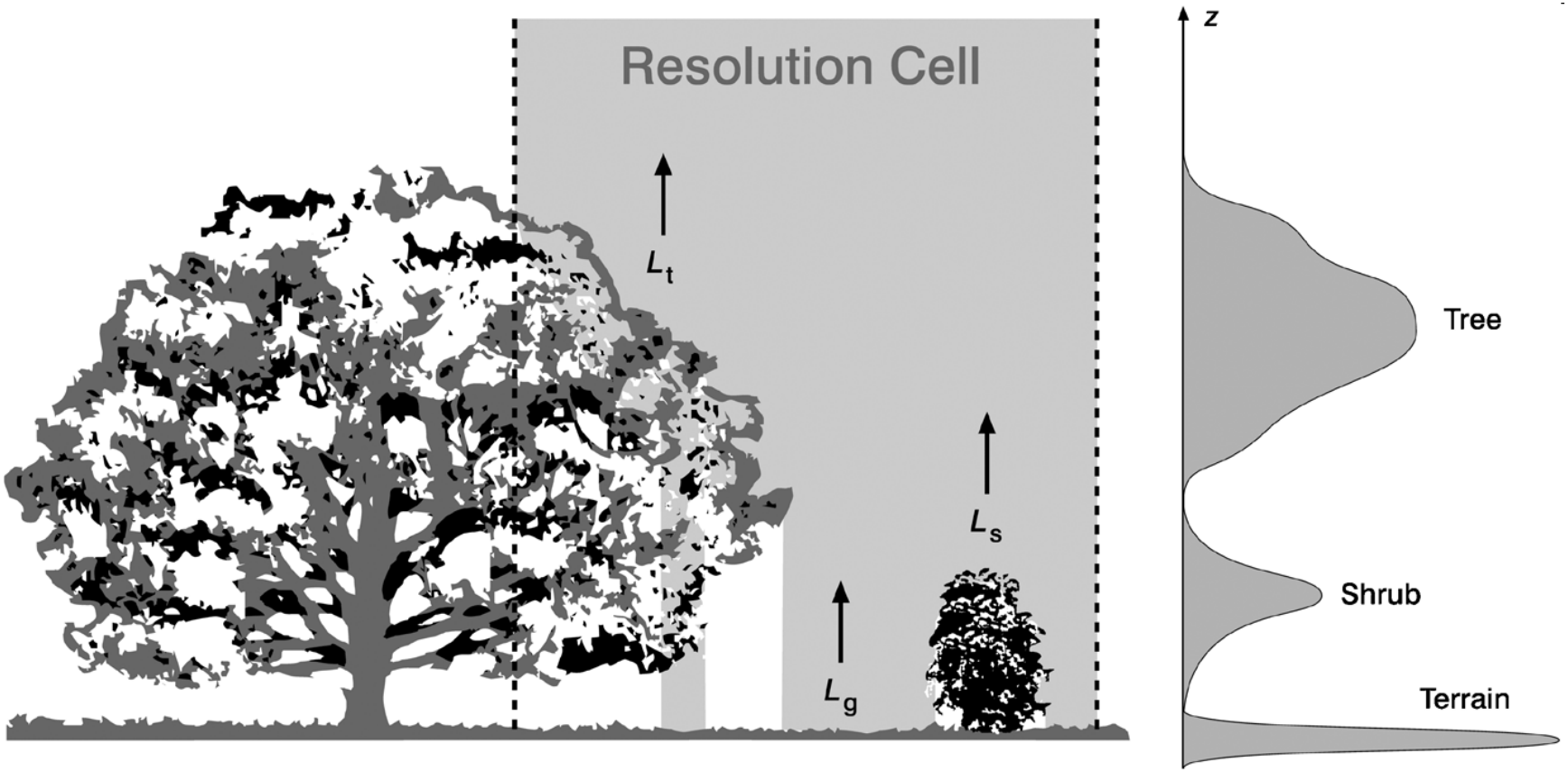


**Up to 5 returns possible per pulse*

Wave Form

Gathers / stores additional attributes

Position, energy & width of each pulse

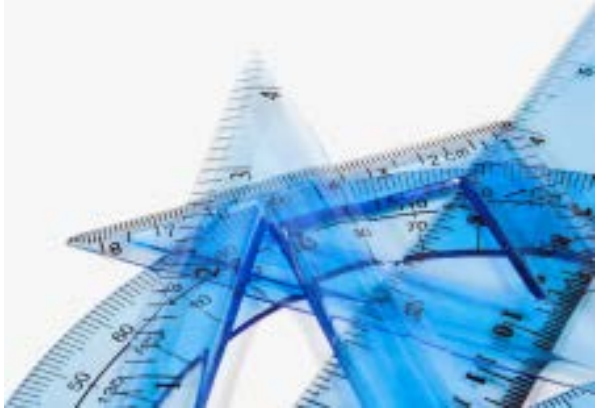


Can offer advantages in vegetation mapping / classification

System “Absolute” Accuracy

Condition(s) dependent

- Sensor accuracy (controlled environment):
  - +/- 2 cm or 1”
- In operation (ideal conditions & non ideal):
  - Vertical 5 cm (2.00”) to 23 cm (9”)
  - Horizontal 10 cm (4.75”) to 30 cm (1’)
- Typical project accuracy (sweet spot)
  - 15cm vertical (6 inch range)
  - 20cm - 30cm horiz (8” - 1 foot range)



*Accuracy relates only to objects hit (tip of tree) & ability to accurately classify a return

**Relative accuracy* *can be* 3x absolute! (point to point – to feature)

*Accuracy vs. precision – LiDAR to ground survey (terrain example)

*Keys to accuracy - correct classification (is it ground?)

SOM Specification:

LiDAR

- LiDAR Sensor - Leica ALS50 II-MPia Waveform
  - GSD (LiDAR Point Spacing) – min 2 ppsm (single pass)
  - 3 returns per pulse (min rqm't)
  - Return "intensity" values recorded
  - Waveform – added record data optional
  - Accuracy V – fundamental 18.5 cm @ 95%. 9.25 (RMSE)
    - Relative V – 7cm within swath, 10cm across lines
  - LAS format, v1.1 or v1.2 (1.4 WF is an upgrade)

**Fly Leaf-on or Leaf-off – decision to be made based on desired uses!!!!*

SOM Specification:

Horizontal / Vertical Reference

All field records and computations will be delivered to the state as part of a project survey report. H/V for all control and data will be reported as:

- **Coordinate Reference System:** Michigan State Plane
- **Horizontal Datum:** Most current realization of NAD83
- **Horizontal Units:** International Feet
- **Vertical Datum:** NAVD88
- **Vertical Units:** International Feet
- **Vertical Reference:** Orthometric Heights
- **Geoid Model:** Most Current NGS Geoid model

SOM Specification (cont.)

LiDAR deliverables

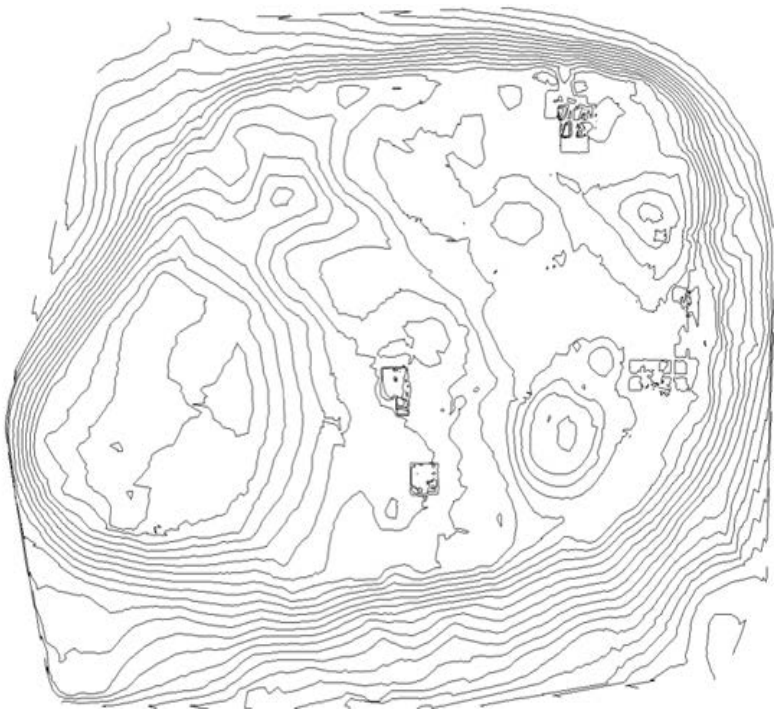
- Metadata - flight logs, control, process reporting, QA/QC reports, etc.
- Point Cloud (calibrated “all-points” unclassified)
- Classified Point Cloud
  1. Bare earth ground (DEM)
     1. 32-bit raster – 3’ cells
     2. Ascii grid XYZ – 3’ posting / GSD
  2. Not ground
  3. Noise
  4. Ignored ground (if hydro enhanced)
  5. Withheld points
- Upgrade:
  1. Water (hydro-flattened / hydro-enforced)
  2. LiDAR Intensity Images

