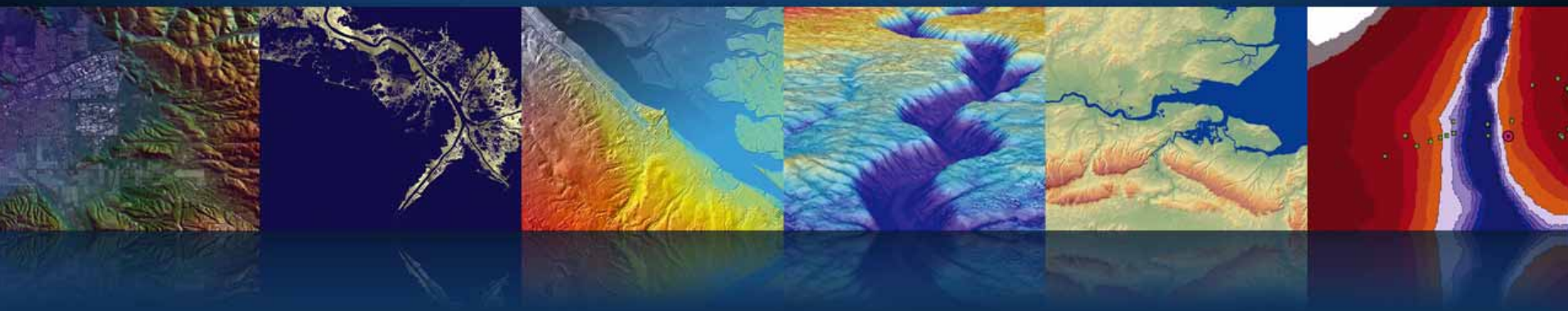


IFSAR AND LIDAR HIGH RESOLUTION ELEVATION DATA FOR MINING APPLICATIONS: ADVANTAGES AND DISADVANTEGES OF COMPLIMENTARY TECHNOLOGIES

M. Lorraine Tighe, Gregory Buckman Intermap Technologies

2008 GEOSPATIAL CONFERENCE
& 2nd National Meeting of SMCRA Geospatial Data Stewards

Overview

- A little over a decade ago, aerial photogrammetry was virtually the only technology available to acquire large scale, precise map data and survey techniques were the only method for to acquire detailed engineering survey data. The advent of commercial LiDAR (Light Detection And Ranging) and IFSAR (Interferometric Synthetic Aperture Radar) Technologies has changed how we acquire accurate mapping and survey quality data.

- This session will look at the similarities and differences of IFSAR and LiDAR technologies.

- Technology Comparisons
  - Definitions/Commercialization
  - Sensor Configuration
  - Specifications
  - Advantages/Challenges
  - Typical Applications
  - Application Examples

Digital Elevation Model Technologies & Applications, 2nd Ed.

https://eserv.asprs.org

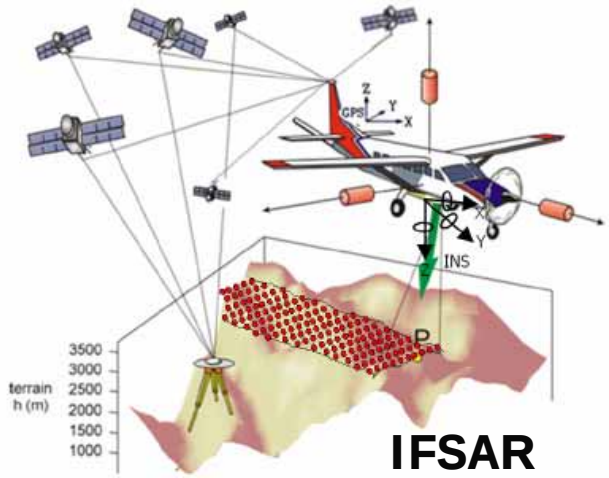
Overview Continued

- Elevation data is a key element in many survey and mining applications.
- Digital elevation models (DEMs) are three-dimensional mapping products which have become more accessible in recent years, in part due to the implementation, acceptance, and availability of LiDAR and IFSAR technologies.

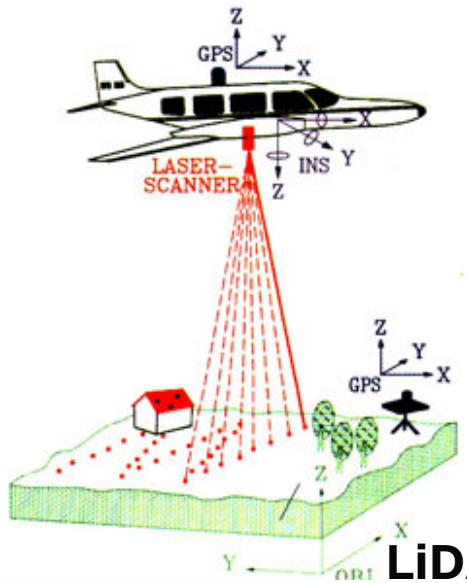
AML Feature
Re-mined Areas
New AML Sites
Acid Mine Drainage
Dangerous Highwalls
Clogged Streams
Clogged Stream Lands
Portals
Subsidence
Dangerous Slides
Hazardous Facilities & Equipment
Apple Cores
Gob Piles
Spoil Piles

Technology Overview - Definitions

- **IFSAR – Interferometric Synthetic Aperture Radar (also InSAR)**
  - Radar-based remote sensing technique that provides X, Y, and Z coordinates of a location imaged by a radar beam at high accuracy. It also produces an orthorectified radar image.
- **LiDAR – Light Detection And Ranging**
  - Laser-based remote sensing technique that provides X, Y, and Z coordinates of a location of a footprint of a laser beam at very high accuracy. It also produces an intensity image.
- **Both systems require knowledge of sensor location w.r.t. the target:**
  - Sensor position is provided by GPS (onboard the platform & ground)
  - Senor orientation is provided by an IMU/INS system (onboard the platform.



IFSAR



LiDAR

Typical Products

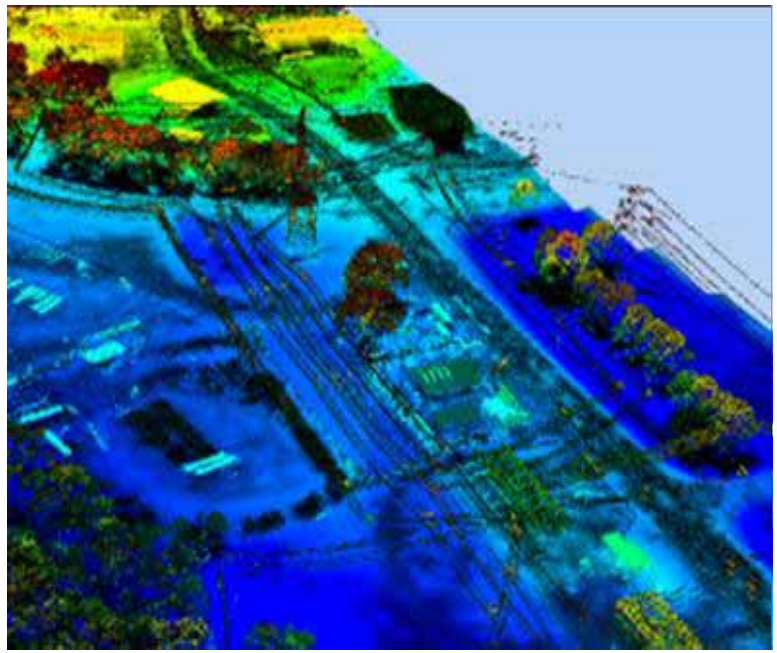
IFSAR

- First Surface Elevation Grid
- Bare Earth Elevation Grid
- Orthorectified Radar Image
- Color Image Layer

Courtesy of Intermap
www.intermap.com

LiDAR

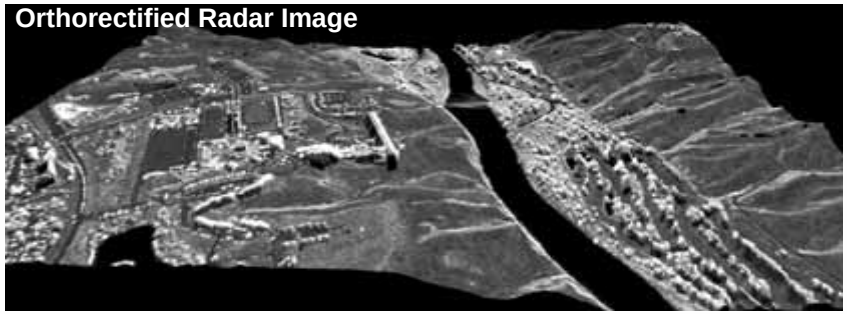
- First Surface Point Cloud
- Bare Earth Point Cloud
- Intensity Image
- Multiple Point Cloud

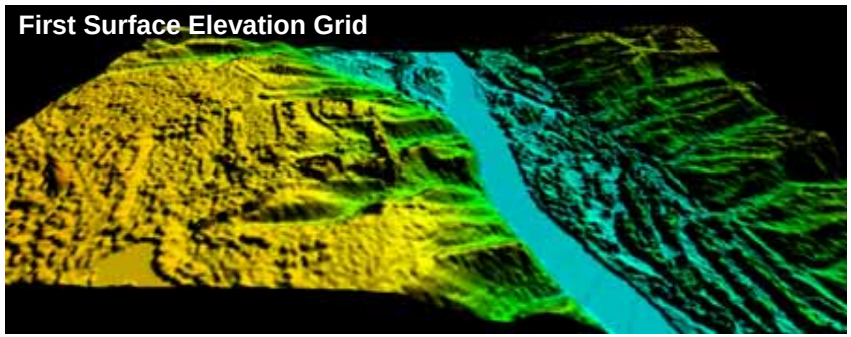


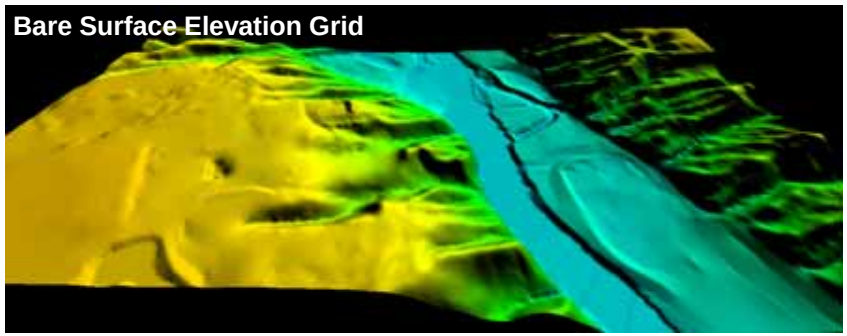
Courtesy of ASPRS (Airborne1 LiDAR Data) www.airborne1.com

