Session 53

Scott Harris

FL. Dept. of Transportation SMO

3d Laser Scanning

Topic Description

Demonstration of Terrestrial Laser Scanner, along with Allen Nobles presentation on actual project results from the past two years from a third party view and how it could save costs on PD&E and other FDOT type projects.

Speaker Biography

Scott was educated at the University of Florida School of Engineering Department of Geomatics. Employed with FDOT for 11 years, his initial experience is with FDOT Location, providing surveys for transportation design. He has participated as technical advisor on several task teams; testing field-surveying equipment including GPS, total stations and data collectors. Mr. Harris is experienced with Geographical Information System development, specifically dealing with the integration of GPS. He is also a certified trainer for the Ashtech and Leica brand mapping grade GPS systems. Scott is currently responsible for the design, deployment and maintenance of the statewide GPS reference network.

Session 53

Allen Nobles

Allen Nobles and Associates, Inc

3d Laser Scanning

Topic Description

Actual projects results from the past two years from a third party view and how it could save costs on PD&E and other FDOT type projects. Along with a Demonstration of a Terrestrial Laser Scanner.

Speaker Biography

Allen Nobles, PSM is a registered Land Surveyor in Florida and Georgia with over 30 years of experience in the survey field. He also is an approver educational provider for the State of Florida and has served as an instructor for many professionals associations in Florida and Georgia. He is currently President of Allen Nobles & Associates, Inc. with five offices located in North Florida and South Georgia providing surveying consultation to both public and private clients. His firm is currently using some of the newer technologies for surveying and has provided his clients with a wide range of survey data on numerous complex projects.

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The Principles of LiDAR

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Course Outline

The Theory
The Technology
Data Processing
Quality Control
Real World Application
The Future

What LiDAR Is:

Light Detection And Ranging

It is an active sensing system

It is the science of using a laser to measure distances to specific points. It uses its own energy source, not reflected natural or naturally emitted radiation

It can be operated both day or night

Ranging based on time difference between emission and reflection of laser pulse

Direct acquisition of terrain information

Photogrammetry is inferential

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What LiDAR Is Not:

NOT Light/Laser Assisted RADAR

RADAR uses electro-magnetic (EM) energy in the radio frequency range; LIDAR does not. It uses light in the near infrared spectrum.

NOT all-weather

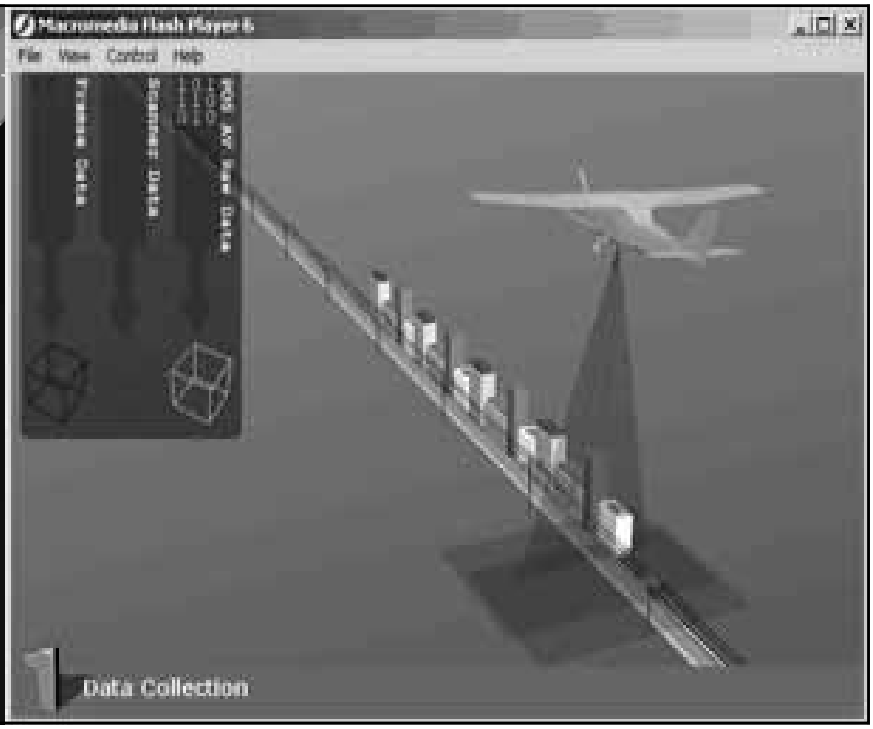
The target MUST be visible. Some haze is manageable, but fog is not.

NOT able to 'see through' trees

LiDAR sees around trees, not through them. Fully closed canopies (rain forests) cannot be penetrated.

NOT a substitute for photography

For MOST users, LiDAR intensity images are NOT viable replacements for conventional or digital imagery.



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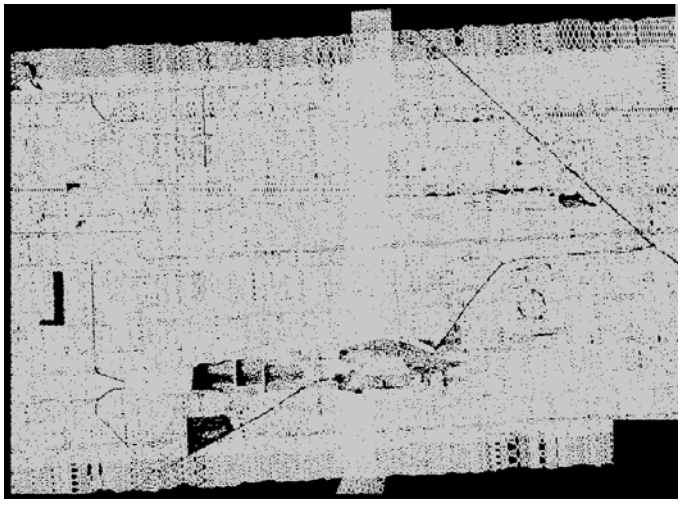
Mass Point Cloud



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Bare Earth Points

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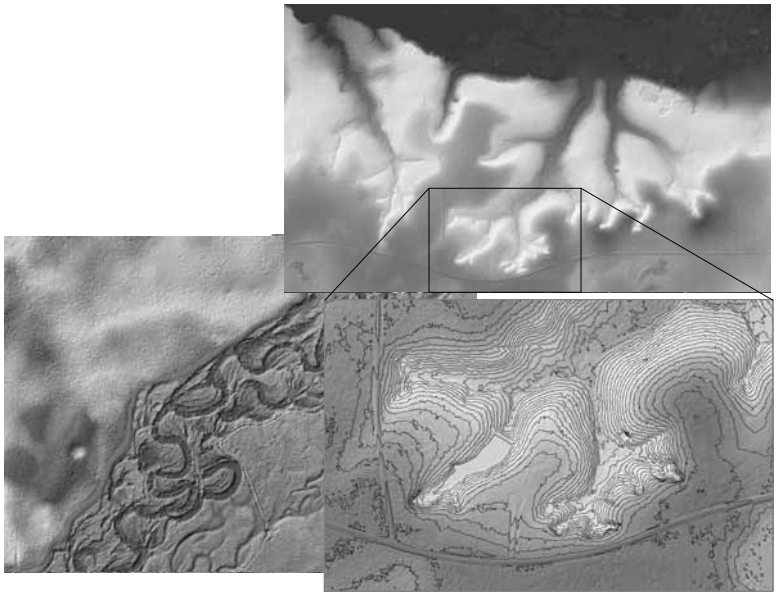
Topographic Mapping with LIDAR



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LiDAR Characteristics

Capable of collecting millions of elevation points per hour – much faster than traditional methods

Produces datasets with much greater density than traditional mapping

Some systems capable of capturing multiple returns per pulse and/or intensity images

Vertical accuracy for commercial applications at 15 cm on discrete points

Supported by rigorous QA/QC

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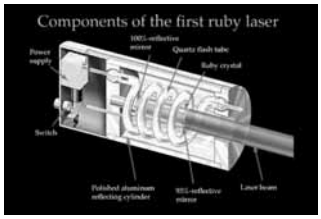
LIDAR Operational Theory

A pulse of light is emitted and the precise time is recorded.

The reflection of that pulse is detected and the precise time is recorded.

Using the constant speed of light, the delay can be converted into a “slant range” distance.

Knowing the position and orientation of the sensor, the XYZ coordinate of the reflective surface can be calculated.