Deliverables Defined - LiDAR

1. Bare-earth ground (DEM) – only those points representing ground surface
2. Not ground – everything else!
3. Noise – low and high ground points
4. Withheld points – points defined as unusable including outliers, noise, caused by atmospheric effect (dust / moisture), birds, swath edge.
5. Ignored ground – Points removed during hydro enhancement
6. (Hydro-enhanced - examples)
7. (LiDAR intensity images - examples)

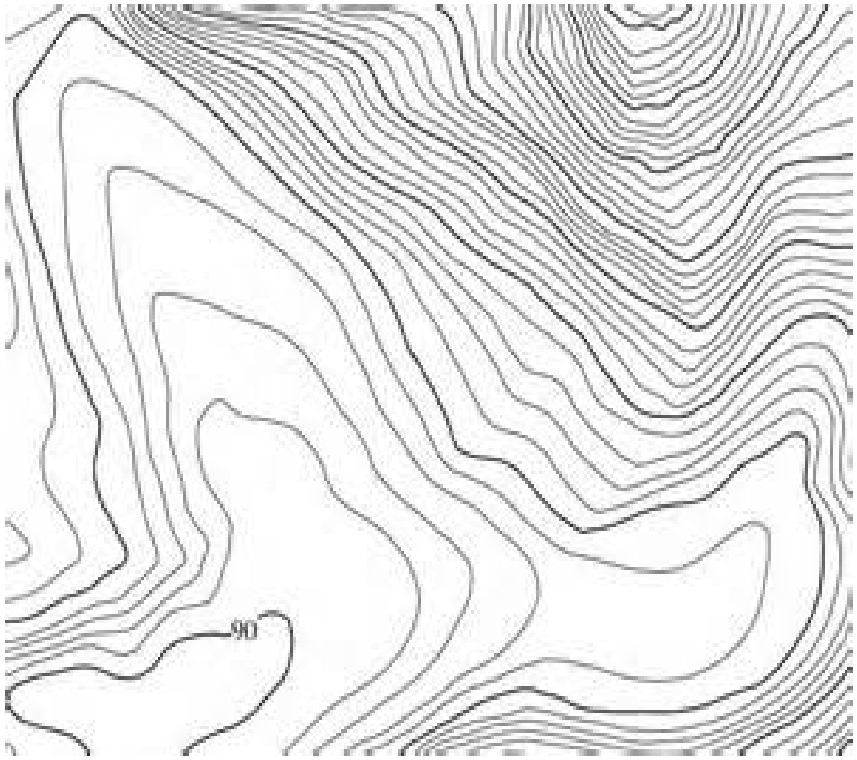
Contour Generation

Mass-point contour rendering



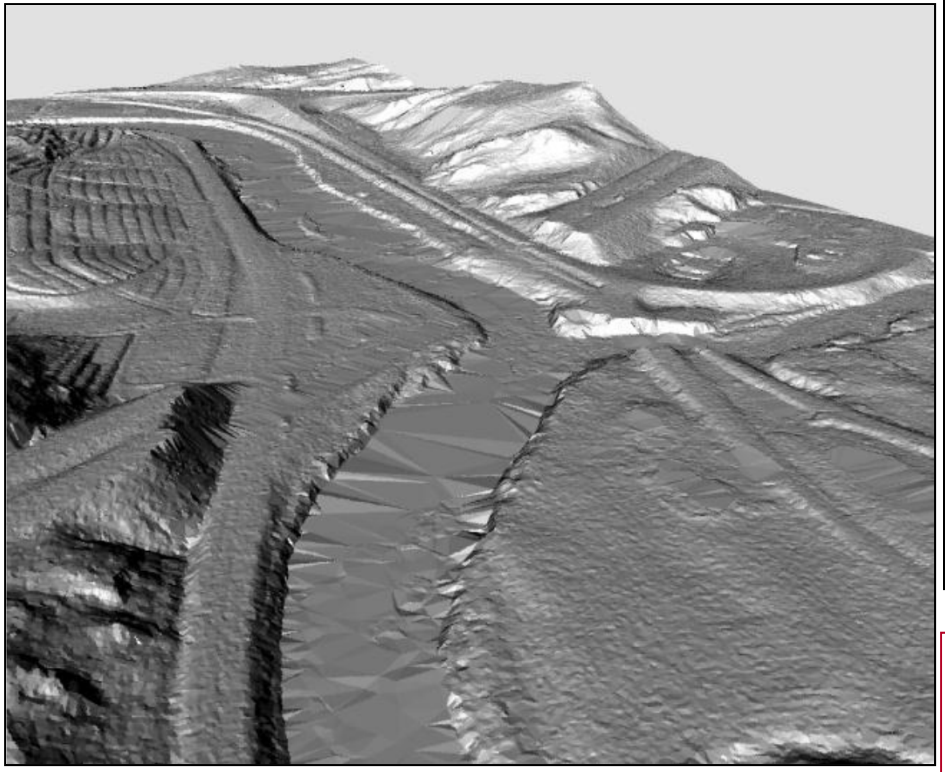
1. Import .las points into Arc/Map
2. Convert to ascii xyz
3. Grid points in Arc/MAP
4. Generate contours