IFSAR - LiDAR – 5 m Posted Samples

IFSAR

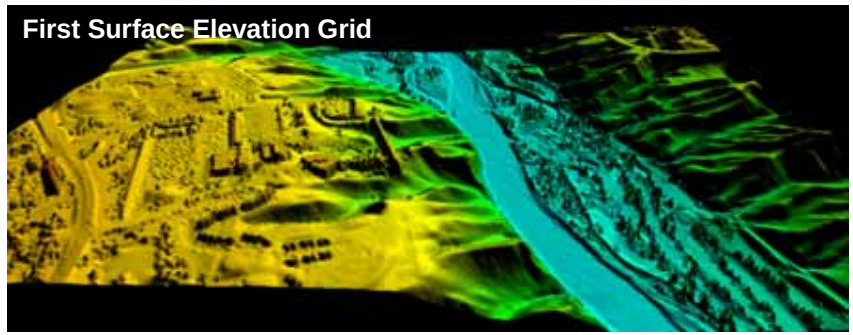


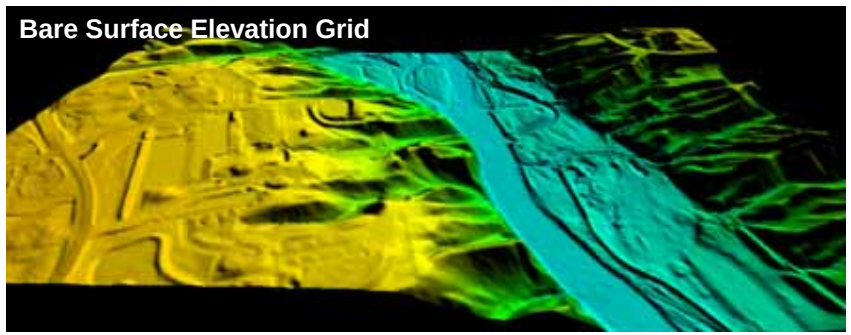




Courtesy of Intermap ww.intermap.com

LiDAR





Courtesy of TerraPoint www.terrapoint.com

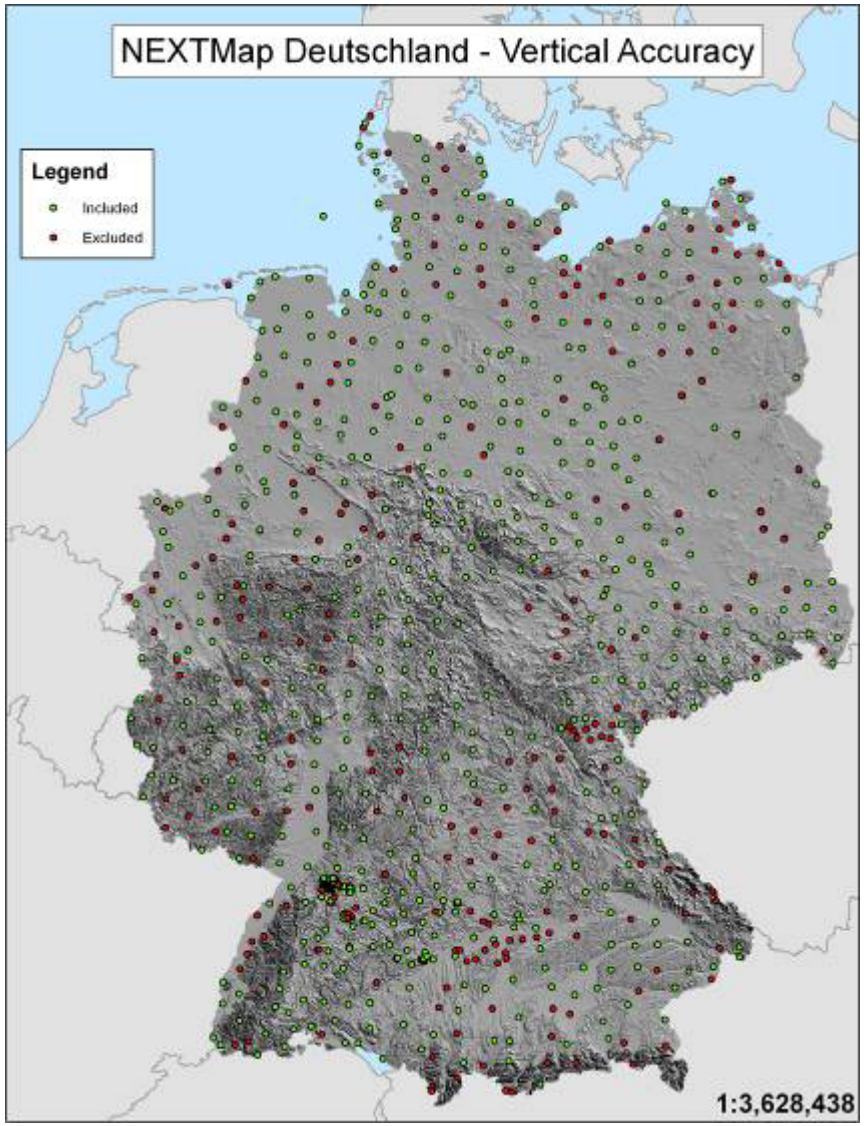
Elevation Specifications

Specification	IFSAR	LiDAR
Data Collection Width (Swath)	5 - 9 km	0.7 - 1 km
Data Collection Rate	~ 4000 km^2/hr	~ 200 km^2/hr
Operating Altitude	6000 m (50 cm DEM); 10000 m (1m DEM)	80 m (~ 15 cm DEM), 6000m 2m DEM)
Scan (Swath) Pattern	Rectangle: 5 - 9 km wide by 1200 km long	zigzag, parallel, sinusoidal
Footprint	collected at 1.25 m, posted at 5 m	posted at 0.25 - 5 m
Scan Angle	35^o - 55^o	0^o - 75^o
Wavelength	3 cm	1.064 nm
Sensor Penetration	cloud, haze, dust, fog, light rain, minimal penetration into canopy	canopy, cannot penetrate clouds, signal is heavily absorbed by water
Post Processing	Mature, Proprietary, Validated	Proprietary (Various), Some Validated
Elevation Surfaces	First Surface (collected) Bare Earth Surface (derived)	Multiple Surfaces (Collected)
Imagery	Orthorectified Radar Image (Collected)	Intensity Image Collected
DEM Data Delivery	Off-the-shelf : 48 hours NEXTMap: 12-24 weeks	20 - 26 weeks
Pricing Standard	$75 square mile	$250 square mile
Pricing Custom	$250+ square mile	$550+ square mile
DEM Data Collection	cost effective for large area mapping (whole states, countrywide) requiring 50 cm - 1 m accuracy	cost effective for smaller areas and projects that require high degree of accuracy (<50 cm)

Advantages/Challenges – Airborne Systems

Sensor	Advantage	Challenge
LiDAR & IFSAR	- Day/evening collections - Very high accuracy - High pont density per square mile	- User understanding of sensor capabilities and limitations
LiDAR	- Multiple returns (vegetation penetration)	- Uncertainty in senor benefits, capabilities,and applications
	- Cost advantage over small areas	- Weather conditions (cold, fog, snow, etc.)
IFSAR	- Orthorectified image included	- side looking collection
	- Cost advantage over large areas	- challening in urban areas
	- Mature technology (standards in place)	

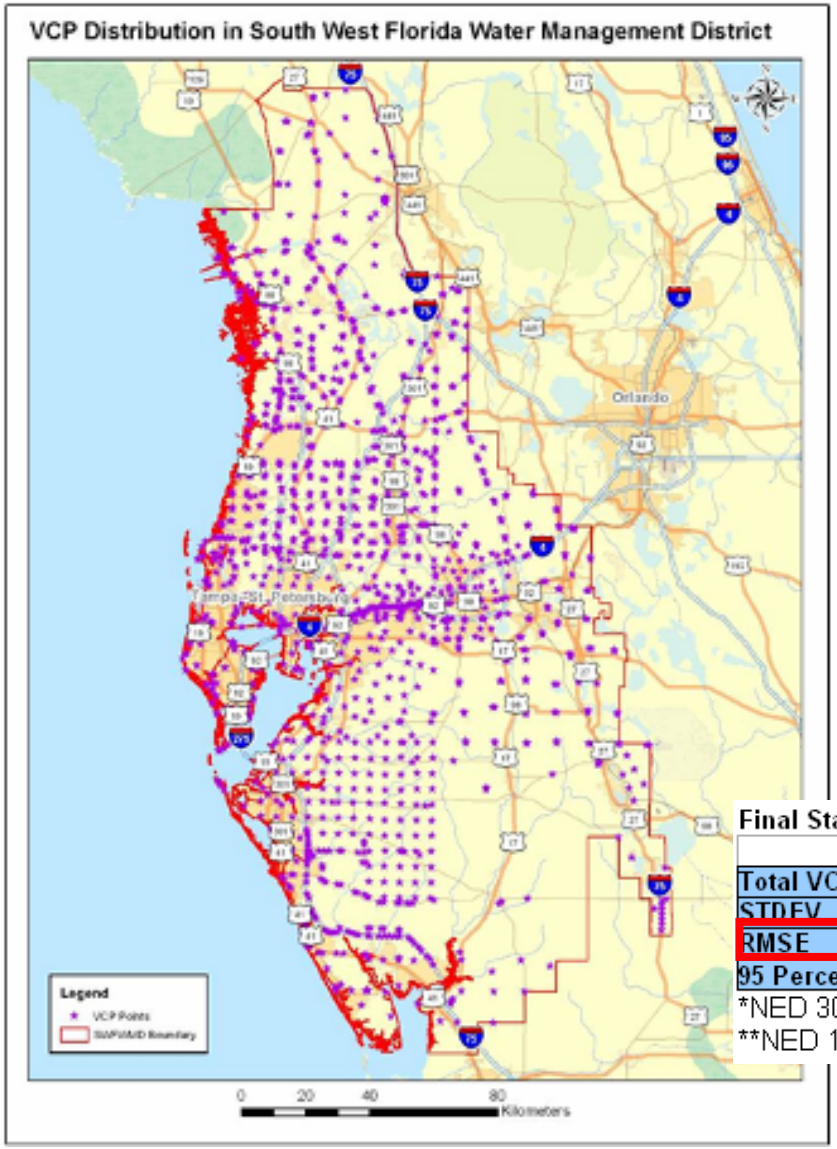
Vertical Accuracy Assessment: IFSAR Example



- 3,209 – 7.5' Tiles covering 357,506 km^2
- Vertical Check Points (VCP) were obtained through the German State agencies
- 689 acceptable VCPs in unobstructed slopes less than 10^{o} were used to evaluate the elevation data

	DSM	DTM	MONA
Number of VCPs	1053	1053	1053
Excluded points	364	364	364
Included VCPs	689	689	689
Mean	0.01	-0.16	-2.45
Max +	2.17	2.37	34.18
Max -	-2.99	-2.97	-29.54
Std. Dev.	0.68	0.68	4.29
RMSE	0.68	0.69	4.93
95 Percentile	1.42	1.47	9.74
Blunder (3x Std dev)	2.03	2.03	12.86

Vertical Accuracy Assessment: IFSAR Example



- Available for customers
- South West Florida Water Management District
- The Intermap DTM is approximately two times more accurate than the publicly available USGS NED10 (**RMSE**: 0.62m vs. 1.36m and **95th Percentile**: 1.21m vs. 1.78m).