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Two Basic Sensors

Topographic (Airborne)

Ground Based

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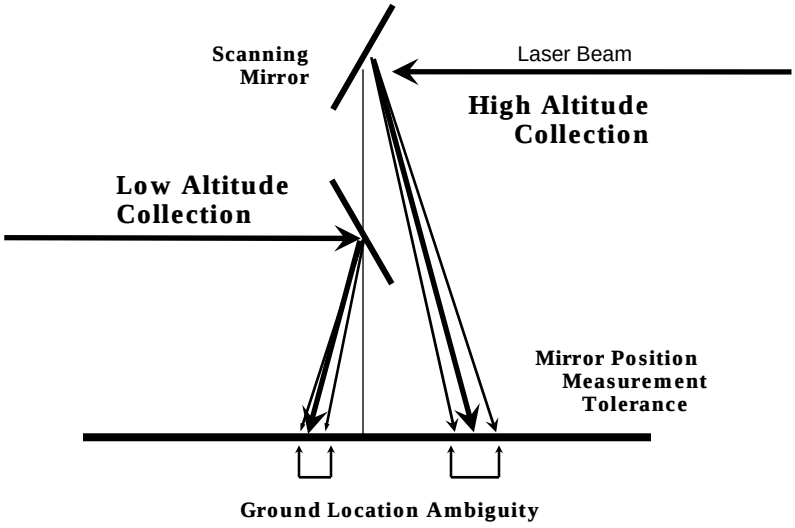
Scanner Mirrors



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Topographic System Accuracy

50,000	Specification	70,000
Vertical:		
15cm @ 1200m		15cm @ 1200m
25cm @ 2000m		35cm @ 3000m
Horizontal:		
1/2000 x altitude		1/2000 x altitude

Typical Results are better on each system

Vert 10cm @ 1200m & Horiz 1/3000 x altitude

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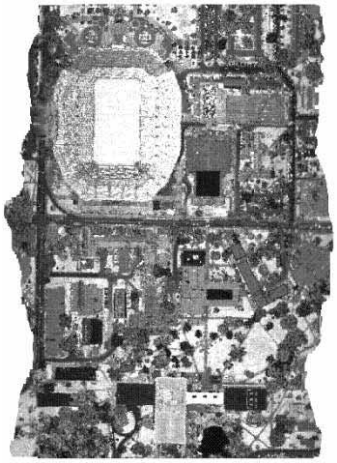
Intensity Image



Scanner

- Return Intensity Capture
  - Provides correction for ranging calculations
  - Can provide useful image information
    - Often not a consistent imaging technology
    - Not the same as a Near-IR sensor image
  - Images can be difficult to interpret
    - Pixel Resolution a Function of the post-spacing
    - Laser wavelength is a factor
    - Holes in the data may be identified quickly
    - Some General Interpretations are Possible

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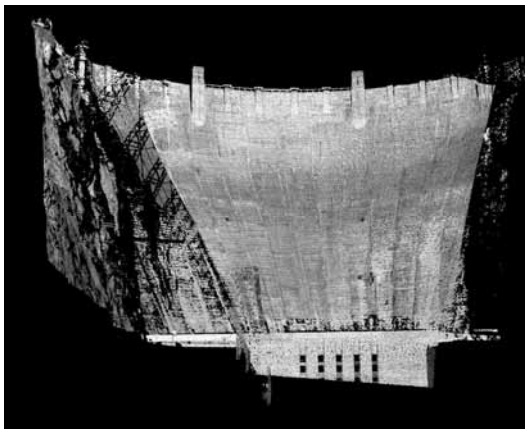
Two Basic Sensors

Ground Based



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Two Basic Sensors

Ground Based

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The Airborne Platform

Laser Scanner

Inertial Measuring Unit

Global Positioning Receiver

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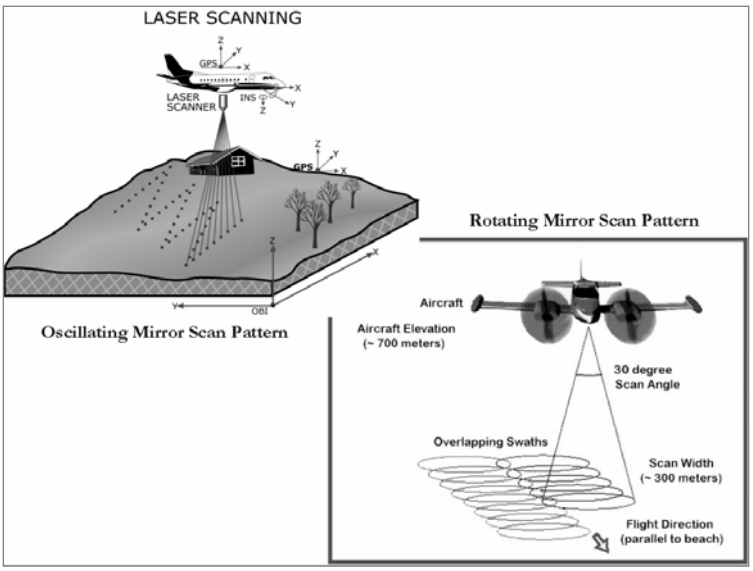
Scan Mirror



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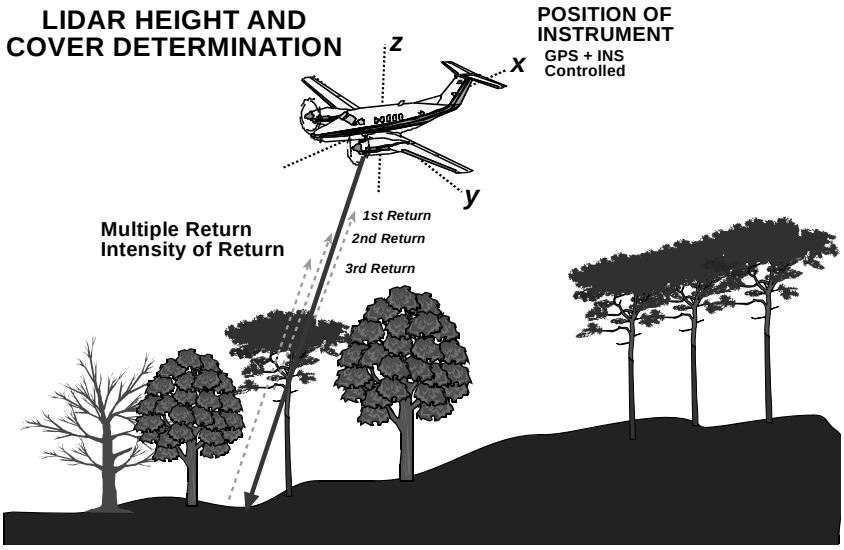
Multiple Returns



Scanner

- Return Per Pulse Detection
  - Single First Surface
    - 1st Generation of Returns
    - Limited vegetation penetration
    - Good for some Urban Applications
  - First & Last
    - Good vegetation penetration & ground detection
    - Some Applications fit this scenario well
  - Discrete Multiple
    - Allows advanced analysis of vegetation structure
    - Widest range of applications for about same cost

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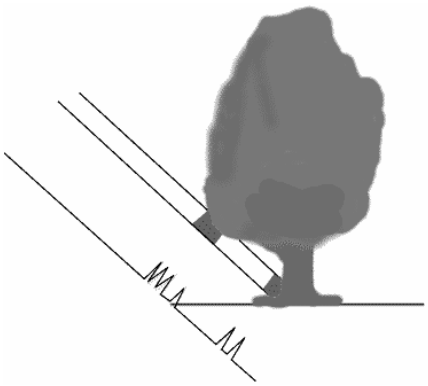
FIRST PULSE Return

- First-pulse
  - Measures the range to the first object encountered - in this illustration, the tree foliage.



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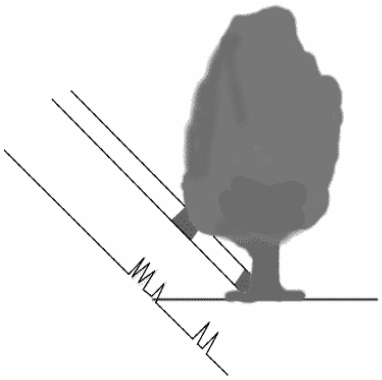
LAST / PULSE Return

Last-pulse

- Measures the range to the last object - in this case, the ground.
- By acquiring first- and last-pulse data simultaneously, it is possible to measure both tree-heights and the topography of the ground beneath in a single pass.



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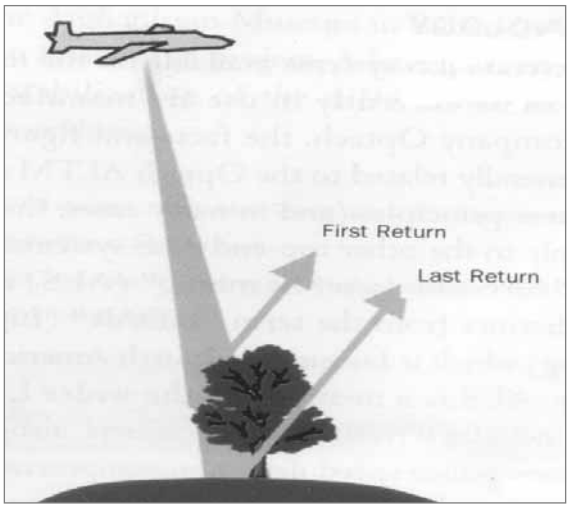
Pulse Return



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Why Now?

Several recent, enabling technological advances have made LIDAR possible:

Airborne GPS

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Why Now?