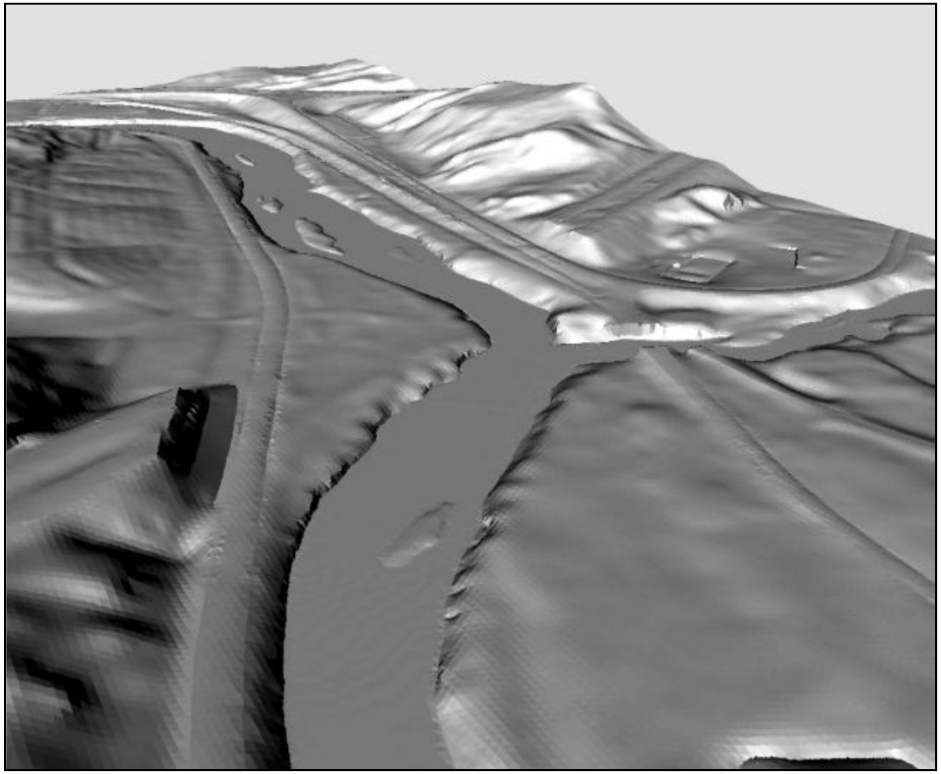
Gridded DEM contour rendering



1. Import ascii xyz
2. Generate contours

6a. Hydro-flattening



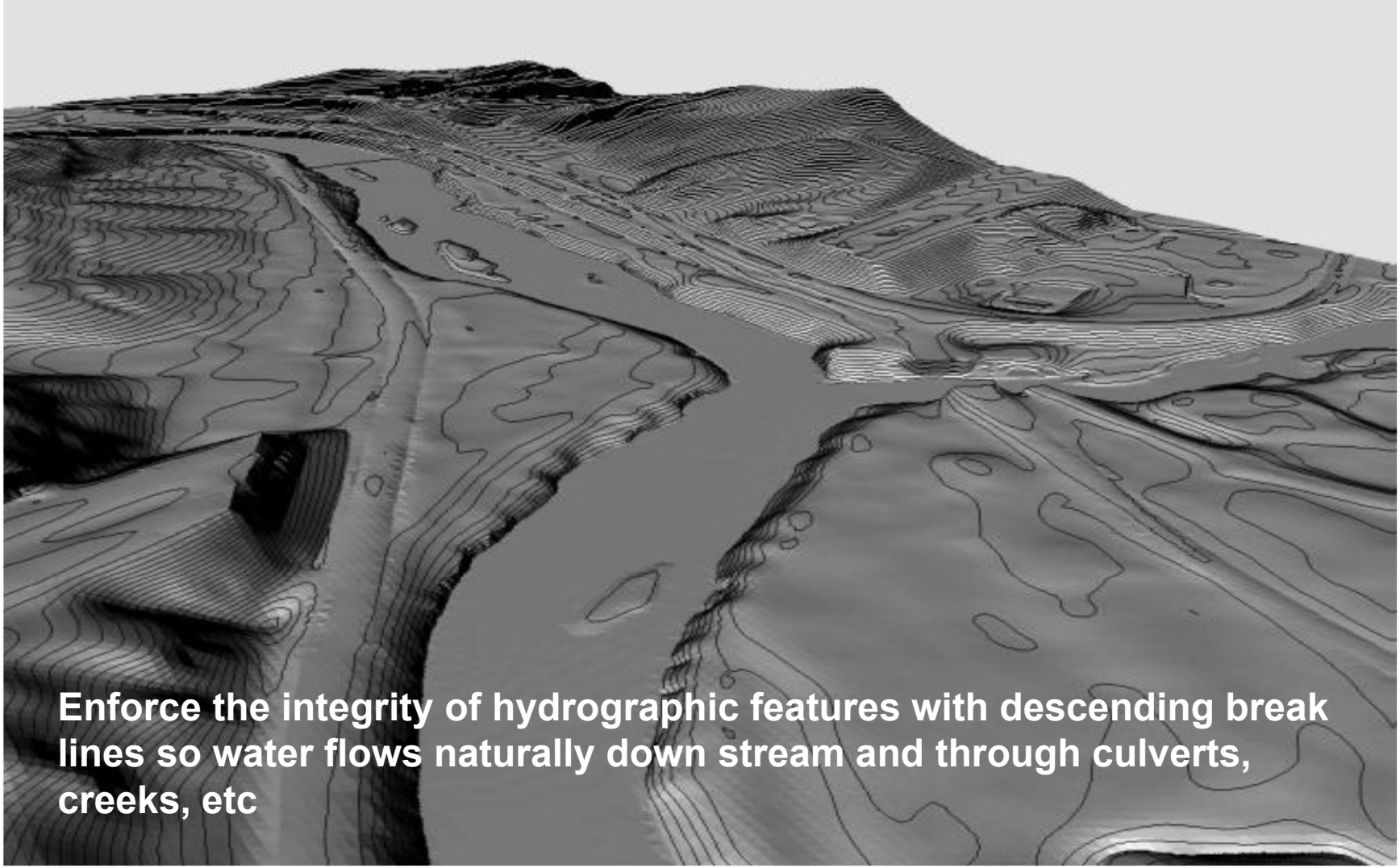


- LiDAR surface with anomalies & before break-line supplementation

- Remove above ground features (bridges, structures) so water flows naturally over terrain model
- Grid DEM – 3’ raster
- Add edge of stream break lines so water is flat bank to bank
- Add break lines to force open water bodies to be flat

*Hydro image examples owned by Sanborn

6b. Hydro-Enforced



LiDAR Intensity “Image”

- Object reflected energy / intensity recorded for each return
- Geo-referenced grey scale raster GeoTIFF

- Holds LiDAR accuracy & allows 3-D measurements in project coordinates
- Resolution (detail) based on LiDAR point density

SOM Specification:

Imagery

- Ortho GSD – 1-foot (6-inch and 3-inch option)
- Sidelap 30%, Endlap 60% = Stereo viewing
- 4-band, 8-bit RGB/NIR GeoTIFF
- Acquisition time Spring 10 am – 3 pm
- 30-degree sun angle above horizon or more
- Conditions – Snow free, leaf off, no clouds, cloud shadows, or other ground obscuring conditions. Streams within natural banks. Dry road surfaces.
- Stereo - obliques