Final Statistics for Accepted VCPs:

	DSM	DTM	NED30m*	NED10m**
Total VCPs	1442	1442	1442	1442
STDEV	0.63	0.61	1.38	1.34
RMSE	0.64	0.62	1.41	1.36
95 Percentile	1.26	1.21	1.95	1.78

*NED 30m purchased from Global Mapper 2004

**NED 10m downloaded from USGS seamless database Feb-06 (http://seamless.usgs.gov/)

Abandoned Mined Land - Reclamation

- Title IV of the Federal Surface Mining Control and Reclamation Act of 1977 (SMCRA)(Public Law 95-87) establishes the Abandoned Mine Land (AML) program, which provides for the restoration of eligible lands and waters mined and abandoned or left inadequately restored.

- Title IV of SMCRA levies fees on active coal mining operations to pay the reclamation costs.

- IFSAR data can assist in many facets of SMCRA – Photogrammetry or LiDAR is NOT always required.

Applicability of IFSAR/LiDAR Data for AML & Mining Reclamation

Abandoned Mine Land Feature	LiDAR	IFSAR
1. Re-mined Area Mapping	+ imagery	yes
2. New AML	+ imagery	yes
3. Acid Mine Drainage	+ imagery	+ imagery
4. Dangerous Highwalls	yes	yes
5. Clogged Streams	?	?
6. Clogged Stream Land	?	?
7. Portals	+ imagery	possibly
8. Subsidence	yes	yes
9. Dangerous Slide	yes	yes
10. Hazardous Facilities & Equiptment	+ ancillary	+ ancillary
11. Apple Core	possibly	possibly
12. Gob Pules	+ imagery	yes
13. Spoil Piles	+ imagery	+ imagery

Following Slide Examples

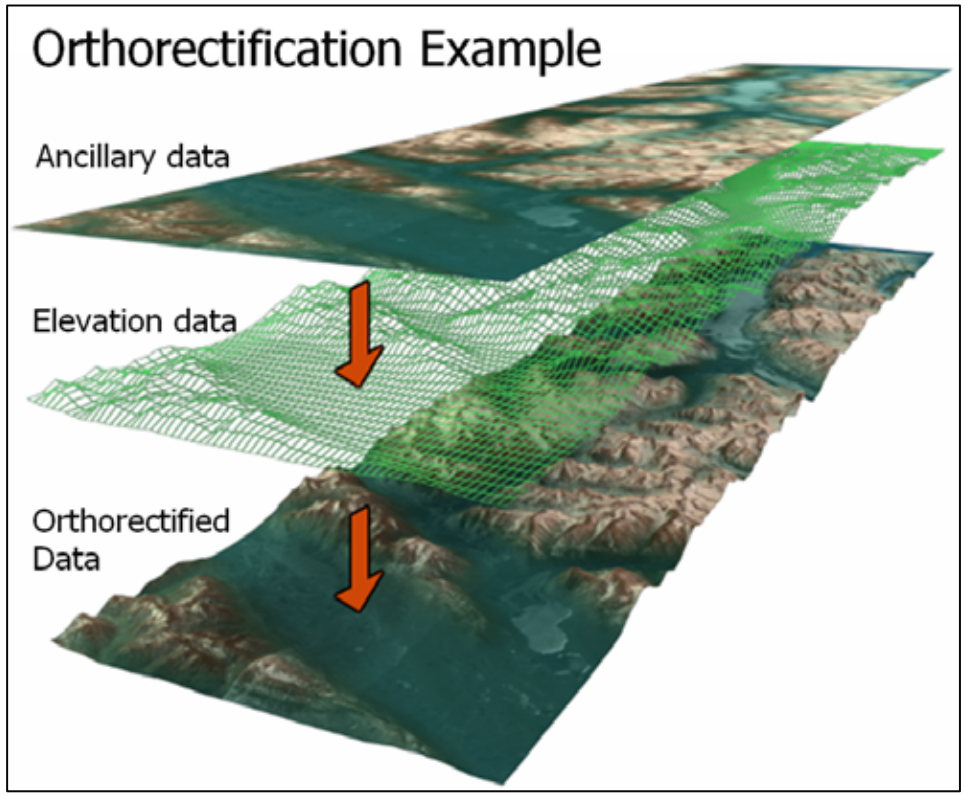
- ✔ Topographic Mapping
- ✔ Contour Generation
- ✔ AOC Mapping
- ✔ Geology Mapping

Re-minded Area Mapping: Requires Orthorectified Data

- Require set of specifications, orthorectified imagery, elevation data and software.
- Orthorectification: existing data may need to be orthorectify (correct for horizontal and vertical distortions) ancillary data

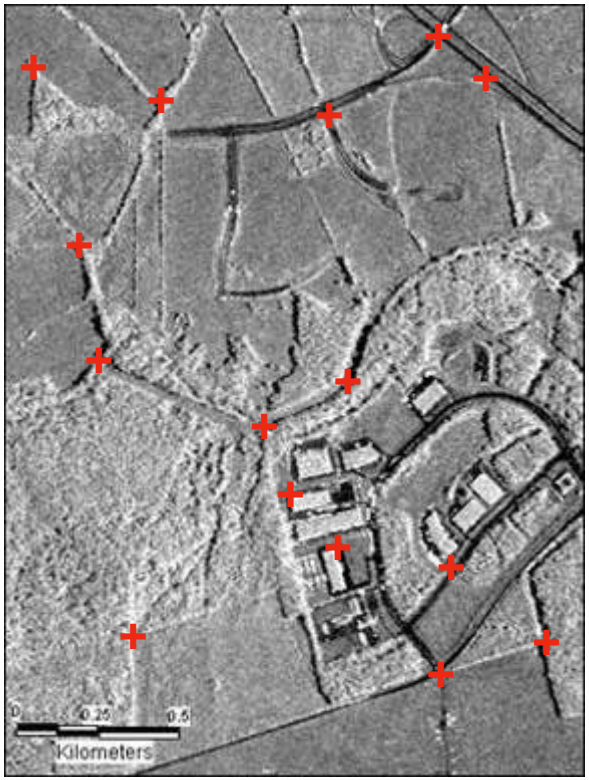
- Input:
  - » Ancillary data
  - » Elevation data
  - » Ground Control Points (GCPs)
  - » Commercial software

  - Output:
    - » Orthorectified data layer



Data Orthorectification – IFSAR Example

- Use radar imagery as a source of GCPs (+)
- Using GCPs + Optical imagery + DEM + Commercial software = orthorectified product



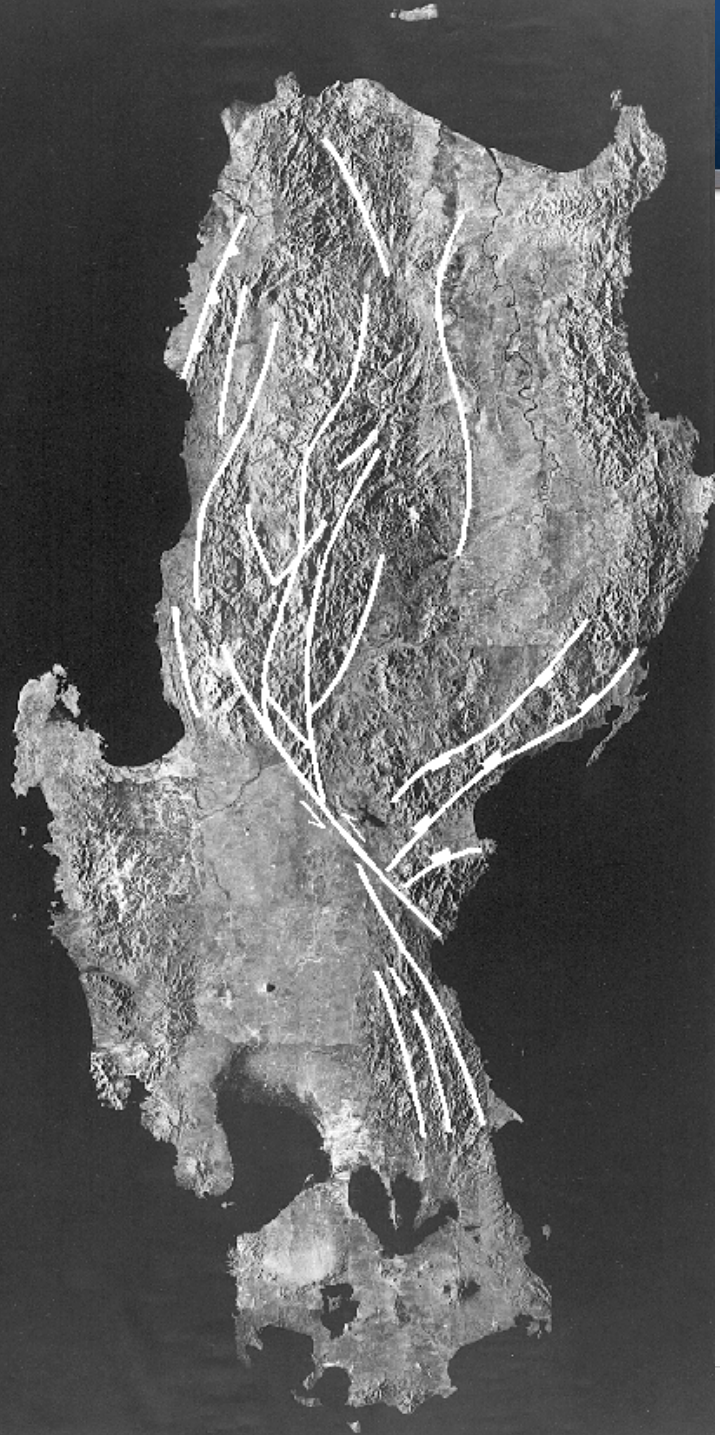
ORI

Landsat 7 (7,4,2)

SAR-sharpened Landsat 7 (7,4,2)