Several recent, enabling technological advances have made LIDAR possible:

Airborne GPS

Inertial Measurement

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Orientation Information

Accurate placement of reflective point requires information on aircraft attitude

Need the rotation around 3 axes of the aircraft - roll, pitch and yaw

Two techniques in practice:

- multiple GPS receivers (less accurate)
- inertial measurement units (very accurate)

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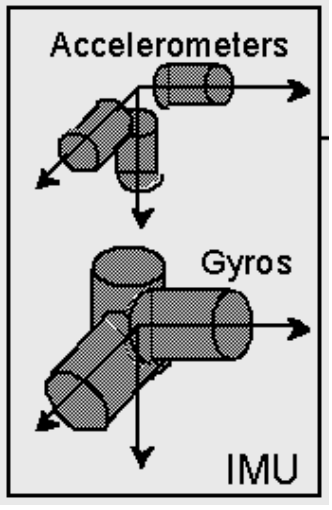
Inertial Measurement Unit

Combination of gyros and accelerometers

Typically integrated with GPS system

Accuracies of 18 - 25 arc-seconds (0.005-deg for pitch and roll, 0.01-deg for yaw)



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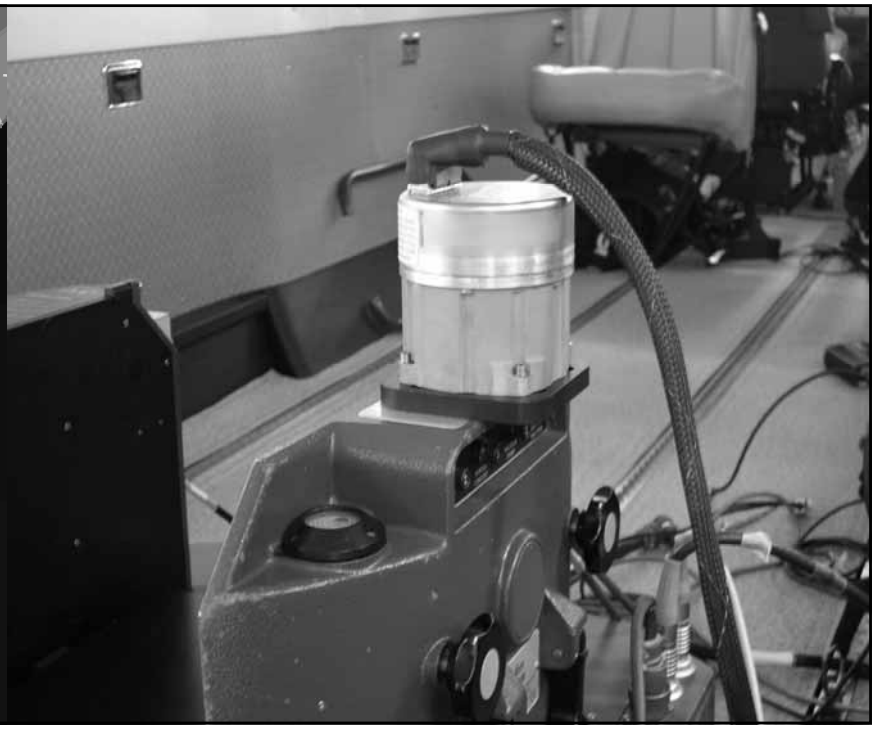

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Orientation Information

Measure 3 axes of aircraft rotation
(roll, pitch, and yaw)
3 Accelerometers and 3 Gyros
Accuracy of 18-25 arc-seconds
0.005 degrees Pitch & Roll
0.01 degrees Yaw
200 Readings per Second

IMU Animation

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Why Now?

Several recent, enabling technological advances have made LIDAR possible:

Airborne GPS

Inertial Measurement

Availability of affordable lasers and other specialized materials and sensors

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Computer Processing System

Real-time Processing, Time Alignment and Data Acquisition, and Data Storage from IMU

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Why Now?

Several recent, enabling technological advances have made LIDAR possible:

Airborne GPS

Inertial Measurement

Availability of affordable lasers and other specialized materials and sensors

Declassified military technology

Why Now?

Several recent, enabling technological advances have made LIDAR possible:

Airborne GPS

Inertial Measurement

Availability of affordable lasers and other specialized materials and sensors

Declassified military technology

Advances in computer technology (speed, performance, size, and of course, price)

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Systems Overview

A combination of three mature technologies:

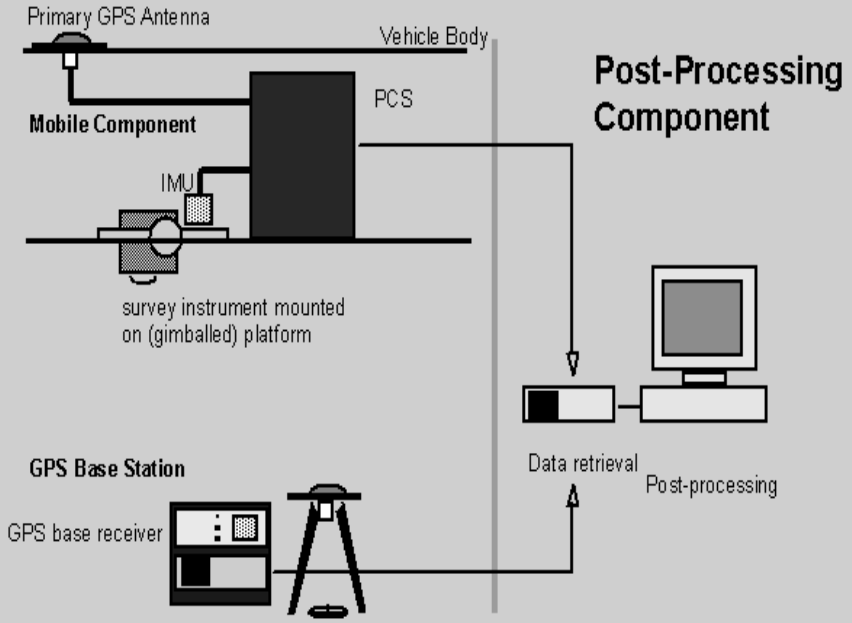
- Compact scanner (a rangefinder)
  - pulses at 1000s of points per second
- Inertial Measurement Unit (IMU)
- Global Positioning System (GPS)

Integration of Components into a Robust Measurement Instrument

- Hardware, software, and Calibration

Installed in an Airplane or Helicopter Platform

Supported by traditional survey principles



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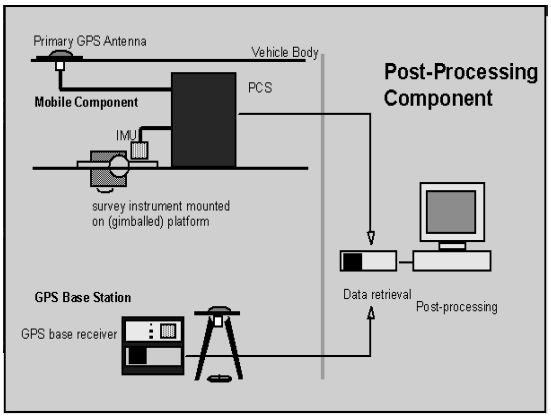

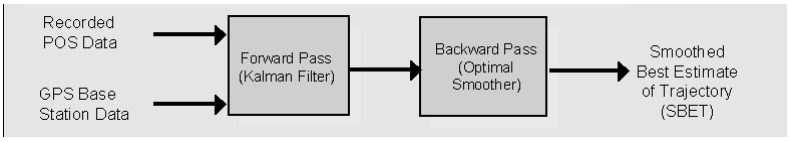

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MISSION PLANNING

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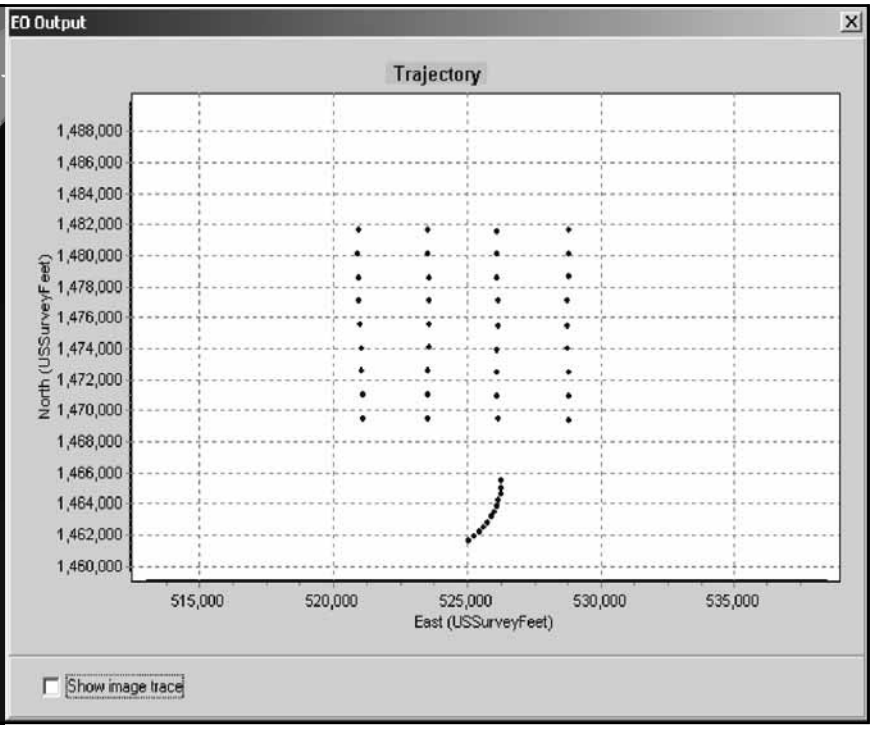