1-foot GSD

3-inch GSD

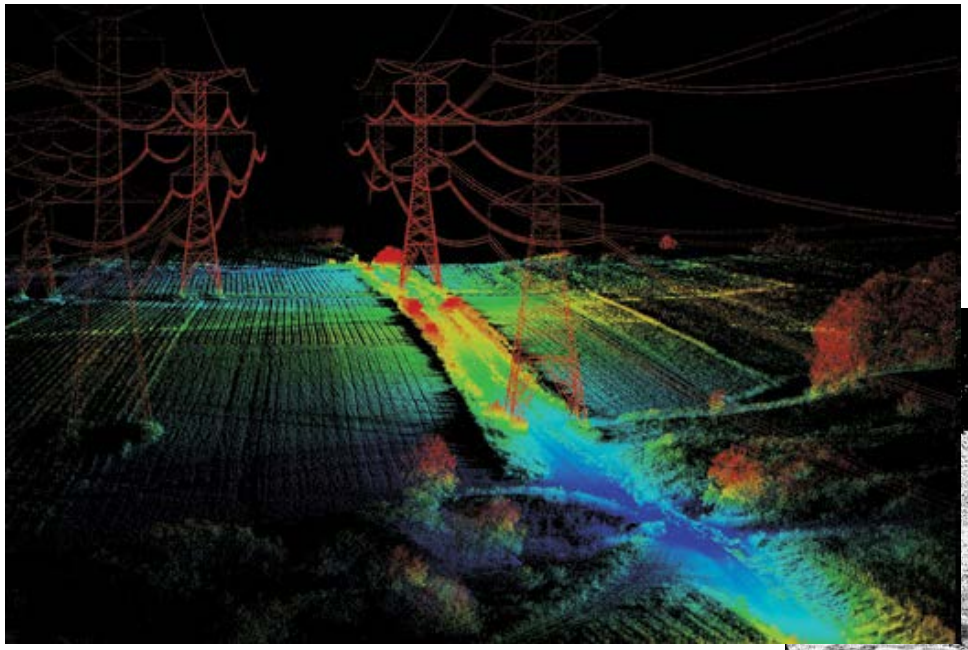
Resulting Products & Services

Calibrated un-classified point cloud

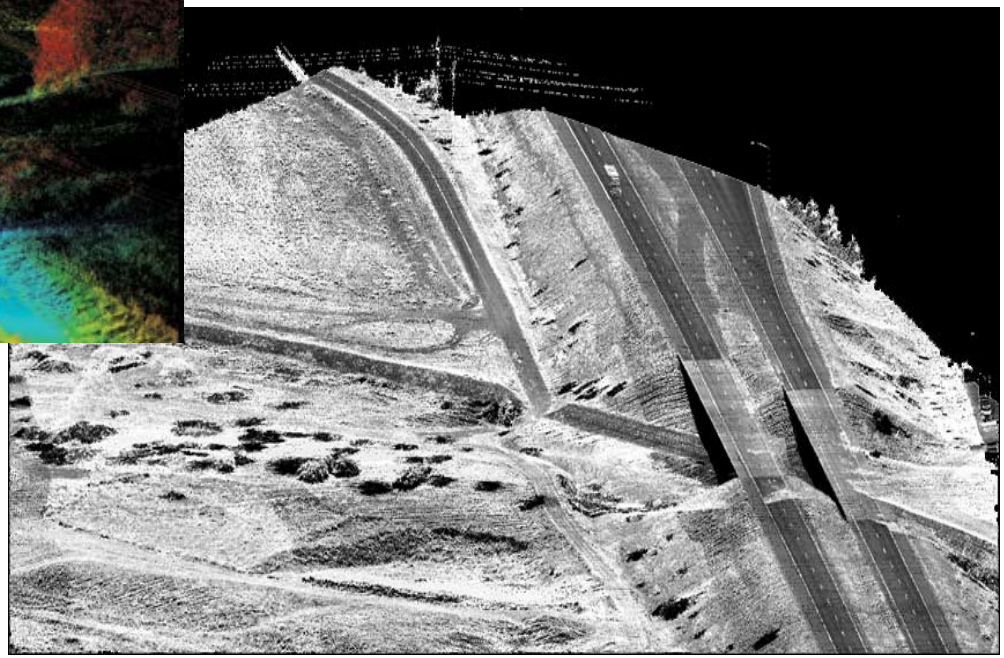
6 – 9 ppsm example

Raw Data from LiDAR fly-over

1. Non-classified .las “point cloud”



2. Intensity “reflectivity” Image

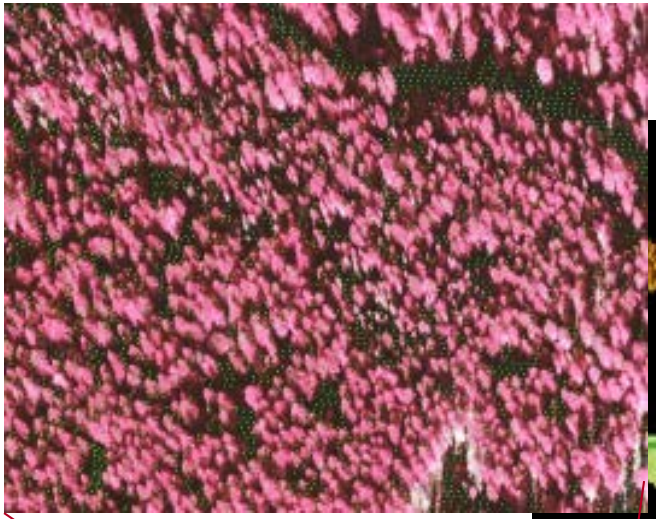


* Resolution “detail” solely dependent on point density of LiDAR

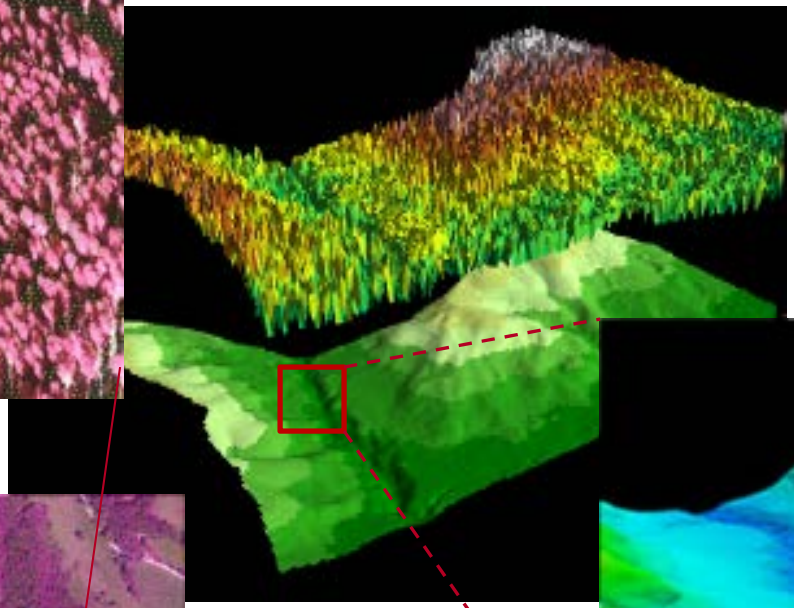
Processed Examples - DEM Generation

Does <u>not</u> see-through vegetation

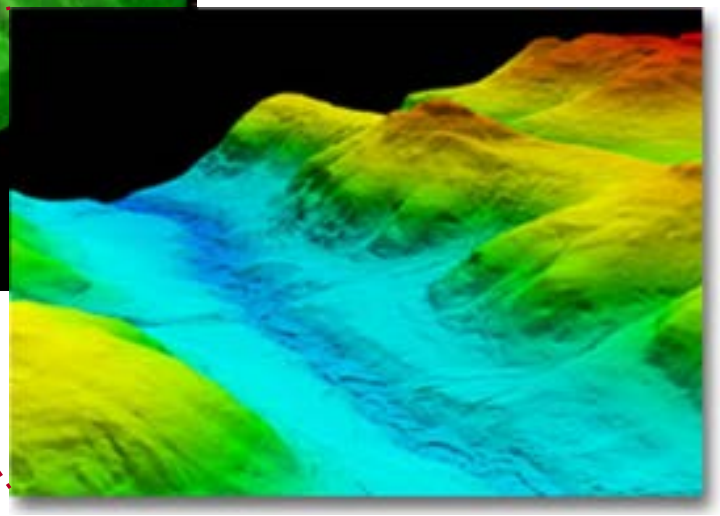
LiDAR in vegetation



3-D Clear-cut calculations



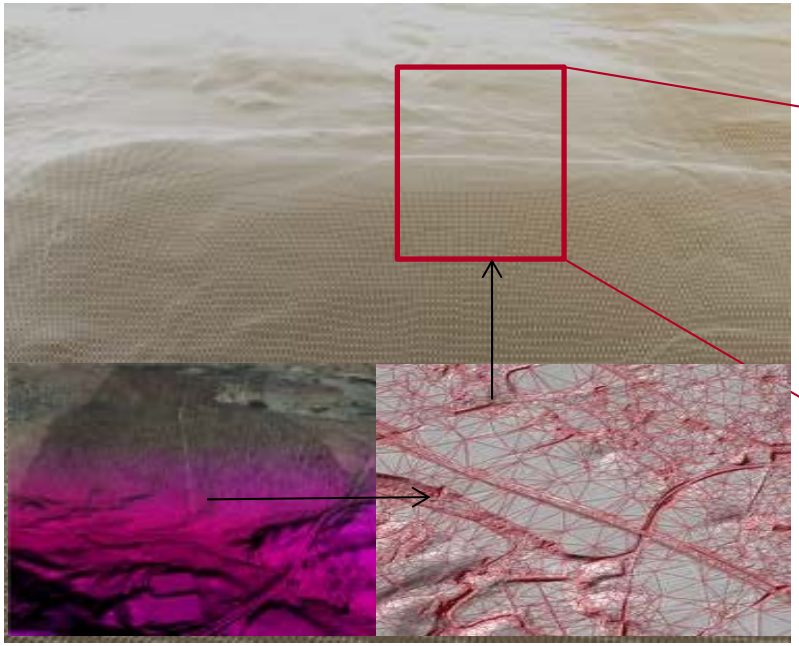
Digital Elevation Model (DEM)