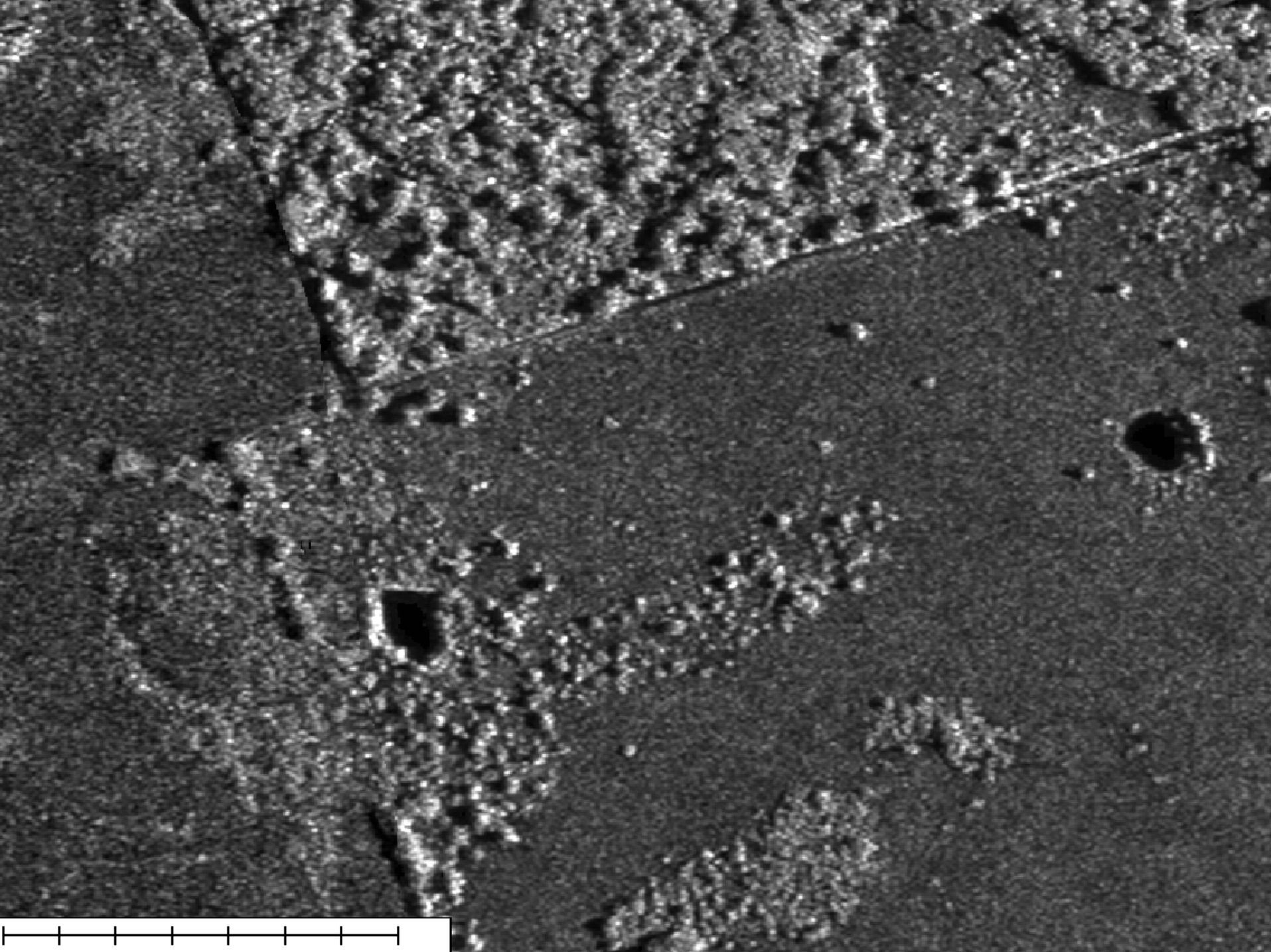
Data Orthorectification: LiDAR Example

Courtesy of www.terrapoint.com



New AML - Reconnaissance Mapping IFSAR

- IFSAR Data provide a synoptic view of the terrain which allows geological information to be collected over a larger region
- Airborne mosaic of the Luzon Island with major fault systems and tectonic elements of the Philippine Fault Zone delineated
- Luzon Philippines
- Movie at our booth

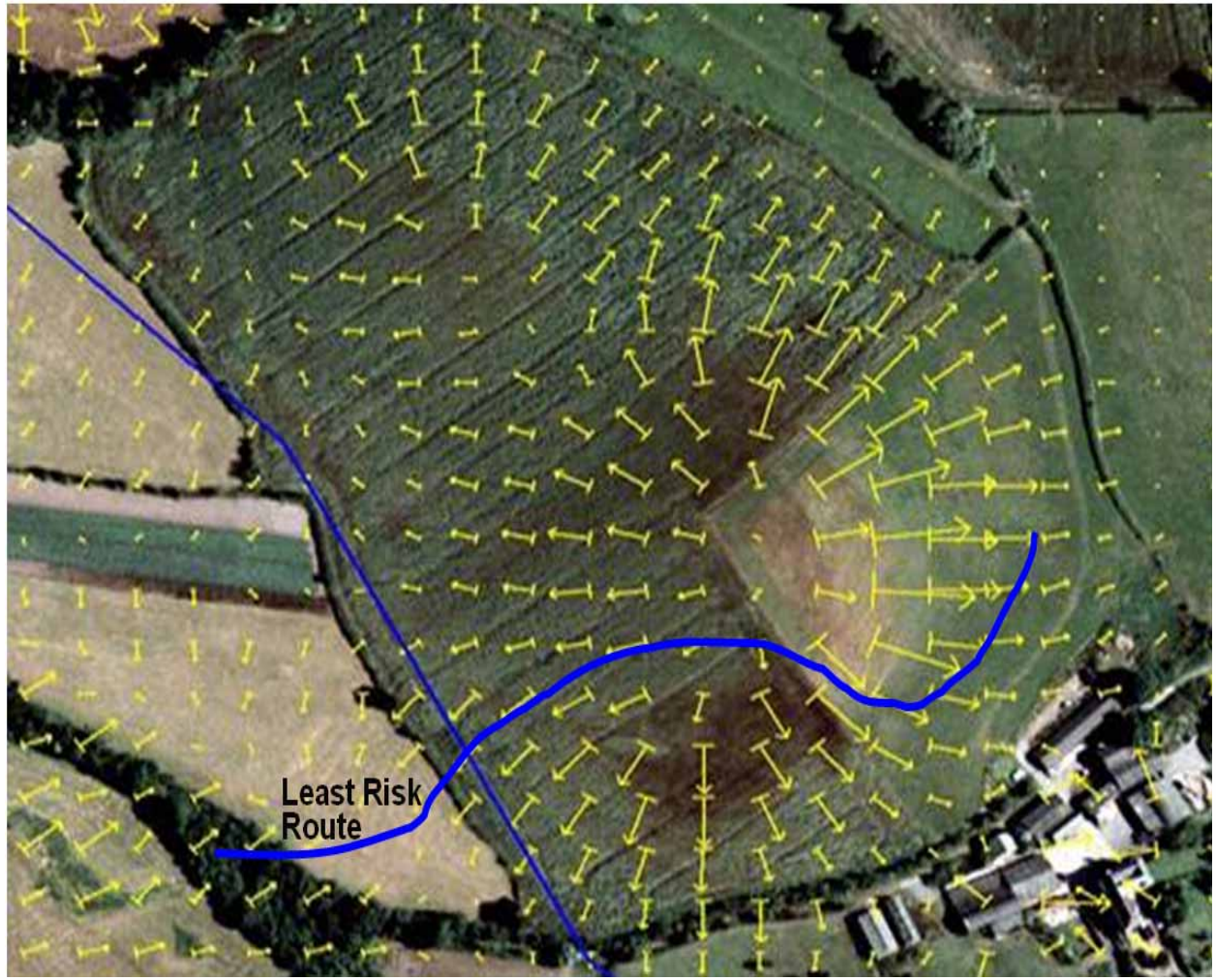


New AML: Black Mesa - Arizona

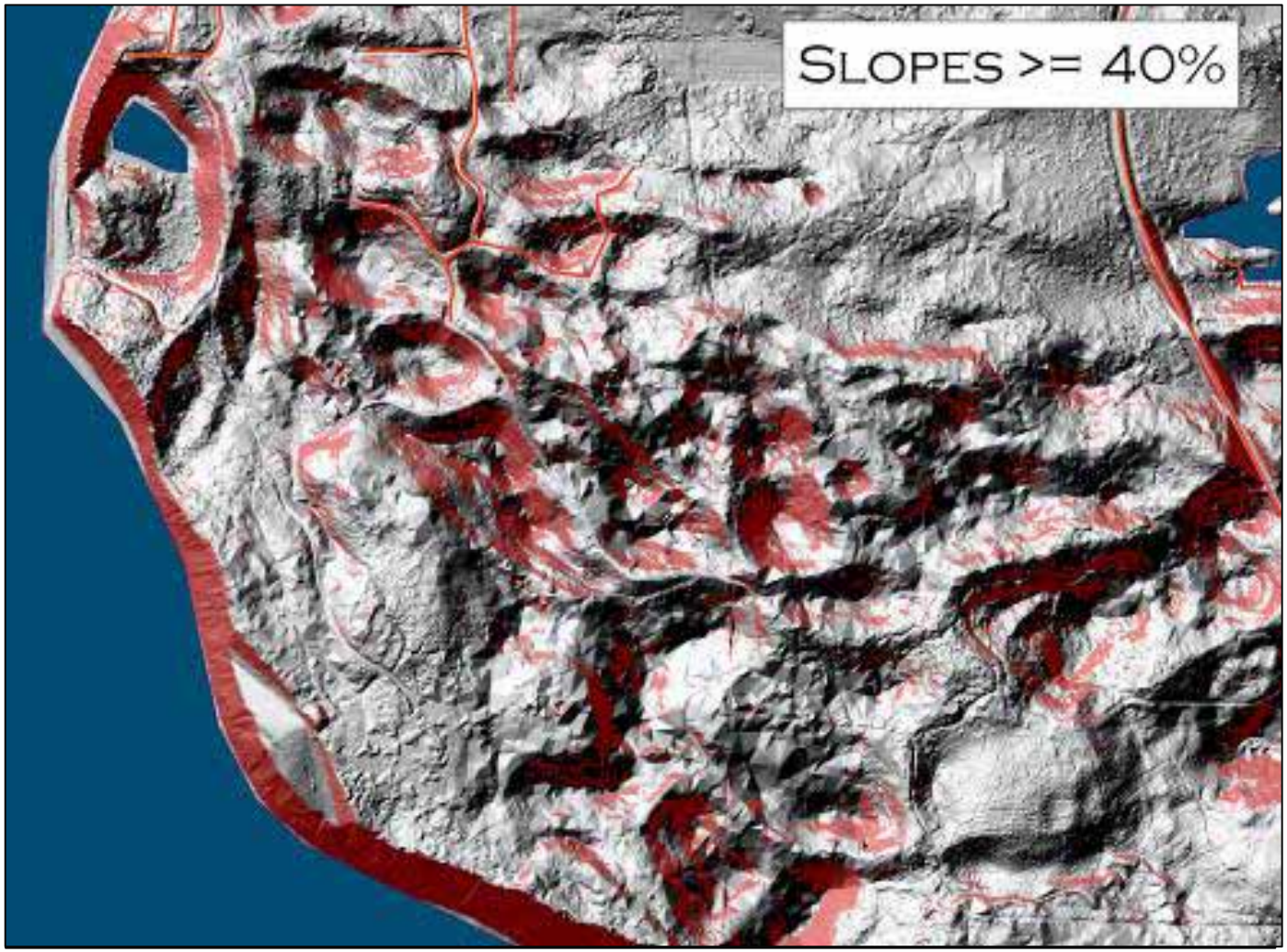
- 3d Visualization tool to assist depiction of AML