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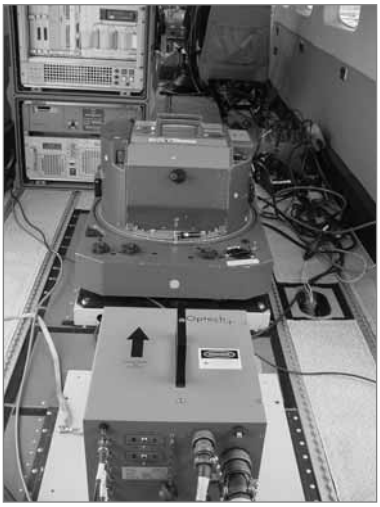
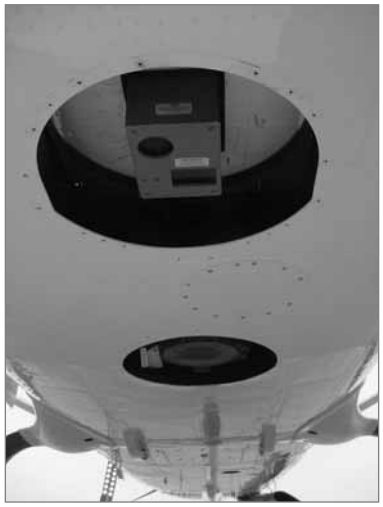
Multi-Functional Aircraft





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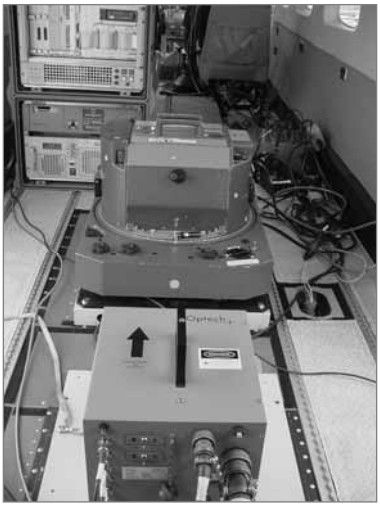
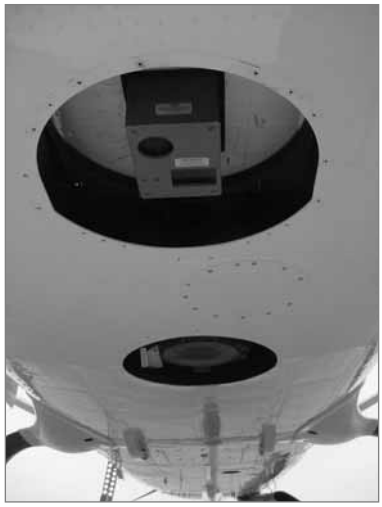
Data Collection and Storage





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Data Processing

Solve for aircraft position (GPS)

Solve for aircraft attitude (IMU)

Solve for the Laser Positions (Ground)

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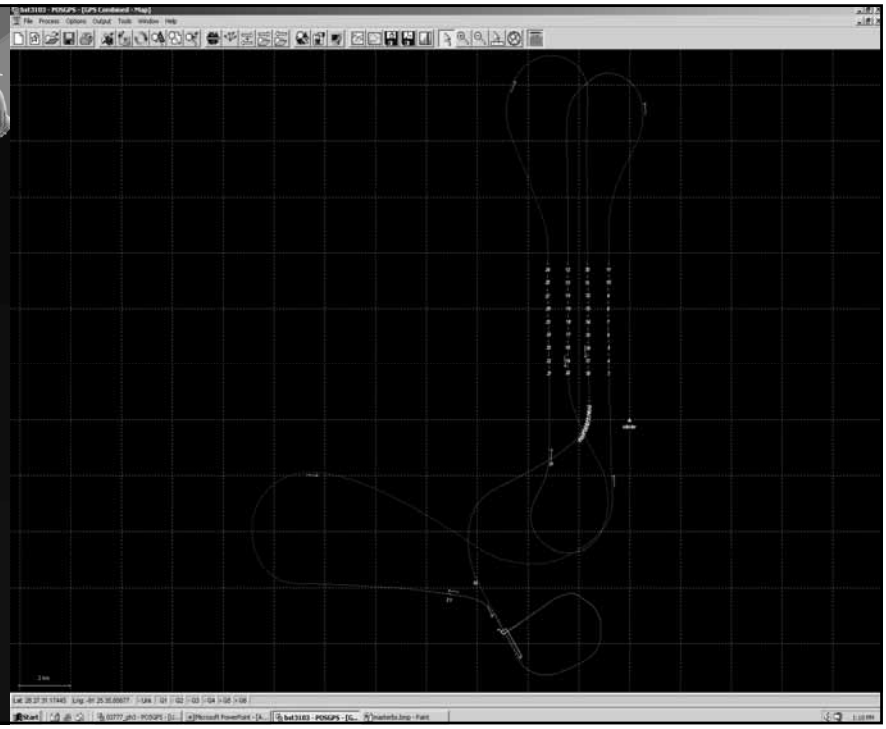
POSITION



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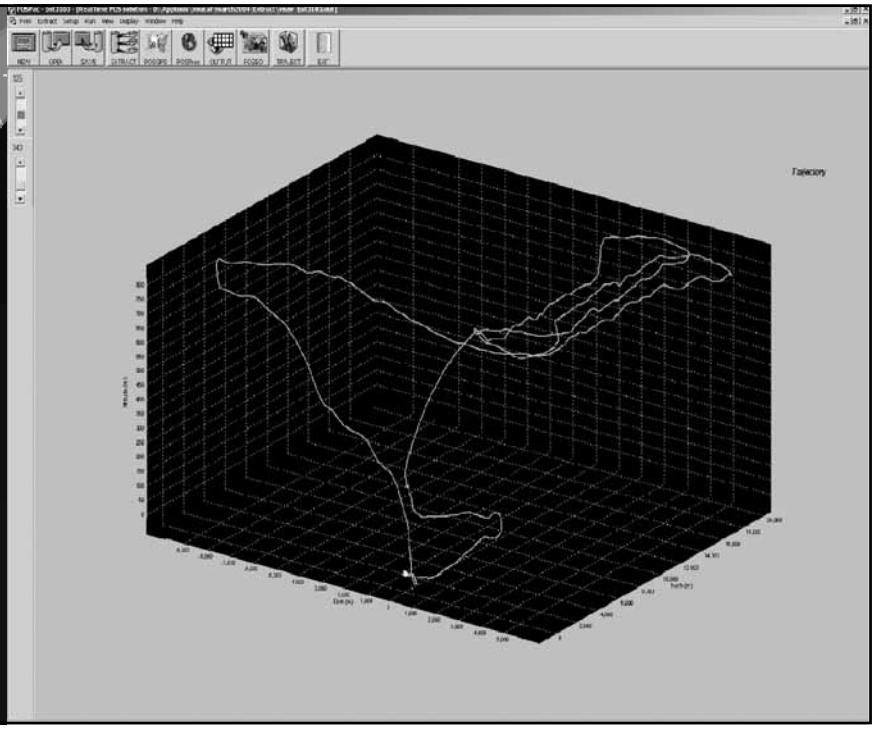
Integration of GPS and IMU Data



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The Processing of Lidar Data

Classification of Data
Breakline Synthesis

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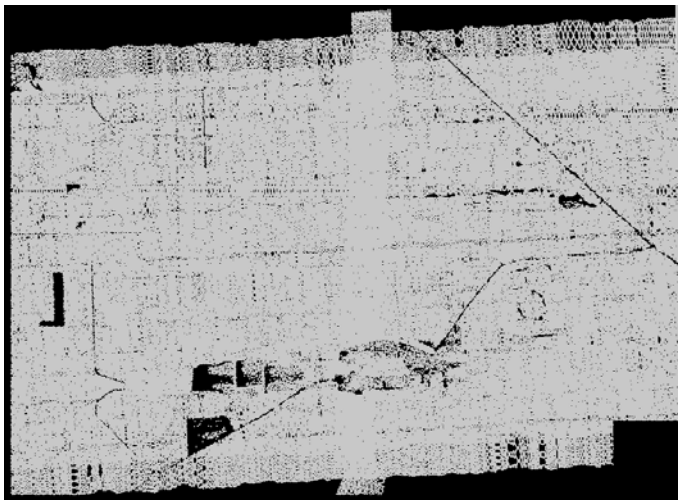
Mass Point Cloud