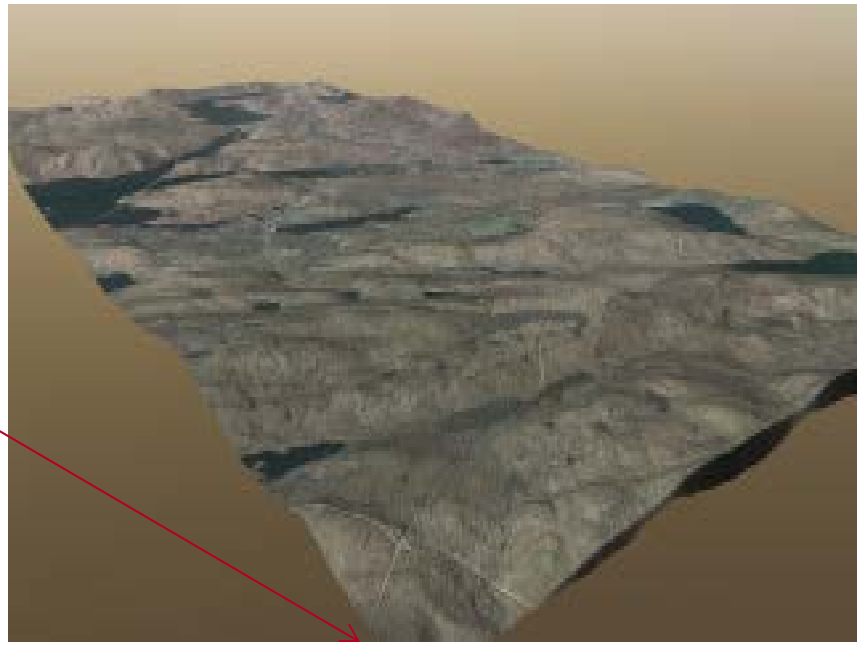
DEM from LiDAR

Ortho-rectification of imagery - accurate base layer for GIS

Gridded LiDAR DEM



Ortho-rectified imagery



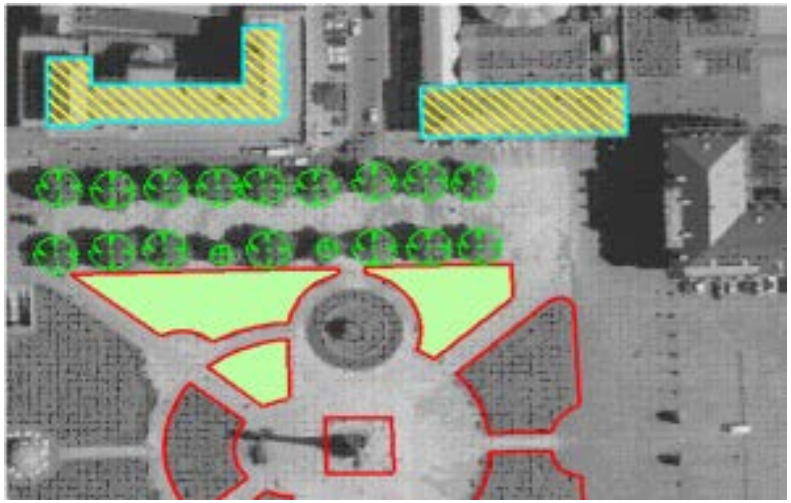
1. LiDAR ground returns "mass-points"
2. Create TIN model
3. Generate point grid even space
4. SOM spec supports 1 or 2' contours

1. Transfer LiDAR accuracy to imagery
2. Map accurate image in ground coordinates
3. Resolution 3" – 1' common per spec
4. Accuracy to 20cm or better (Absolute)

High resolution imagery requires / deserves an accurate DEM

Accurate Ortho Base Map!

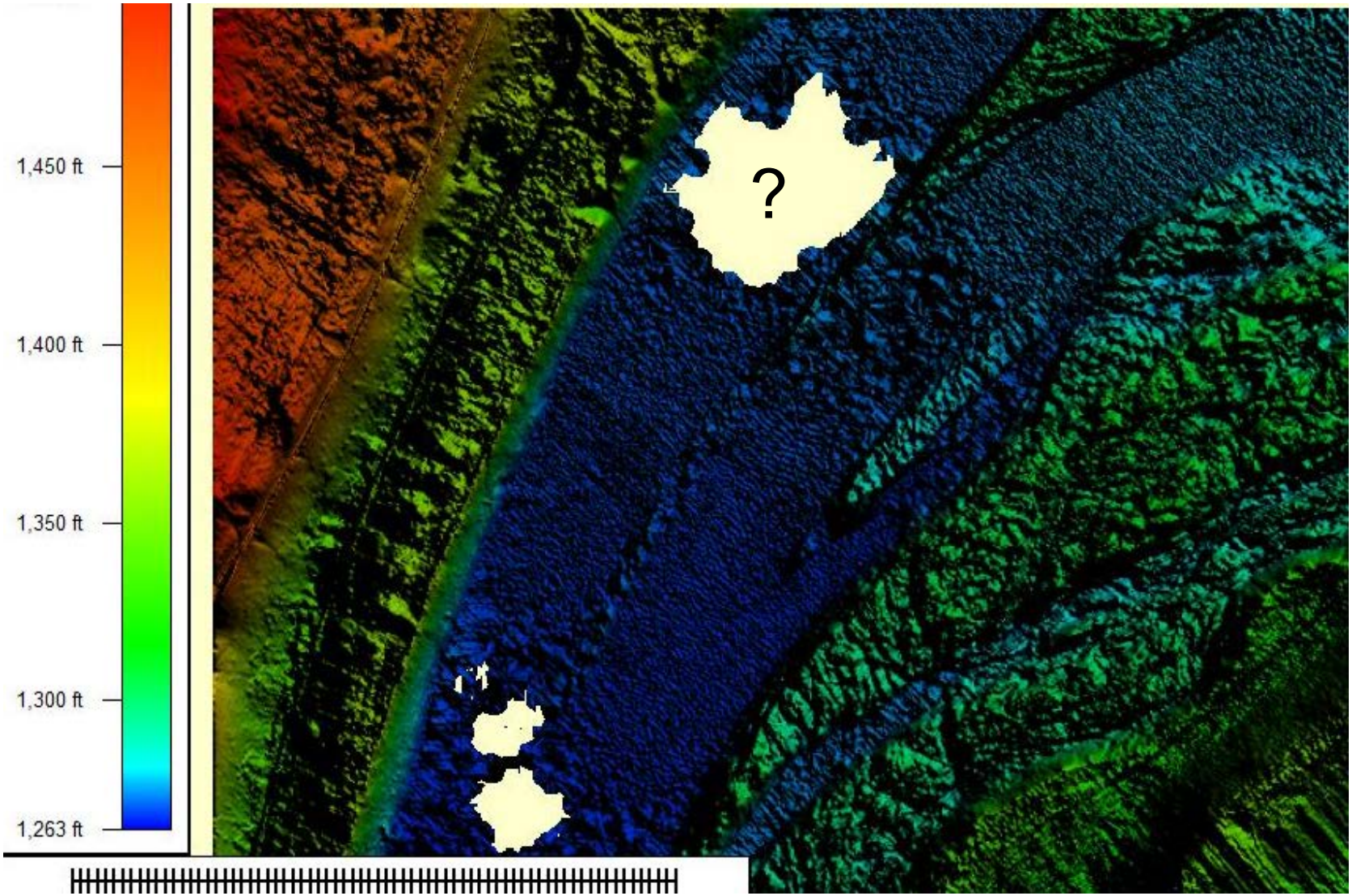
Precise display of assets with LiDAR DEM's



- Precise GIS base layer
- Aerial in ground coords
- Accurate OTS data aligns (parcel, trans, vehicle scans, utility, wetlands, etc.)
- Inaccurate OTS data can be geographically improved
- Digitize road centerlines, curb lengths, paint striping, etc.
- Better in-office decision making
- Obtain 3D "true length" measurements

Limitation or Benefit of LiDAR?