Dangerous Slide Prediction – IFSAR Example

- Dangerous slide assessment as a means of highlighting buckling and cross slope threat
- integration of;
  - Aerial imagery
  - Elevation data
- determine dangerous slide regions (in red) and least risk route with IFSAR (green line)



Dangerous Slide Prediction – LiDAR Example

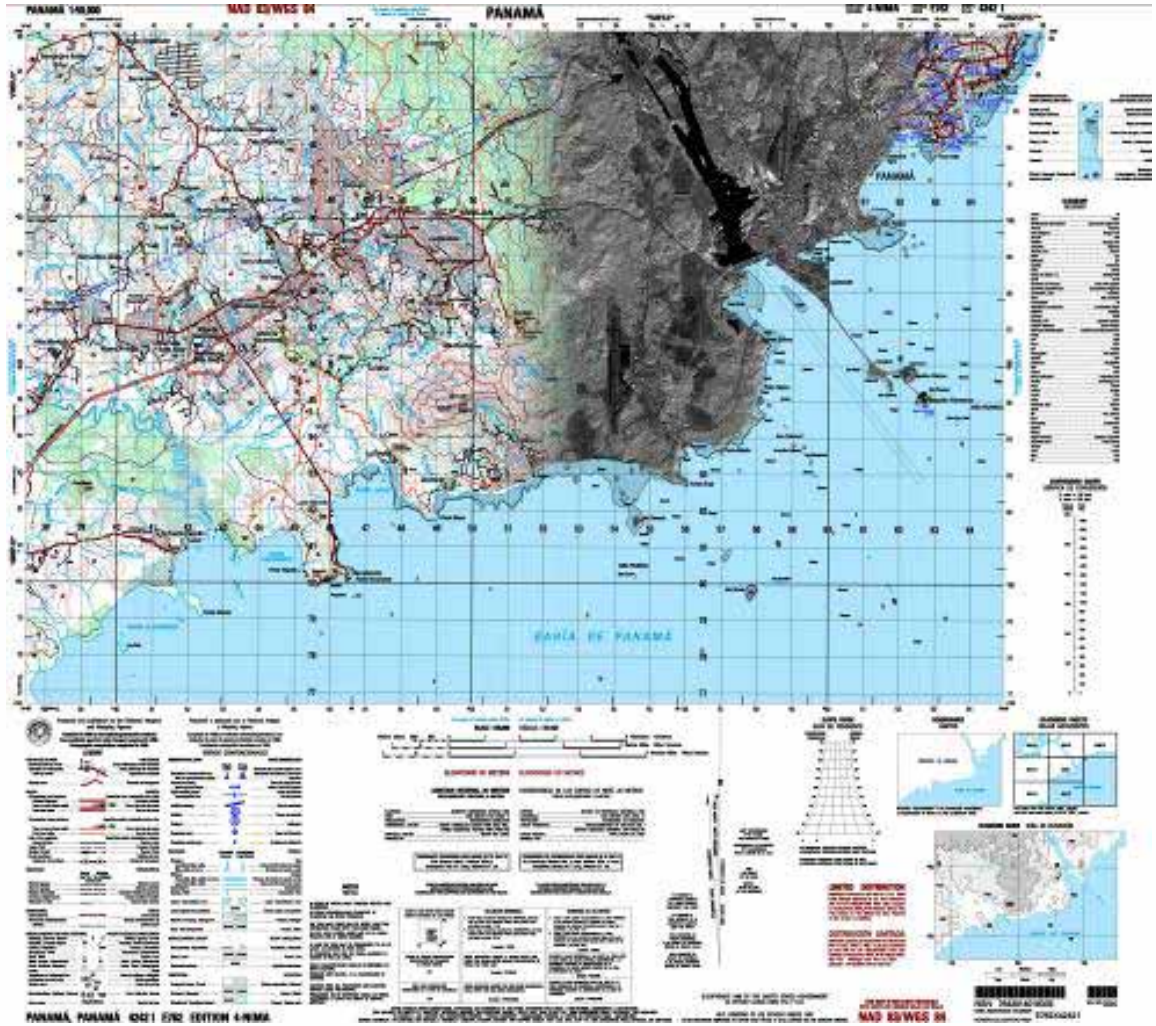


Courtesy of www.terrapoint.com

www.terrapoint.com

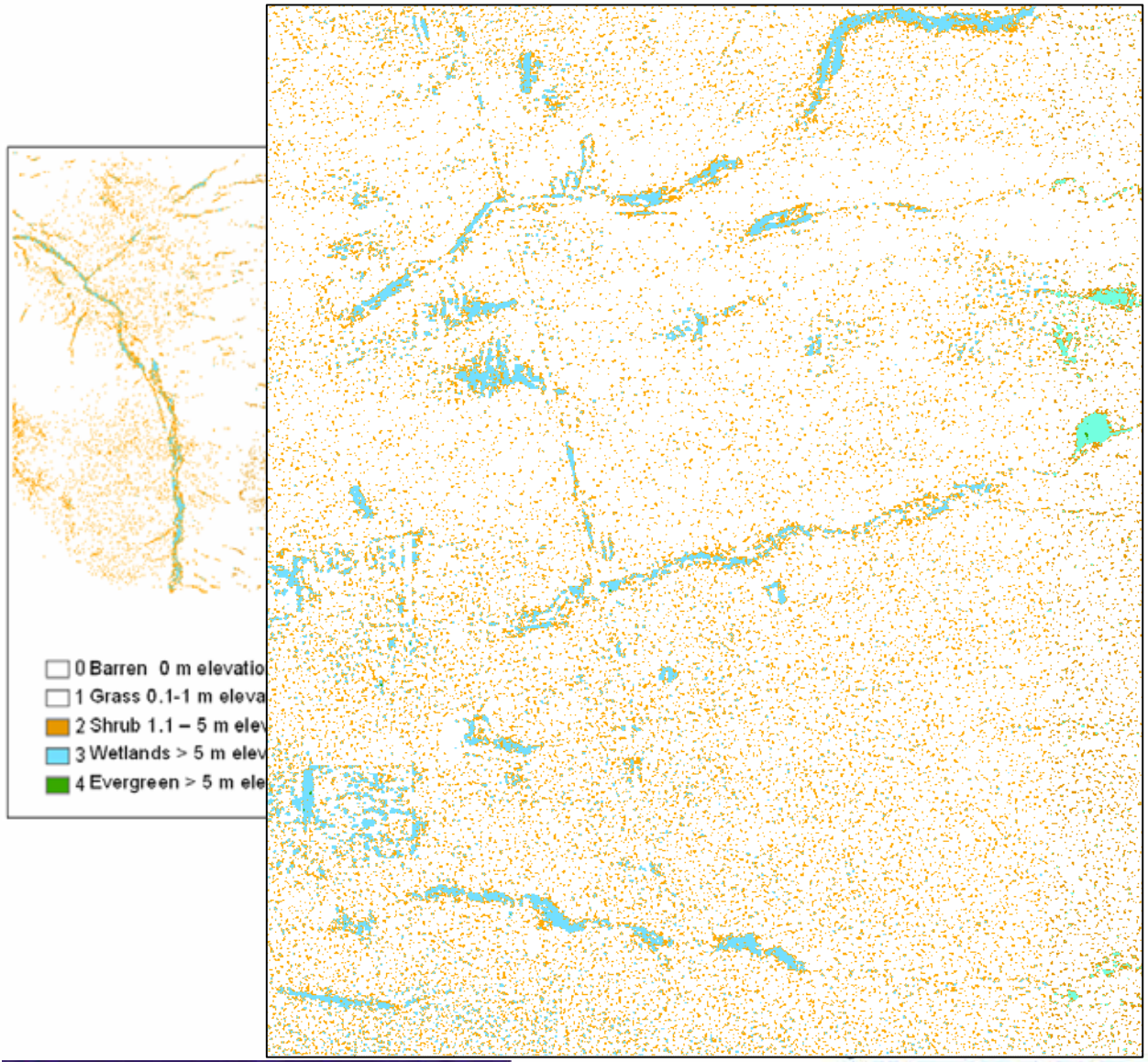
Topographic Map Sample: IFSAR

- IFSAR Data and 3D viewing to within a Radargrammetric workstation allow for the generation of topographic maps
- 20,000 – 100,000 scale Topographic Maps
- 5,000 scale contours