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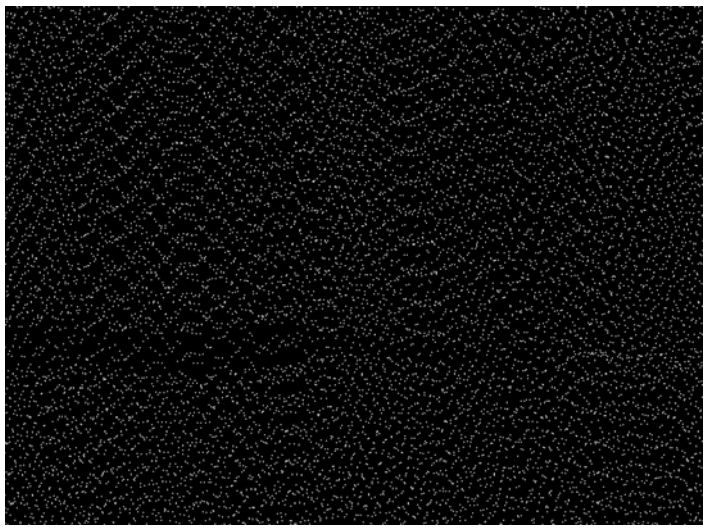
Enlarged Cloud



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Intensity Return

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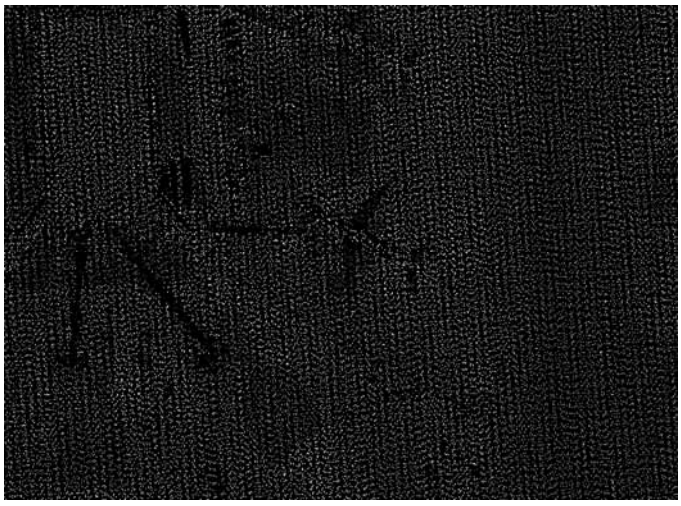
Mass Point Cloud



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Mass Point Profile

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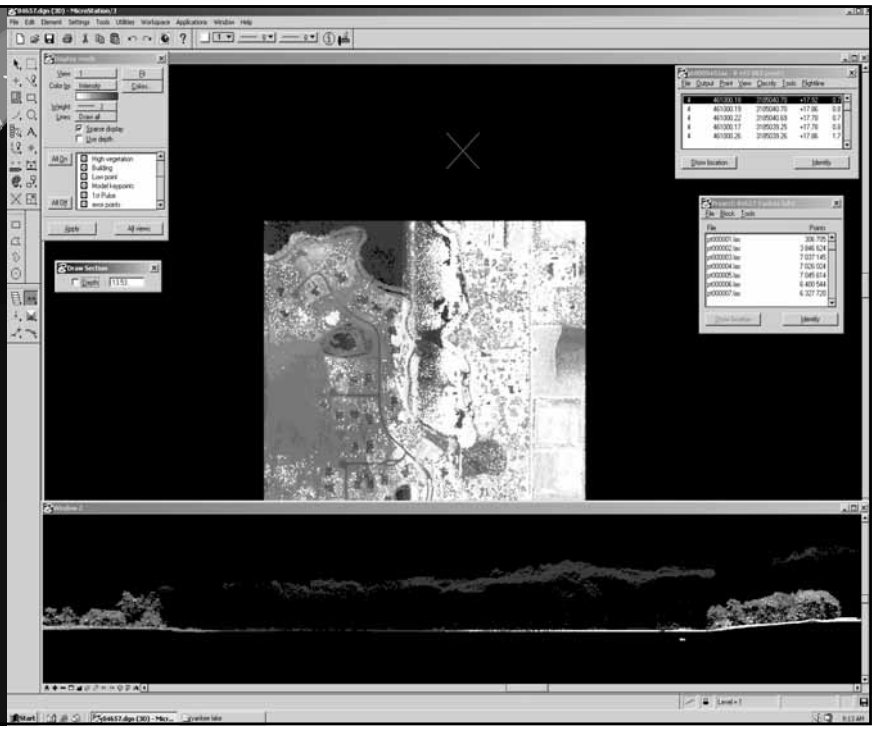

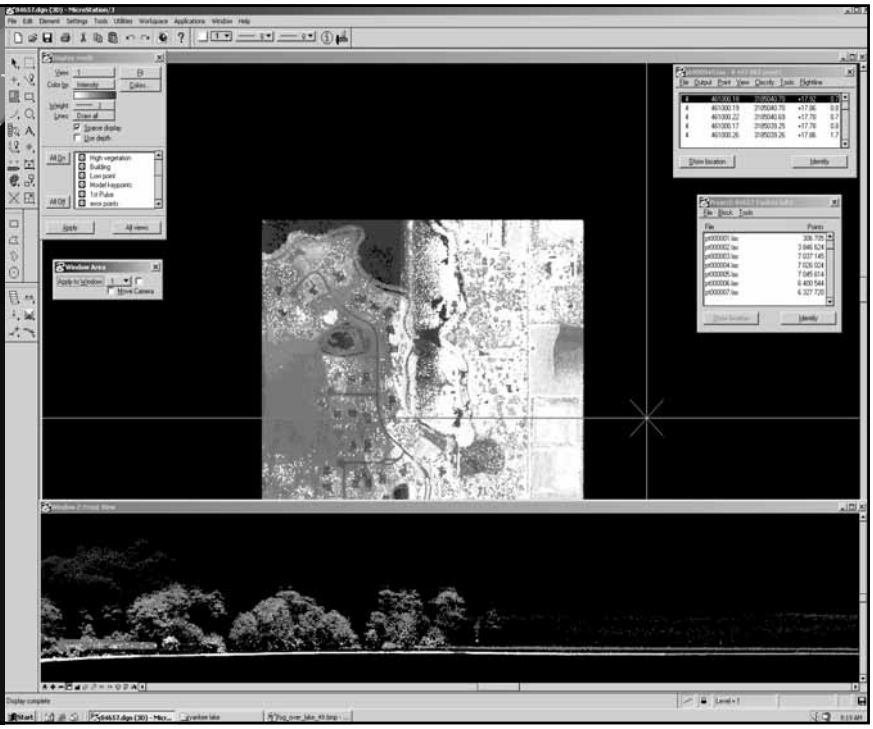

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Data Classification

Filtration Process to extract above ground features

Classification is necessary to determine an accurate bare earth DEM

Done correctly it is a powerful Quality Control tool

Commercially Off The Shelf Software

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Mass Point Profile

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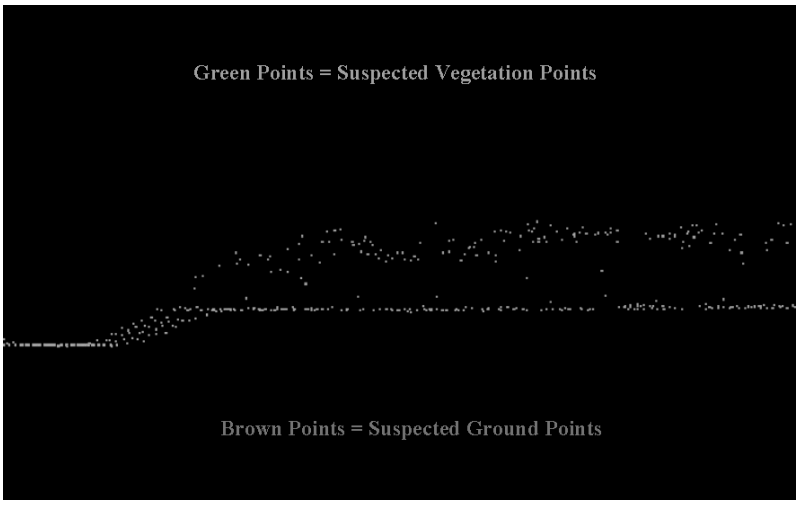
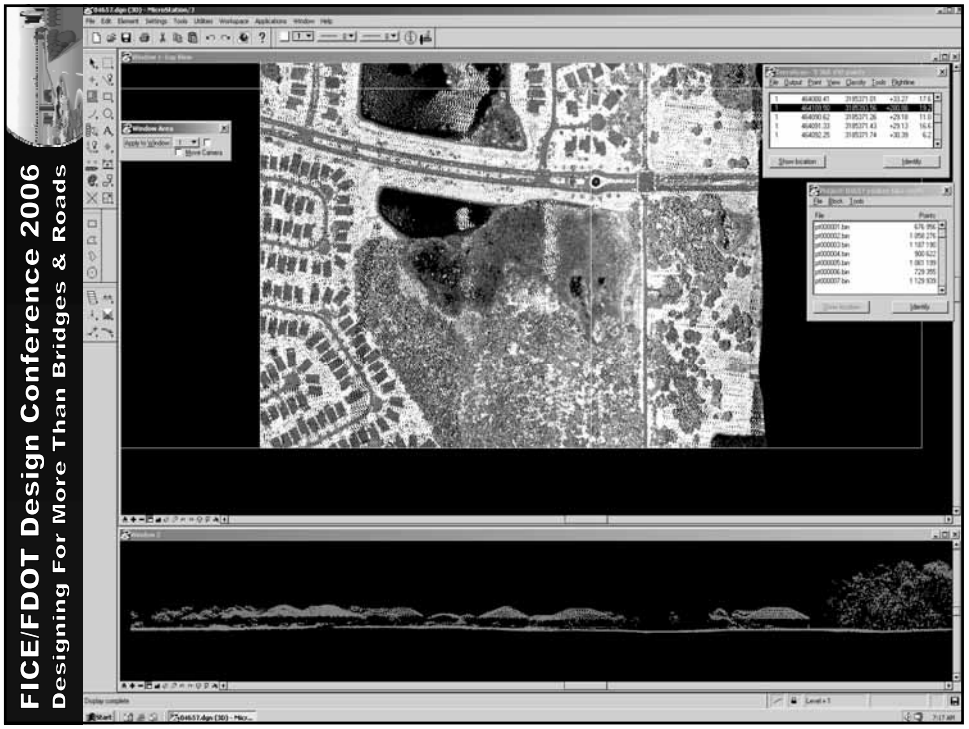
Classified Features Profile