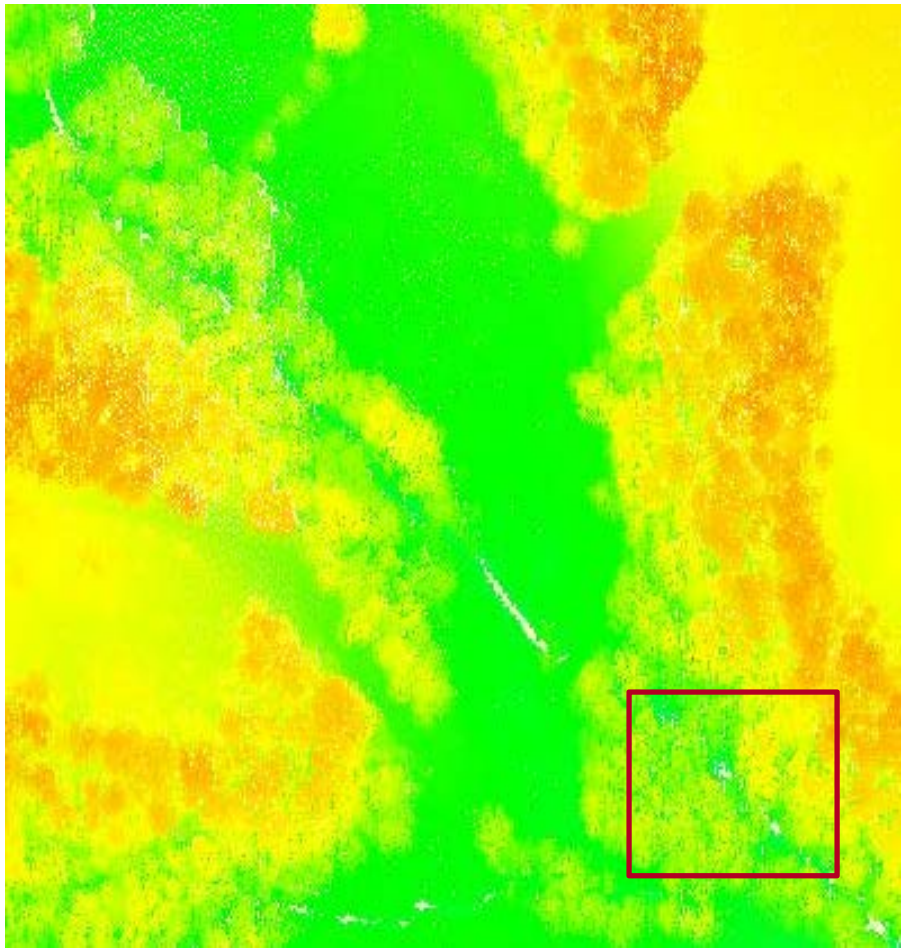
Can you identify white areas?



Wetlands Delineation

Field navigation / verification

Color Ortho-image



LiDAR 2D point cloud

<u>Automated</u> Image Analysis / Segment

3D vs. 2D data

- Project requirement to identify structure ***Changes (+/-) in size of buildings***

- Inputs I. (2008 – 2010)
  - 1M RGB NAIP
  - No LiDAR

- Inputs II. (2008 – **2012**)
  - 1M RGB/**IR**
  - 1M res **LiDAR**

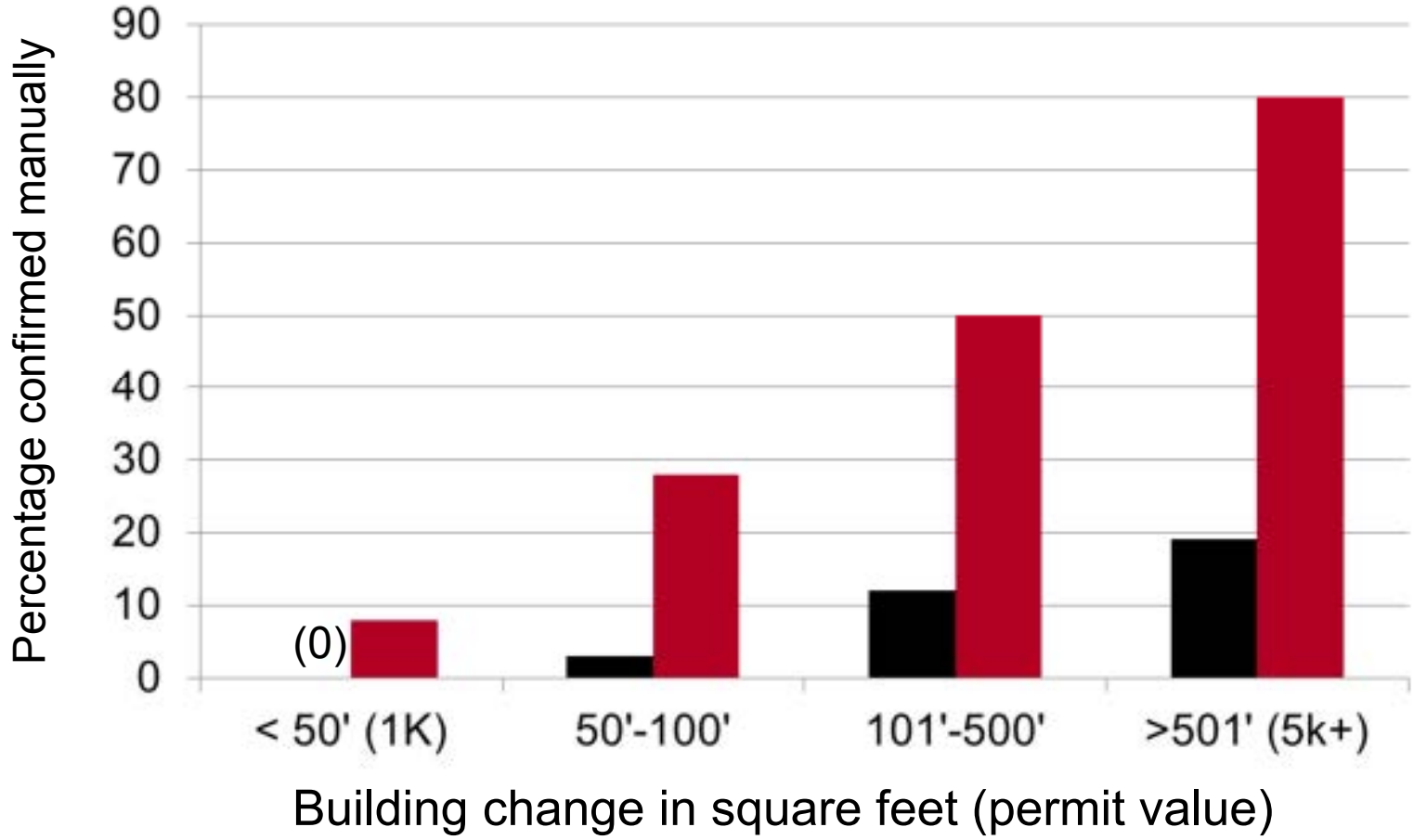
Validation Methodology

- Gather Permit of changes from County
- Geocode using address data to provide physical location
- Overlay on vendor Change Detection map
- Compare results manually

Automated **Results**

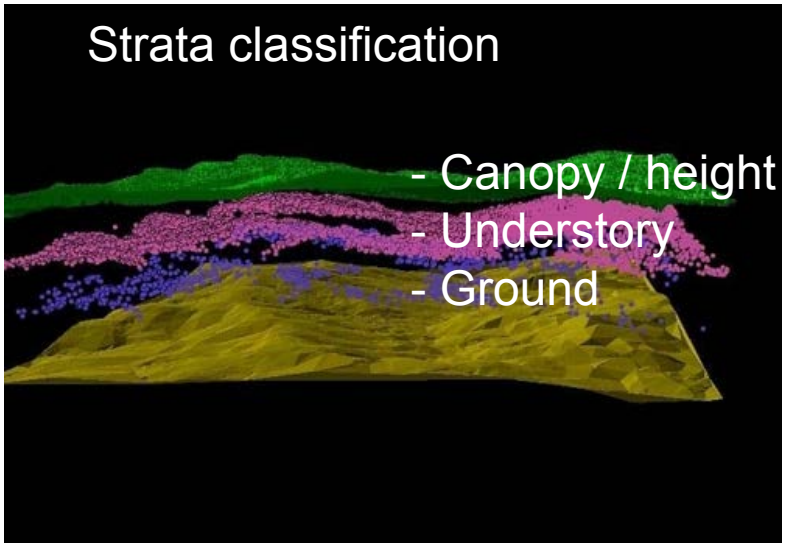
Detecting change in building size with and without LiDAR and IR band

- 2008 – 2010 (1 mtr RGB ortho's only)
- 2008 – 2012 (1 mtr RGB/IR & LiDAR DEM/DSM



Natural Resource applications

- **Vegetation management - LiDAR**
  - Canopy height, tree density, biomass (living matter), basal area, volume, crown competition factor, etc.
  - growth stratification and slope stability
  - Carbon Offset Credits (COC)