Vegetation Mapping - IFSAR

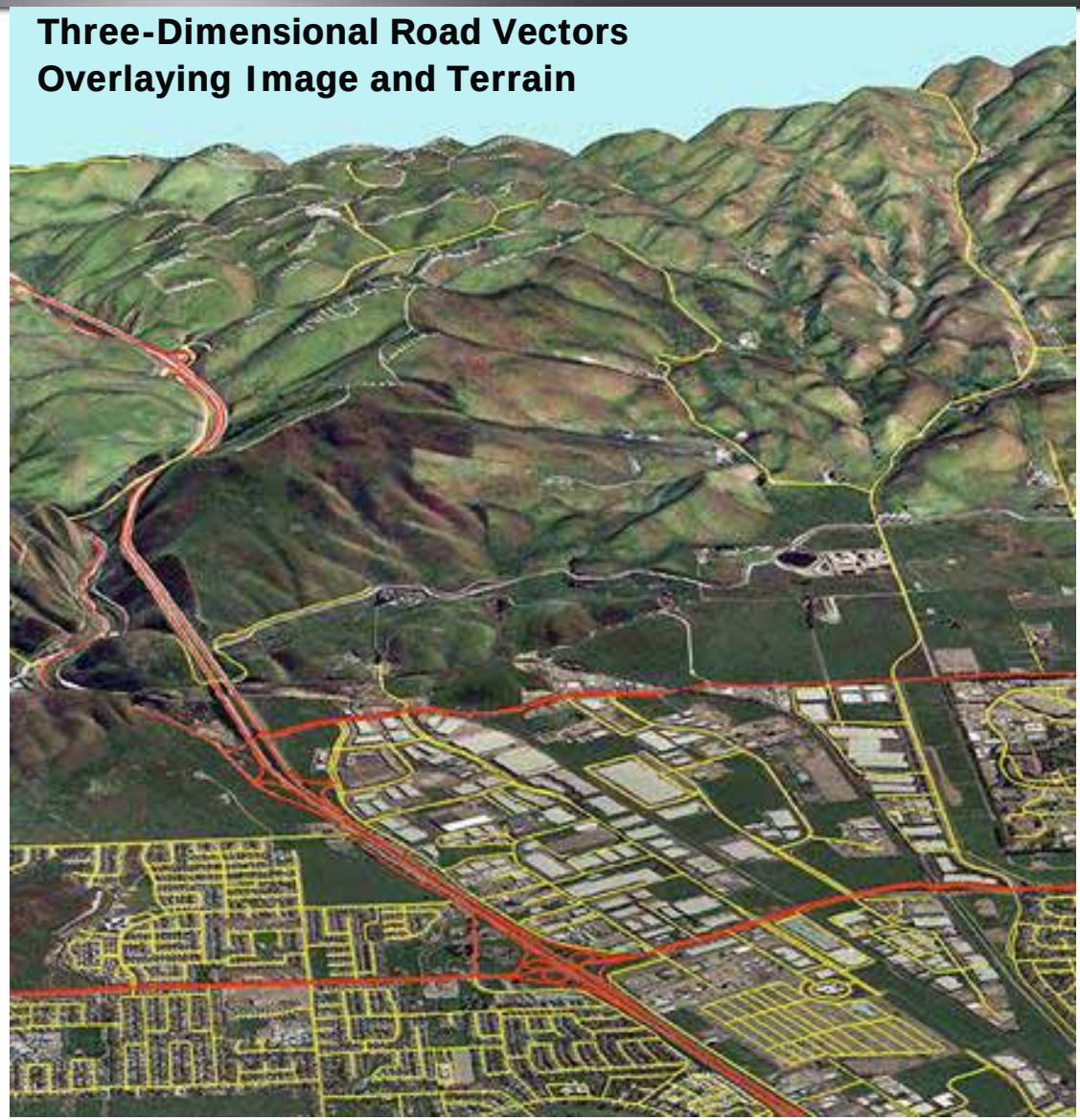
- 1:12,000 scale mapping – largest scale (updated NCDL)
  - Forest and Woodland
  - Savanna and Shrub-Steppe
  - Upland Grassland and Herbaceous
  - Woody Wetlands and Riparian
  - Herbaceous Wetland
  - Mixed Upland and Wetland
  - Sparsely Vegetated



2D/3D Road Vectors For Planning

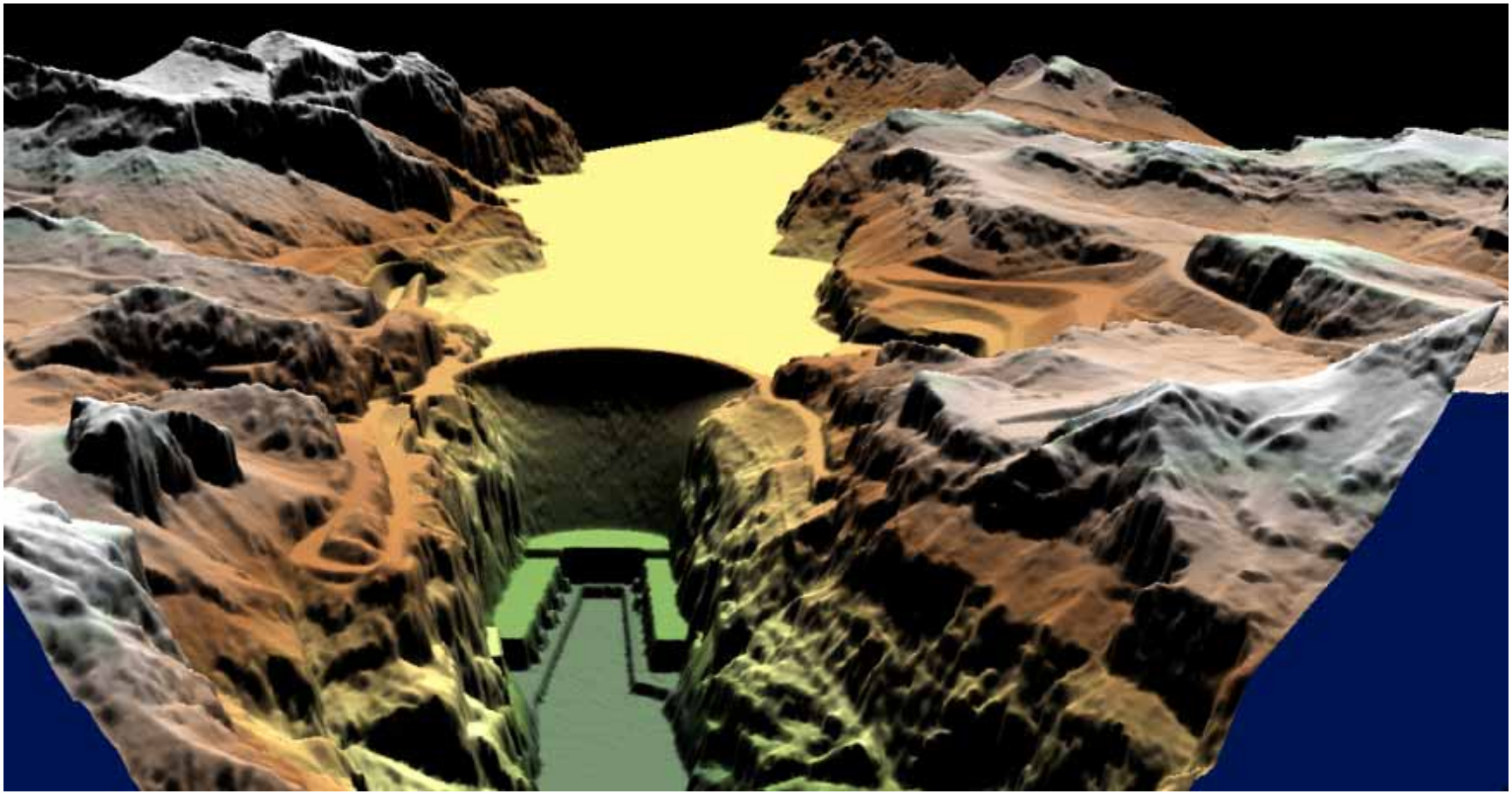
- Requirements:
  - CORE Products
    - » DSM/DTM
    - » CORI
  - 3D Work Station
  - Road Vector Collection Software
- Outputs:
  - 2D Road Vectors
  - 3D Road Vectors
  - 3D Drapes

Three-Dimensional Road Vectors Overlaying Image and Terrain



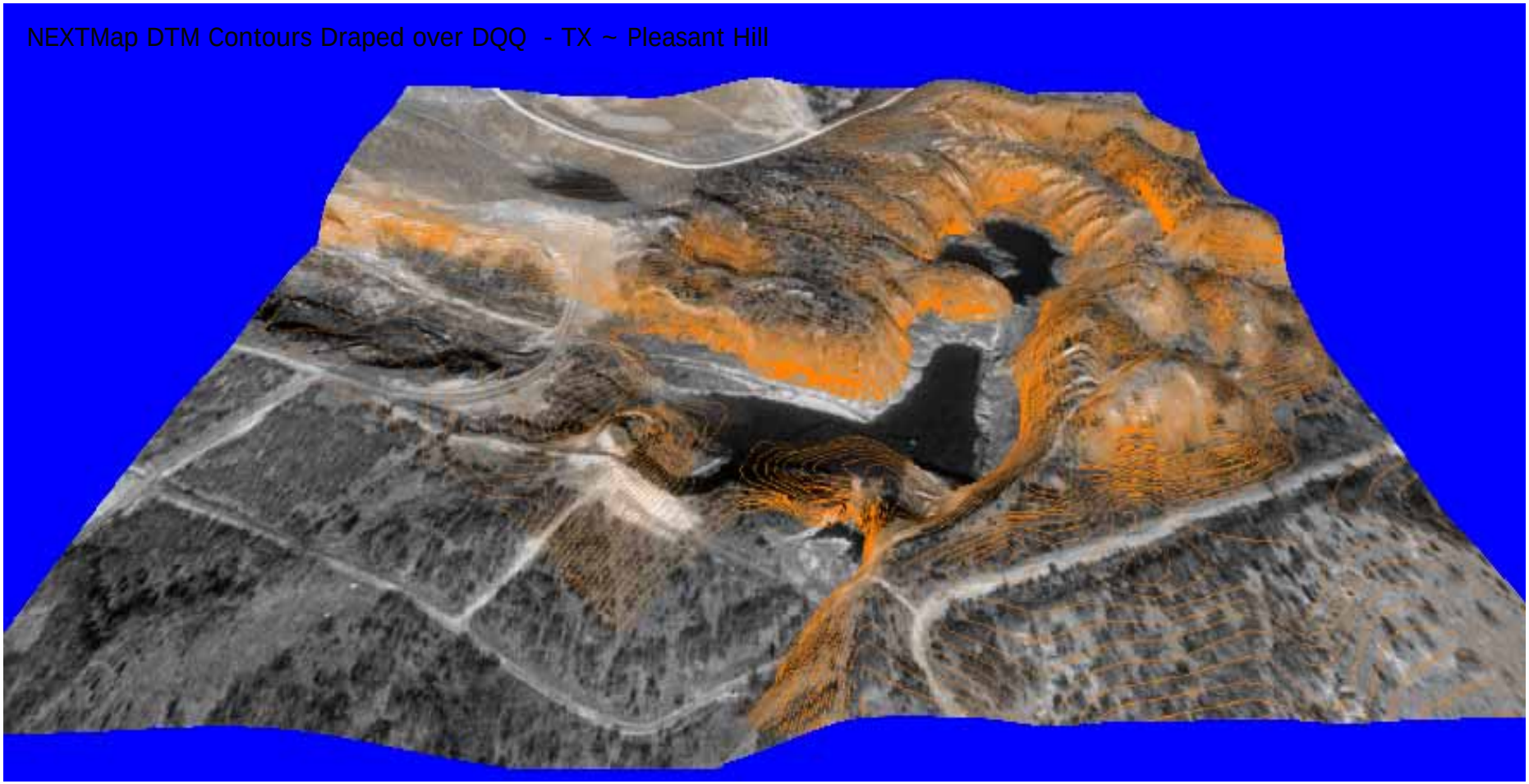
Surface Analysis: LiDAR Example – Hoover Dam