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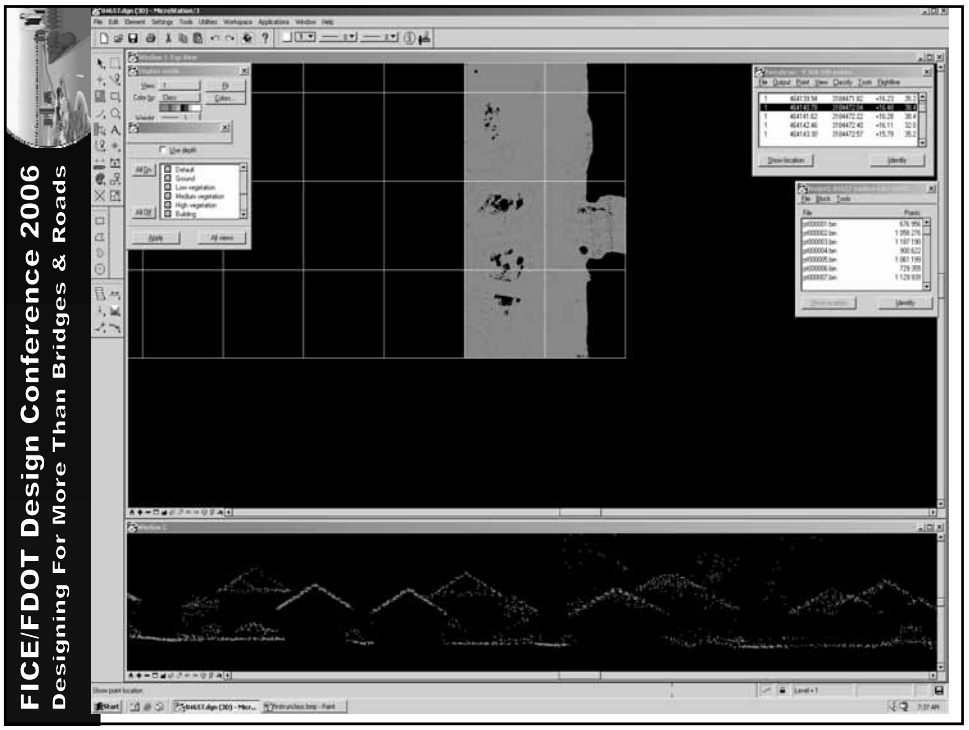
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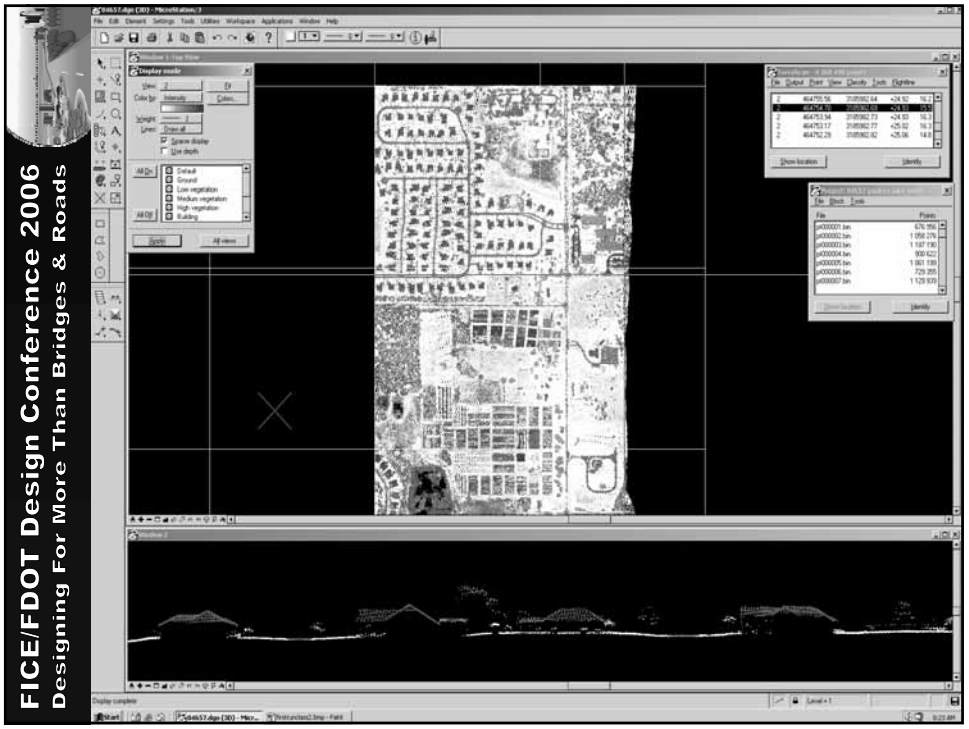
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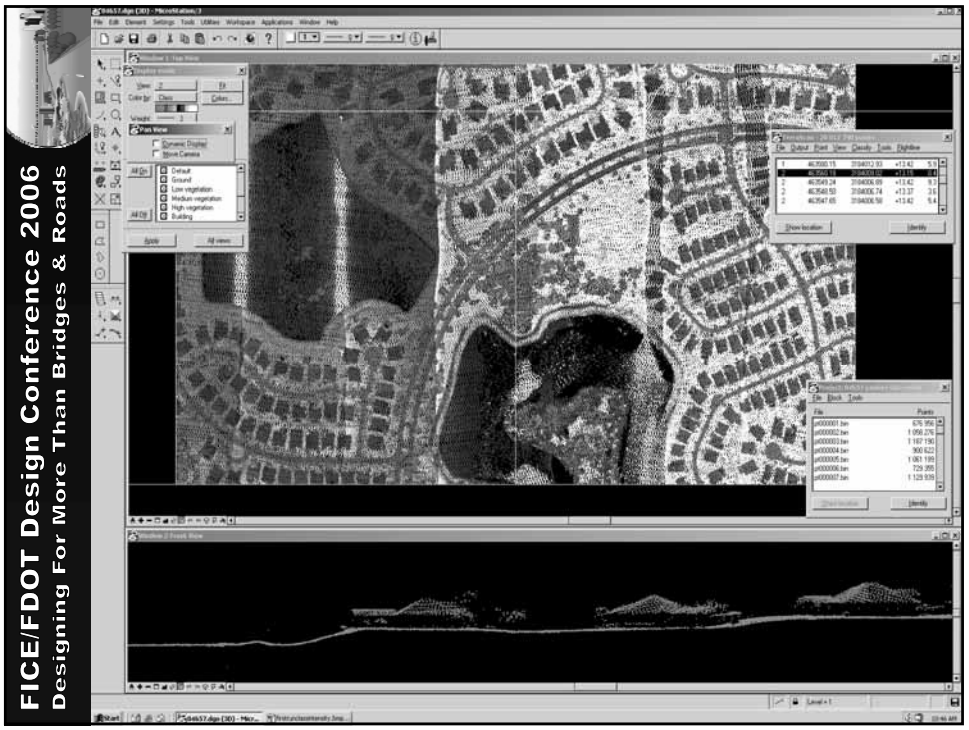
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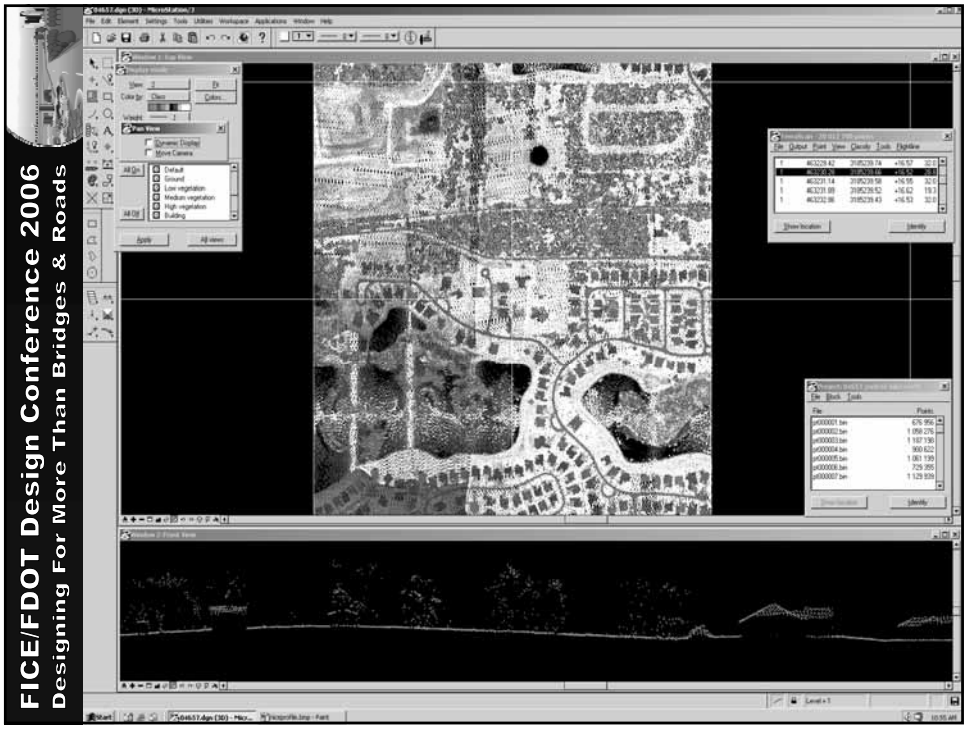