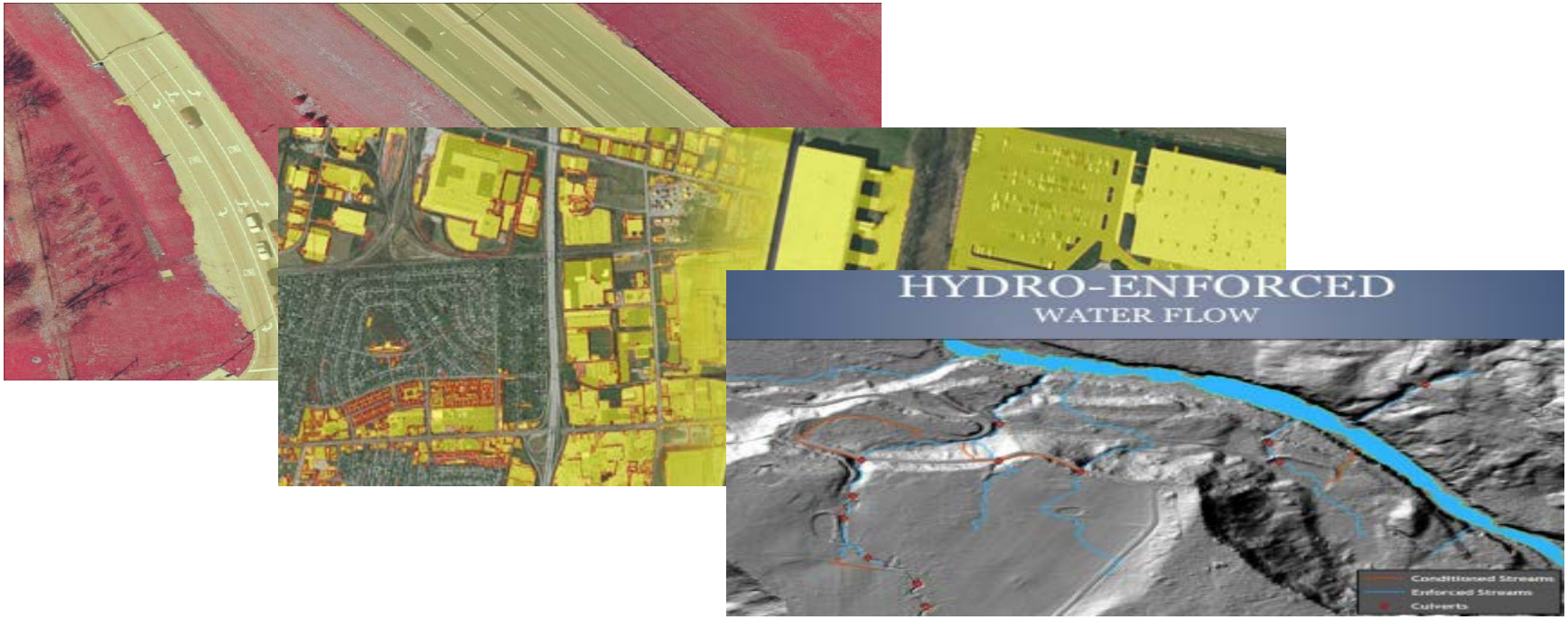
Normalized Difference Vegetation Index

- **Vegetation species / condition – IR Imagery**
  - Species – (calibrated in field)
  - Chlorophyll detection – condition
  - Area calculation / condition
  - Determine NDVI
  - Crop condition (fertilizer mgt.)
  - Model run-off

Pervious / Impervious Determination

- Storm Sewer planning
  - Impervious / non-impervious (LiDAR / image analysis & feature segmentation)
  - Watershed model (LiDAR enforced surface model)

**Model current & potential impact of development – roads, buildings, parking lots, etc. on storm system.*



Useable Derived Data "Summary"

Land cover / Land Use

- Land cover datasets created include:
  1. Water delineation (wetlands, lakes, ponds, etc)
  2. Building / structure footprint (Urban, sub, etc.)
  3. Impervious surfaces (buildings, roads, parking, sidewalks, etc.)
  4. Vegetation (canopy, area, density, type & condition)
  5. Other?

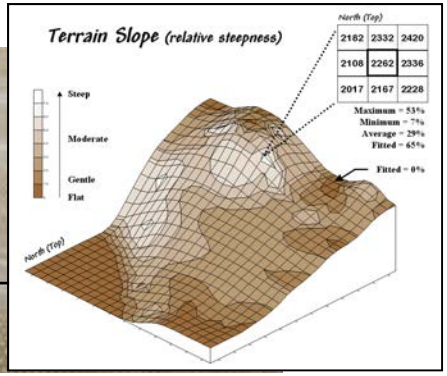
Transportation, Pipeline, Electric T-Line