- Flight Date: October 2004 LiDAR System: Optech ALTM 2025
- Accuracy: Data suitable for 1-foot contours (18-cm vertical accuracy at 95% confidence level)



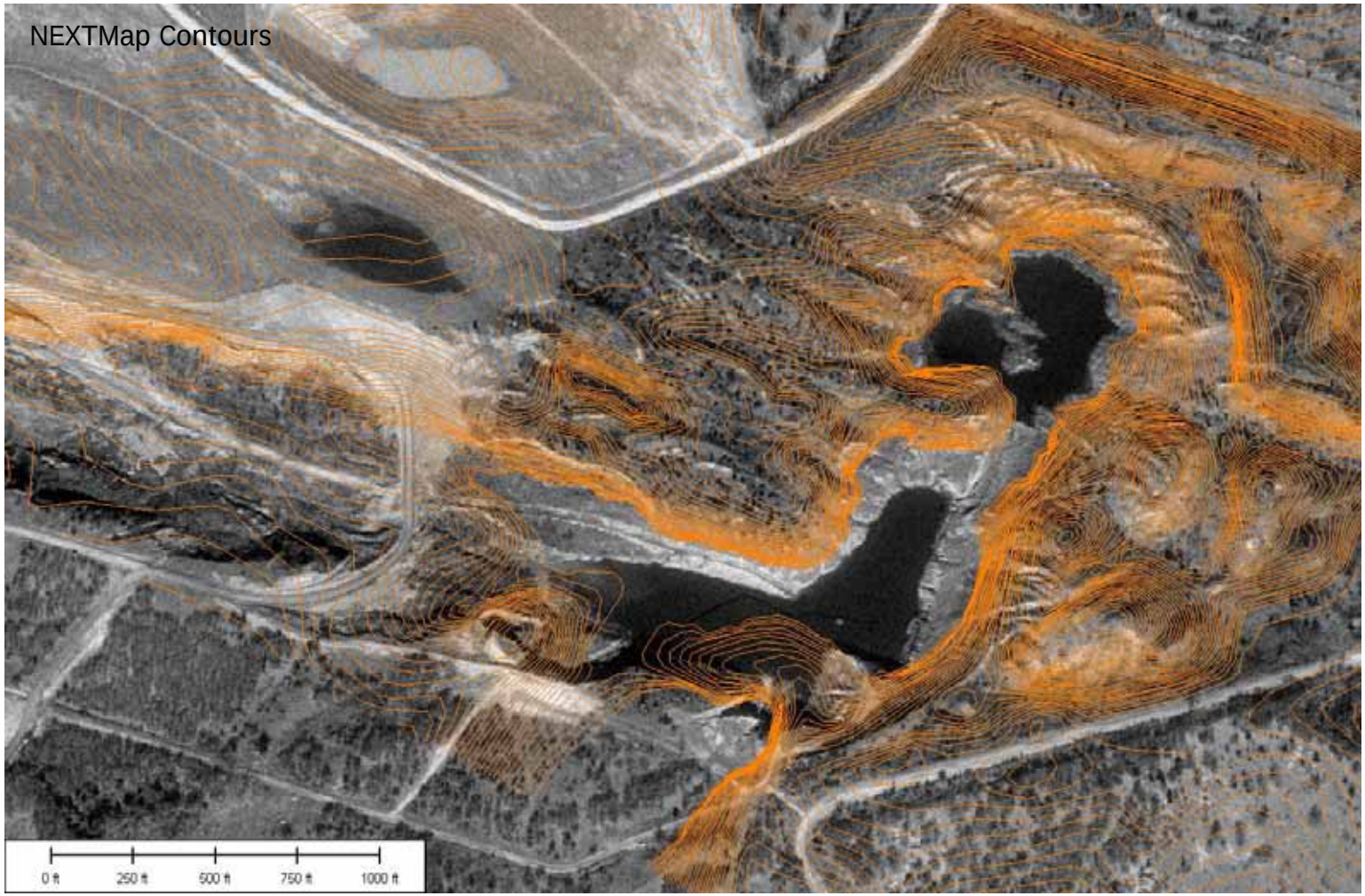
Courtesy of ASPRS (Airborne1 LiDAR Data) **www.airborne1.com**

Approximate Original Contour (AOC)