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Comparing Technology

LiDAR vs. Stereo Compilation

1”=100’ Scale Mapping

Compiled Mass Points more widely spaced: 60’ vs. 7’

Compiled DTMs use breaklines; LiDAR *usually** does not

Compiler can place points; LiDAR is semi-random

Compiler must see the ground; LiDAR is self-illuminating

**Technology is beginning to close this gap*

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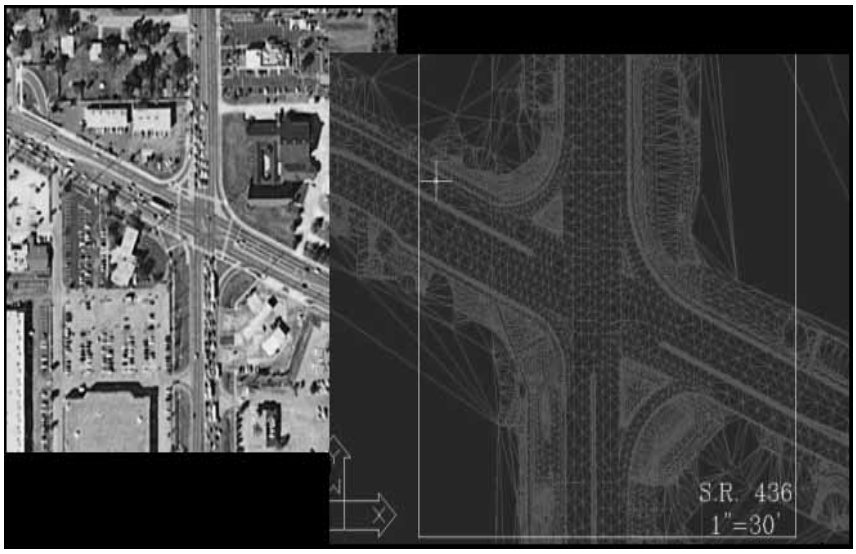
SR436 & Curry Ford Rd



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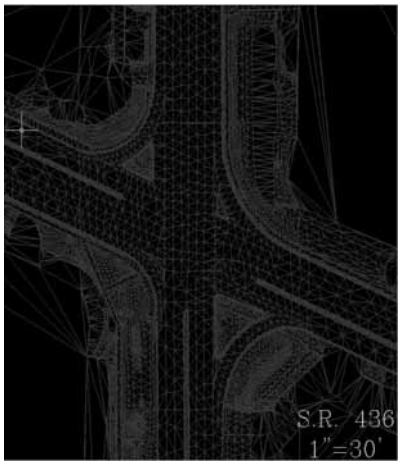
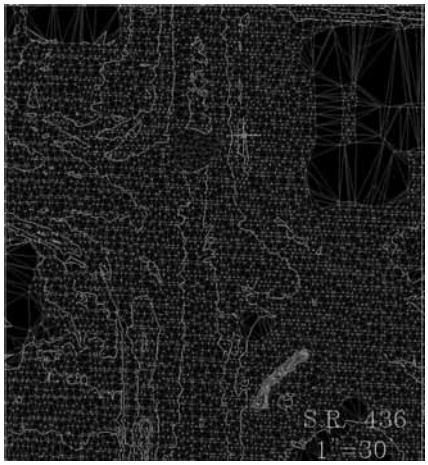
TIN Comparison



Photogrammetry



LiDAR

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Contour Comparison

Photogrammetry

LiDAR

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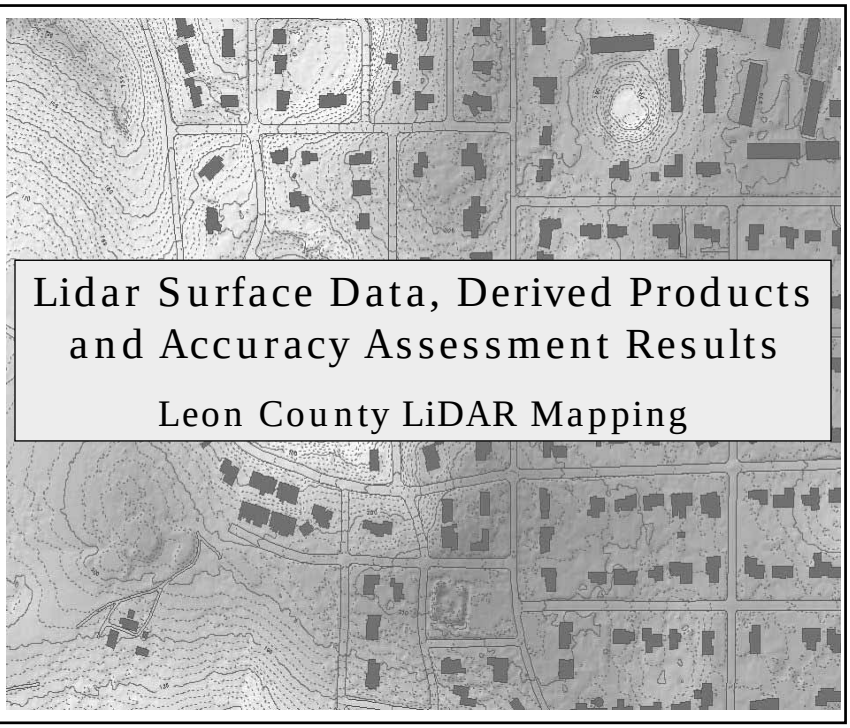

Lidar Surface Data, Derived Products and Accuracy Assessment Results

Leon County LiDAR Mapping

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Tallahassee-Leon County LIDAR Mapping Project

- Acquisition Date: January, 2002
- Project Area: 702 Square Miles
- Elevation Accuracy Specification: 2 Ft Contour
- Breaklines captured from 1 : 7920 photography
- Pulse Rate: 40 KiloHertz
- 1239 Checkpoints for QA/QC
- -0.40 feet adjustment to correct systematic error

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LIDAR Checkpoints

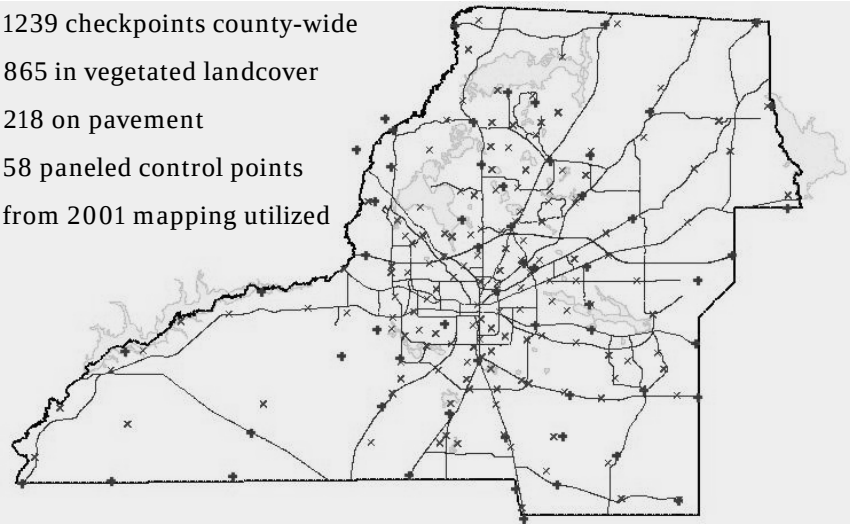
1239 checkpoints county-wide

865 in vegetated landcover

218 on pavement

58 paneled control points

from 2001 mapping utilized



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Accuracy Assessment Results

Table1: All Checkpoints

Data Source	# Pts	Std Dev	Mean	Min	Max	SSE	RMSE
Base01	58	0.35	-0.02	-1.30	0.94	7.098	0.349
Asphalt	218	0.52	-0.05	-2.39	2.09	59.081	0.520
Ground	865	1.24	-0.08	-5.68	12.08	1329.98	1.240