In-Office Functionality / Assessment

Create accurate "as-is" alignment sheets

6. Create bid documents

PI



1. Plan digitizing
2. Preliminary route selection

5. Side slope calculations

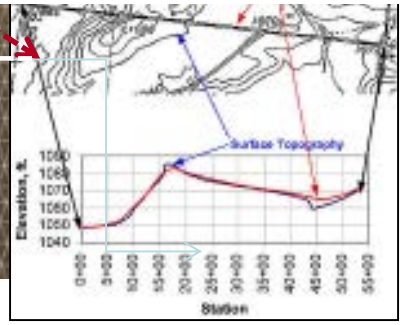
Primary route C/L

Alternate route PI selection

3. Earth quantity's topography / contouring

4. Generate PI's & profiles (C/L. left, right)

PI

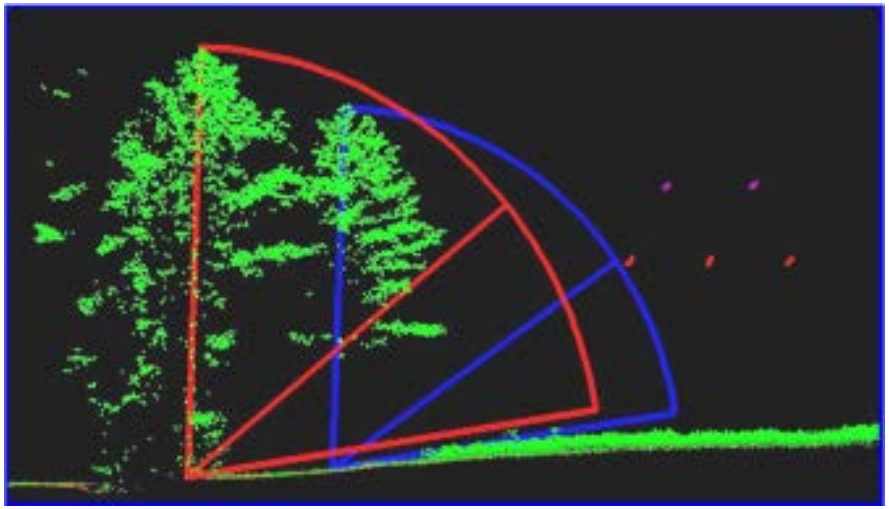


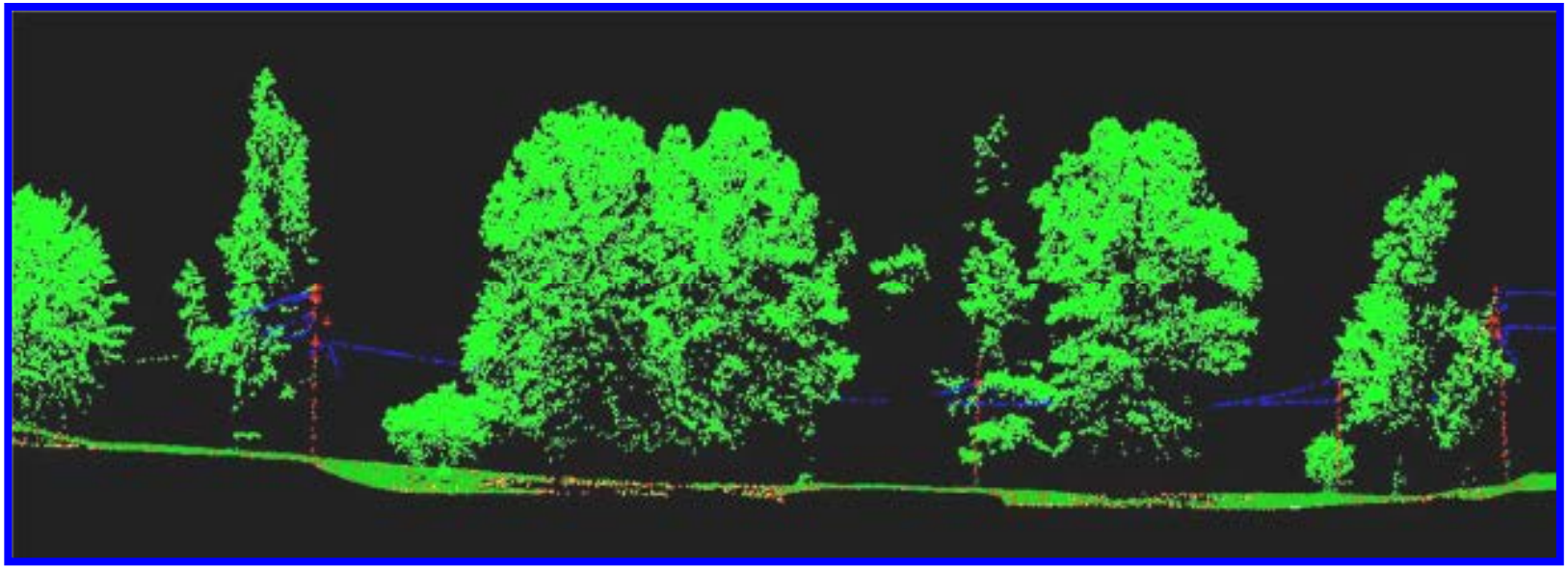
Electric Utility Corridors

T/L ROW assessment and management

1. New route assessment
2. Create “as-is” model of existing
3. Vegetation Management
4. Danger tree assessment
5. Erosion Detection
6. Encroachment Detection
7. Asset Management
8. NERC alert

(No American Reliability Council)

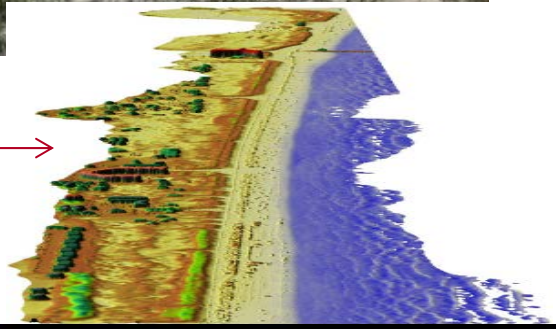


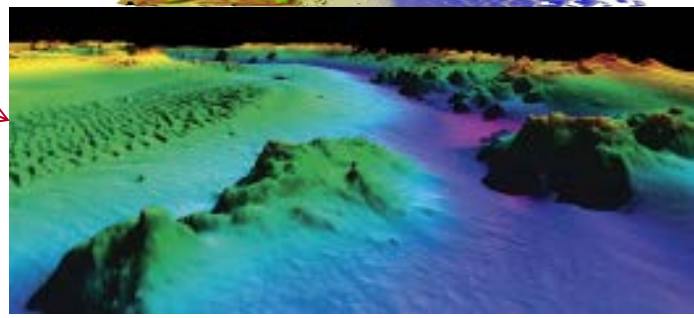


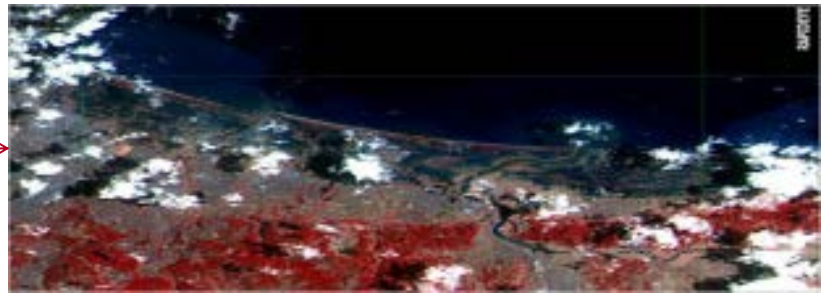
Coastal Zone Monitoring / Managing

with LiDAR

- Shore baseline & erosion monitoring
- Vegetation baseline & change monitoring
  InfraRed imagery
- Merging of datasets from:
  1. Airborne terrain mapping – NIR airborne LiDAR to obtain shoreline
  2. Airborne bathymetric LiDAR - wavelength of 1064nm that penetrates water
  3. Vessel - SoNaR or Sound Navigation and Ranging (speed of sound in water) for water depth (Echo)







Retail / Land Development

- Accurate base imagery for planning
- 3D simulation models
- Site topography / quantities balance
- Environmental impact
- Constructability analysis
- Readily available

Return on Investment – LiDAR

How is value determined?

I. Mobilization of LiDAR - min 5k to 15k before any work is started

II. LiDAR system charged p/day - fly 1 mile or 300 square miles (15k – 25k)

III. Traditional stereo contour mapping – PSM basis = 2k – 3.5k (5k-7k 1st mi w/ mob / de-mob)

IV. Traditional survey – 1k to 1.5k PLM (trans, utility)

V. What is the value to the owning agency and users?

(local developers, engineers, surveyors, planners, energy providers, storm water mgt, GIS, emergency response, farmers, GIS, DOT, assessors, environmental, etc.)

Advantages of LiDAR

Generally speaking

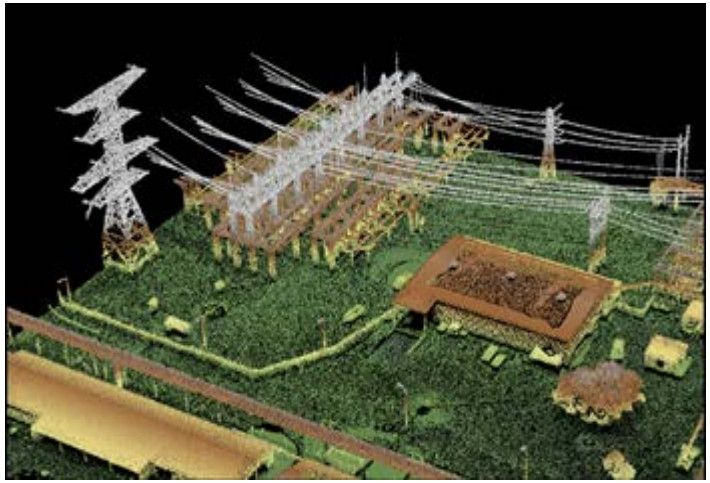
1. Numerous applications (examples to follow)
2. Collect / store data - process only when needed
3. Converts GIS from 2D to 3D
4. Improves accuracy of rectified imagery
5. Un-impeded schedule once collected – no weather issues
6. Quality of data - accurate & detailed
7. Value $ – proven cost savings over traditional ground & photogrammetry methods
8. Detects elevated and suspended objects w/ height
9. Fewer field revisits – improves safety
10. Collect in rugged & vegetated conditions (no GPS)
11. Interfaces w/ CADD & GIS software
12. Other?

.LAS Point Cloud

Data Classification Software

- Terra Model's - Terra Scan
- QCoherent - LP360
- Virtual Geomatics
- MARS (Merrick)
- VR Mesh

3D Building footprints



Automated Feature Classification

Viewing LiDAR .LAS Format

- FREE DOWNLOADS
- View classified or non-classified data in these viewers (LiDAR / Imagery)
  - Global Mapper
  - MARS
  - Virtual Geomatics
  - QT Modeler
  - Earth Eye
  - LP360
  - More

CloudMAP Services → Web enabled fulfillment

Oil/gas Pipeline | Transportation | Electric utility | Oil/gas Exp & prod | Environmental

International | Development | Insurance | Government

Client / Web interface

Intellectual pool & specification development
contract negotiation & project management
Unlimited processing - Independent compliance / QA/QC

Industry leaders / network partners

Photogrammetry
LiDAR Consulting
Magnetic / Electro-Seismic / Gravity
Multi-spectral imageryTerrestrial LiDAR
Project management Survey
OTS source data Hyper- spectral
QA/QC

Local Acquisition Network

Local & International coverage

*Experienced technical oversight

*Scalable data acquisition

*Scalable custom processing

Public Awareness

- 3D fly-though (Overlay image on LiDAR)
  - Arc/GIS Explorer instructions (download)
  - (Specifications, software download and examples – available for inclusion in aerial bid documents)
  - Fly-through metadata
- Public meetings
- Proactive with regulators DOT/FERC/NERC?

Sample - NEU Fly Through example

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