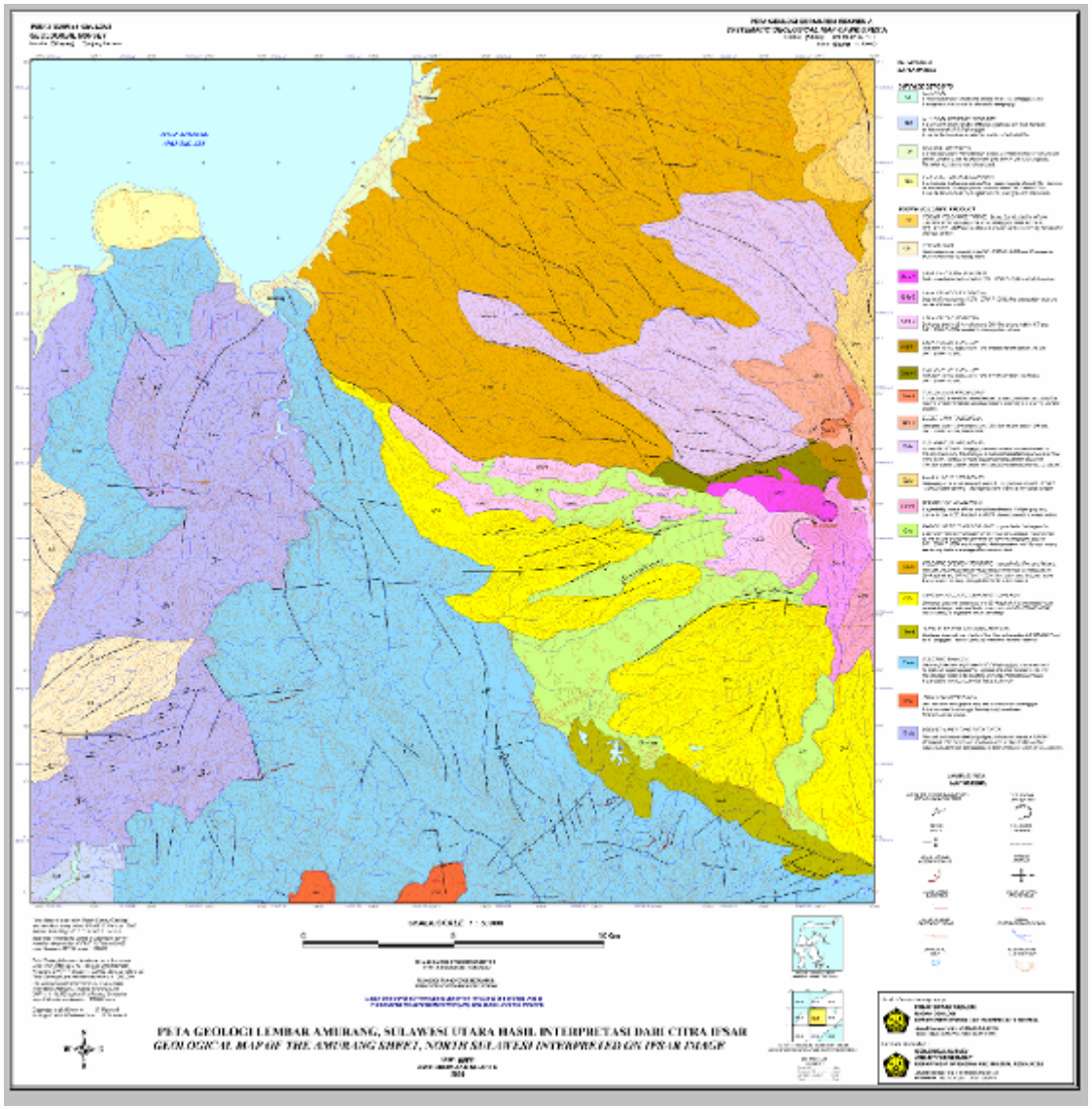


Approximate Original Contour (AOC) continued

- Mine Site Example: TX – near Pleasant Hill

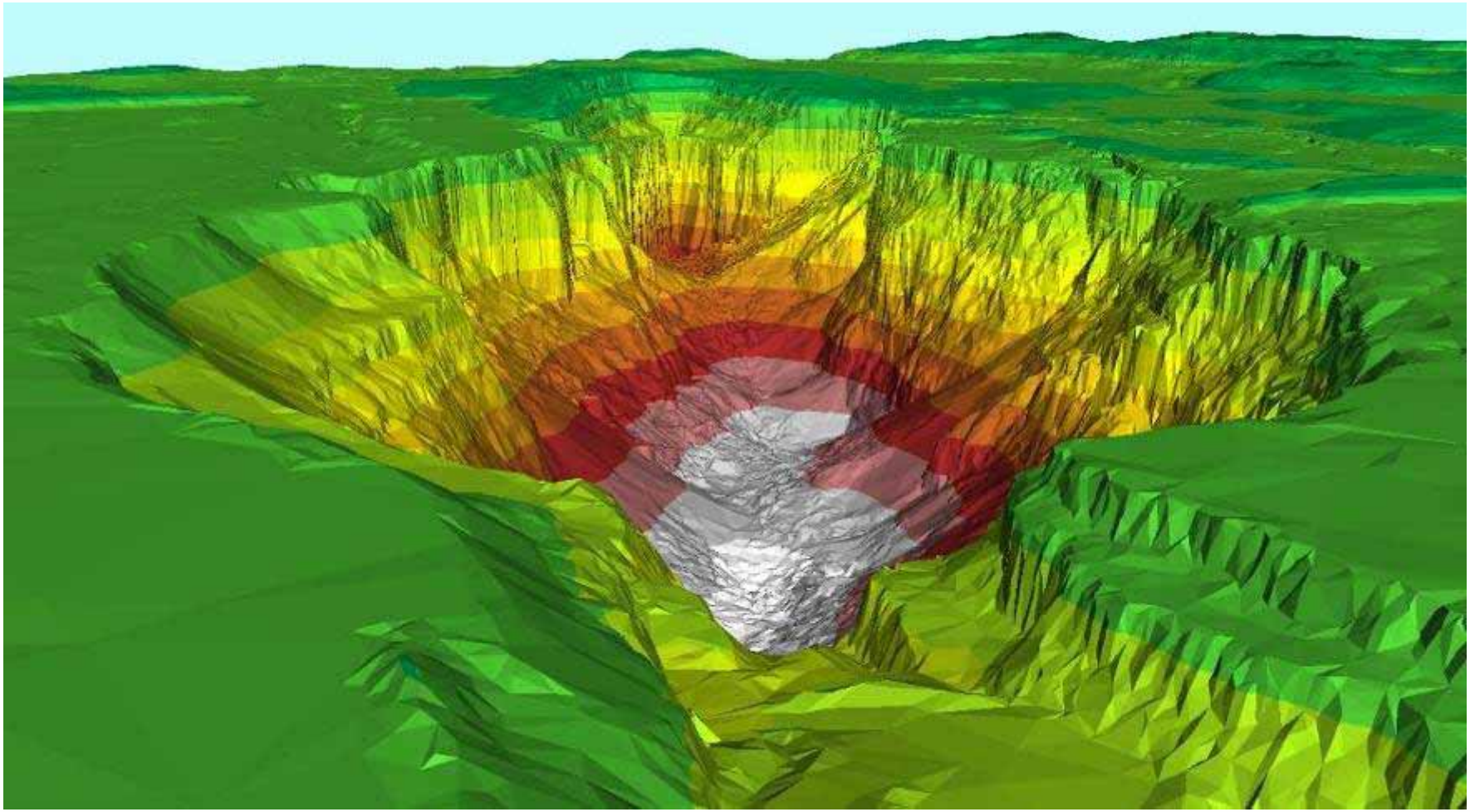


Geology Map – IFSAR



- 1:50,000-scale geology map for Amurang, Sulawesi, Indonesia
- Created using high-resolution airborne IFSAR and Landsat TM data

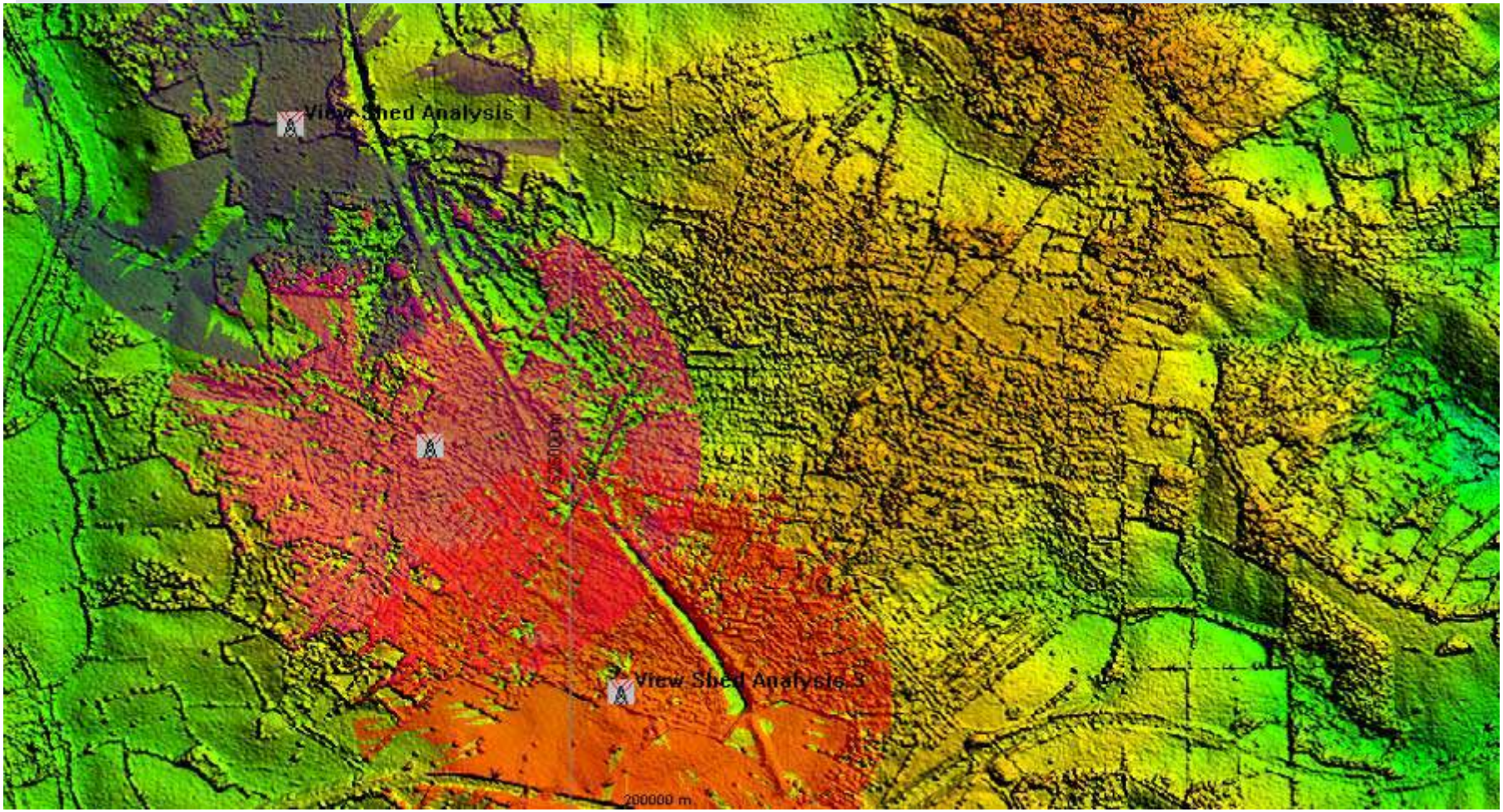
Geological Application – LiDAR Example



www.terrapoint.com

Courtesy of terrapoint BETTER INFORMATION FASTER

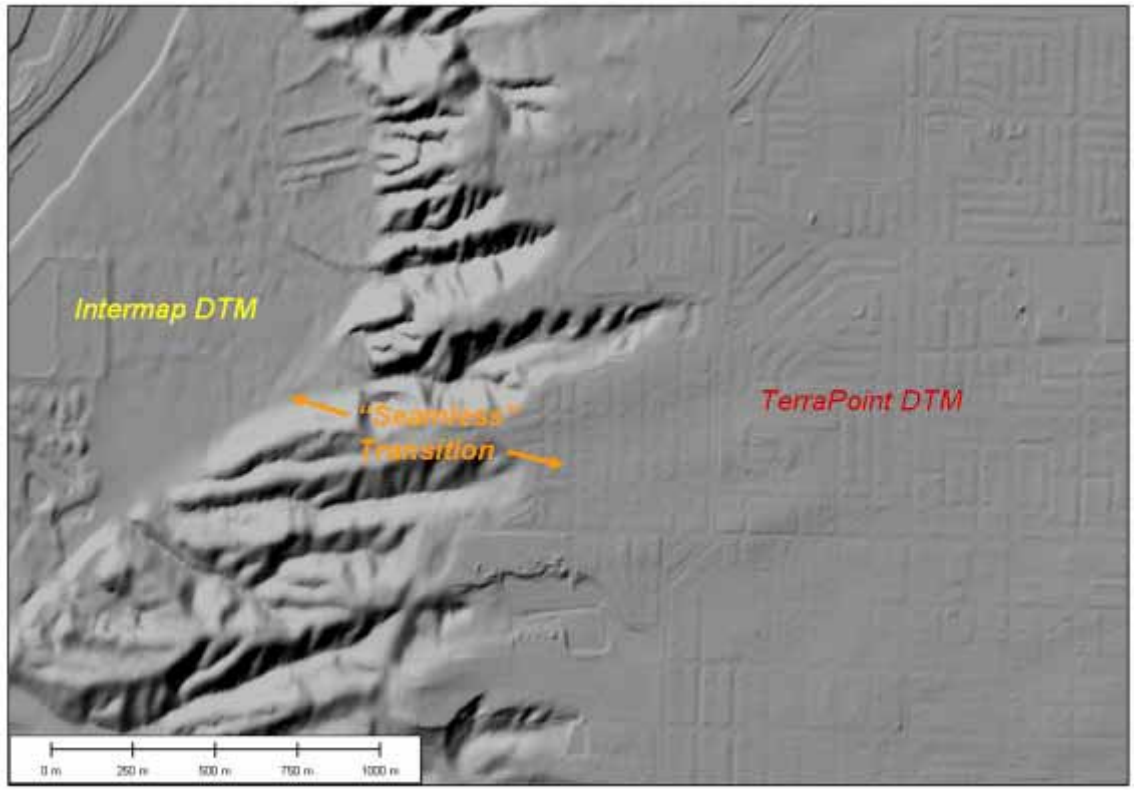
Line of Site: IFSAR Example



Future - DEM Data Fusion: IFSAR & LiDAR

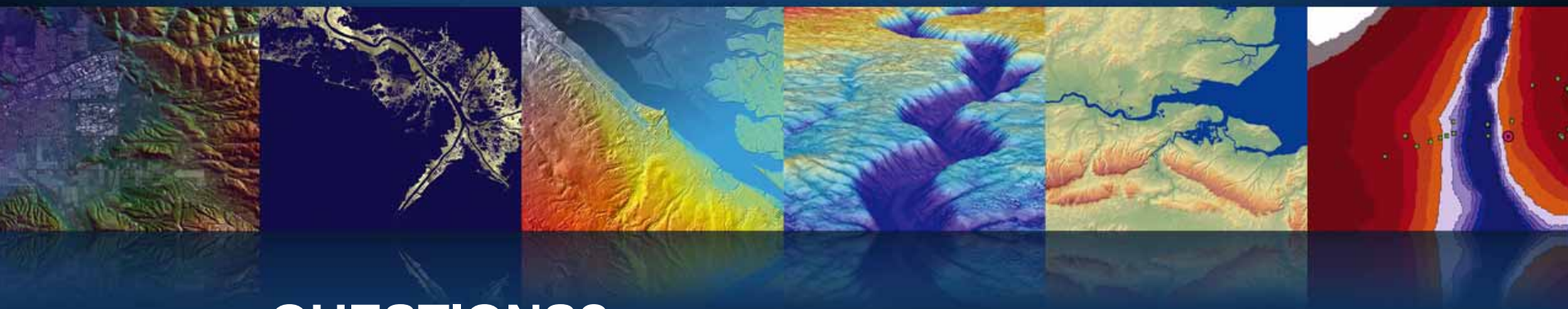
- Fusion Methodology
  - IFSAR for State-wide regions
  - LiDAR for some site survey quality analysis

- Fusion Method Validation:
  - Seam Lines
  - Visualization
  - Hydrology
  - Contours



THANK YOU

Sincere thanks to Dianne Osborne for her assistance with this presentation.



QUESTIONS?

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