Table2: Points greater than 3 Std Deviations from the mean removed

Data Source	# Pts	Std Dev	Mean	Min	Max	SSE	RMSE
Base01	57	0.33	0.01	-0.63	0.94	5.408	0.308
Asphalt	211	0.42	-0.02	-1.35	1.22	39.928	0.383
Ground	842	0.76	0.05	-3.57	3.46	405.377	0.694

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Positional Accuracy Exceeding Standards

(2001 panel control)

Vertical Accuracy Objective	1
Control Points in Report	81
Elevation Calculation Method	Interpolate
Control Points with LiDAR Coverage	58
Control Locations in Spec (+/- 1.0)	57
Percent of Control Locations in Spec (+/- 1.0)	98.28
Average Control Error Reported	-0.02
Maximum (highest) Control Error Reported	0.94
Median Control Error Reported	0.01
Minimum (lowest) Control Error Reported	-1.3
Standard deviation (sigma) of Z for sample	0.35
RMSE of Z for sample	0.35
FGDC/NSSDA Vertical Accuracy	0.68
FEMA Vertical Accuracy	0.83

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Positional Accuracy Exceeding Standards

(2001 / 2002 control)

Vertical Accuracy Objective	1
Control Points in Report	134
Elevation Calculation Method	Interpolate
Control Points with LiDAR Coverage	102
Control Locations in Spec (+/- 1.0)	97
Percent of Control Locations in Spec (+/- 1.0)	95.1
Average Control Error Reported	-0.1
Maximum (highest) Control Error Reported	0.94
Median Control Error Reported	-0.05
Minimum (lowest) Control Error Reported	-2.82
Standard deviation (sigma) of Z for sample	0.49
RMSE of Z for sample	0.5
FGDC/NSSDA Vertical Accuracy	0.98
FEMA Vertical Accuracy	1.12

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Positional Accuracy Exceeding Standards

(in vegetation)

Vertical Accuracy Objective	1
Control Points in Report	865
Elevation Calculation Method	Interpolate
Control Points with LiDAR Coverage	865
Control Locations in Spec (+/- 1.0)	743
Percent of Control Locations in Spec (+/- 1.0)	85.9
Average Control Error Reported	0.08
Maximum (highest) Control Error Reported	12.09
Median Control Error Reported	0.11
Minimum (lowest) Control Error Reported	-5.68
Standard deviation (sigma) of Z for sample	1.24
RMSE of Z for sample	1.24
FGDC/NSSDA Vertical Accuracy	2.43
FEMA Vertical Accuracy	2.53

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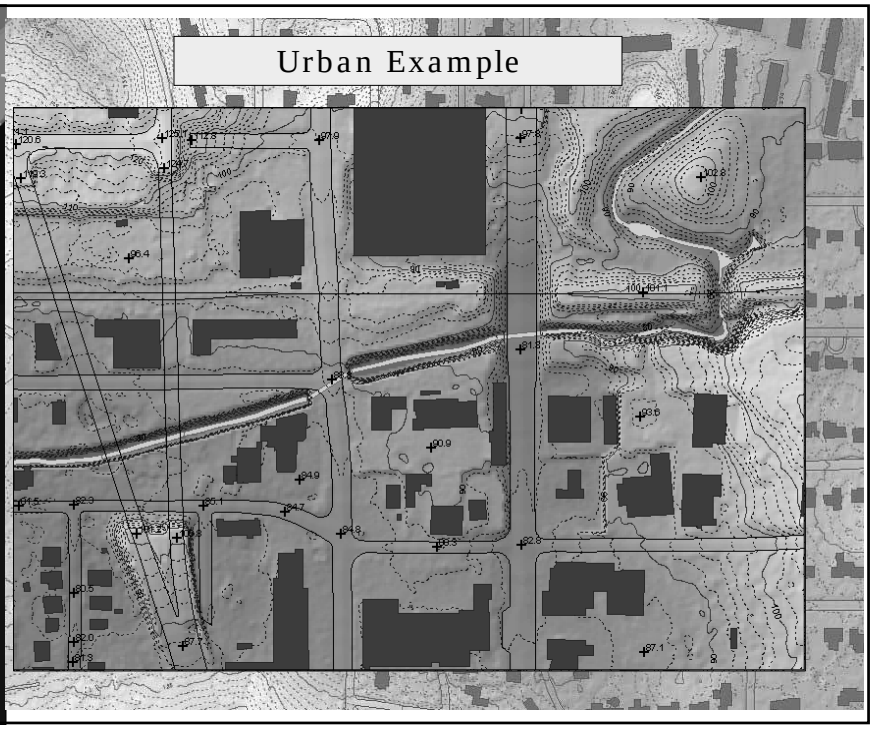
Urban Example



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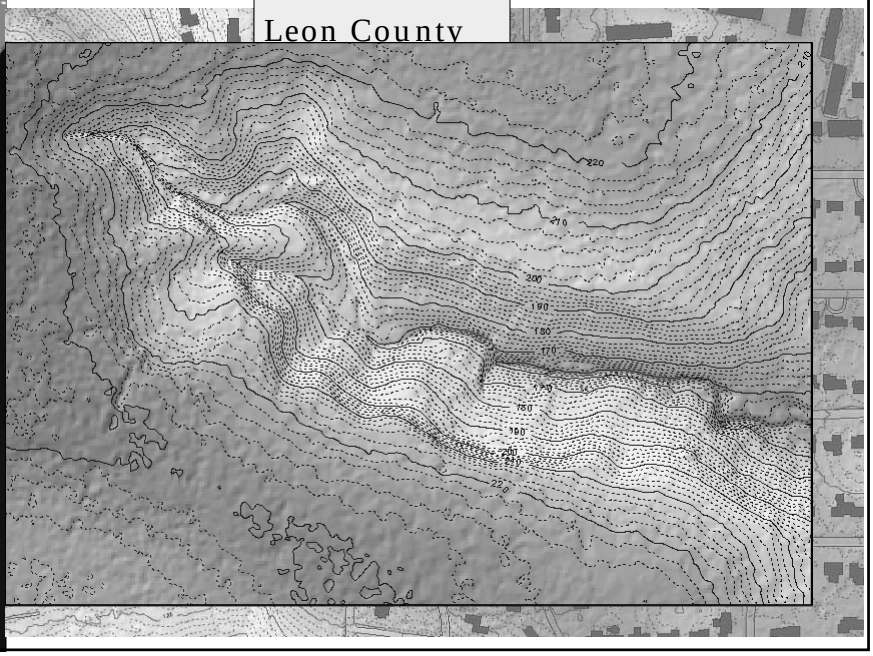
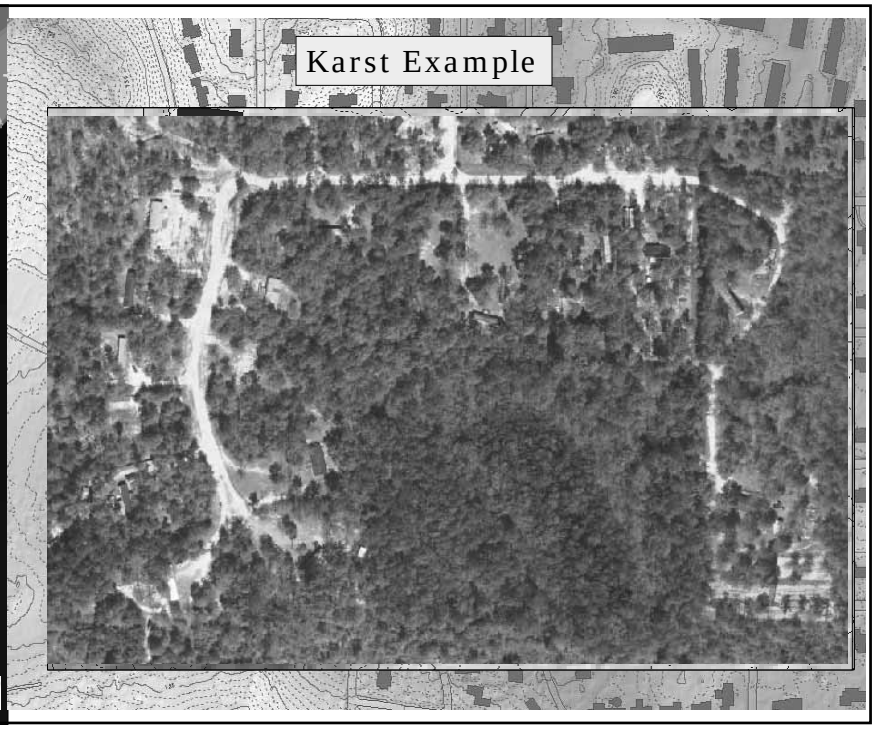
Rural Example

Leon County





Questions?

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