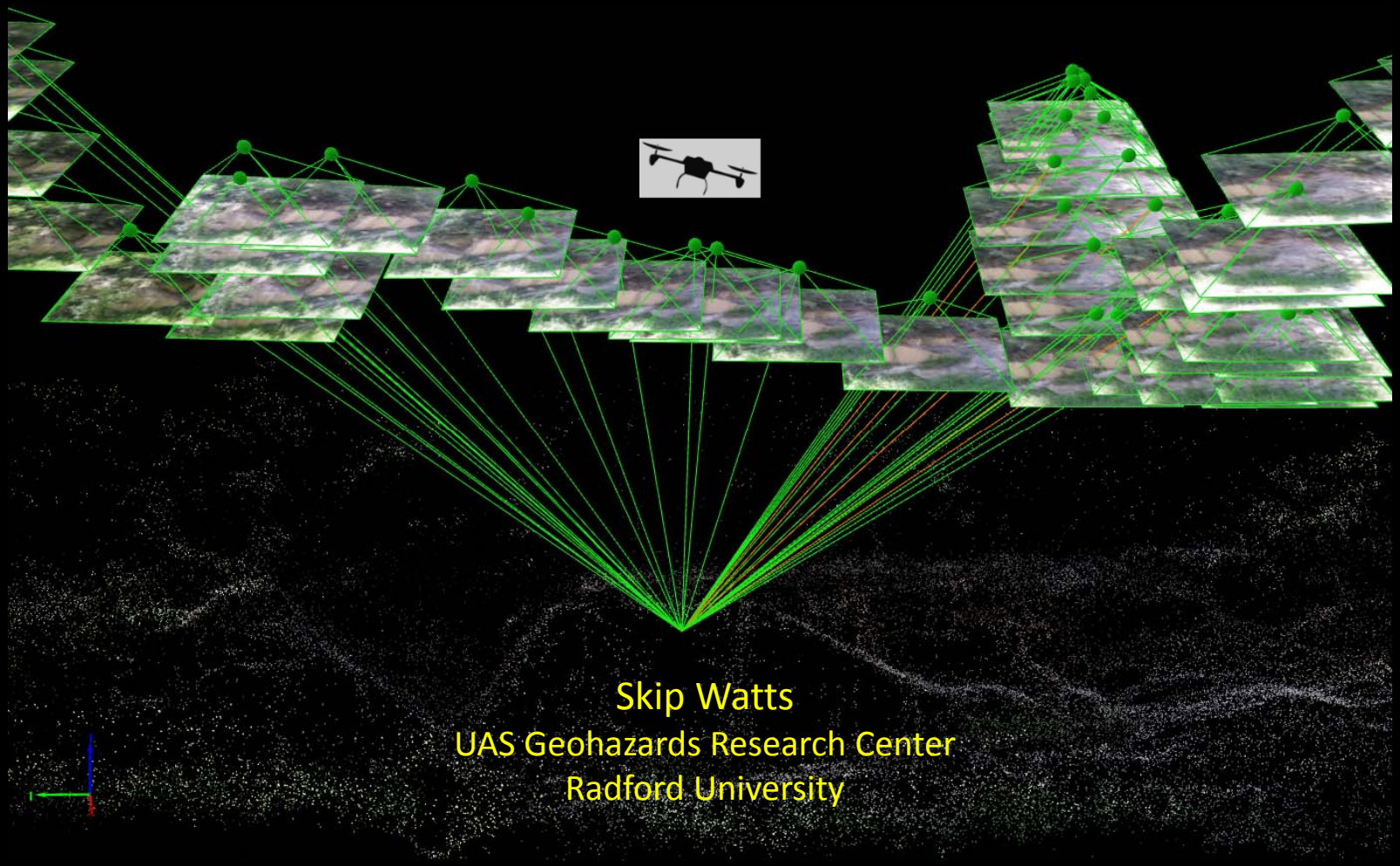
An introduction to the use of unmanned vehicle systems for mapping geohazards: background, capabilities and regulations

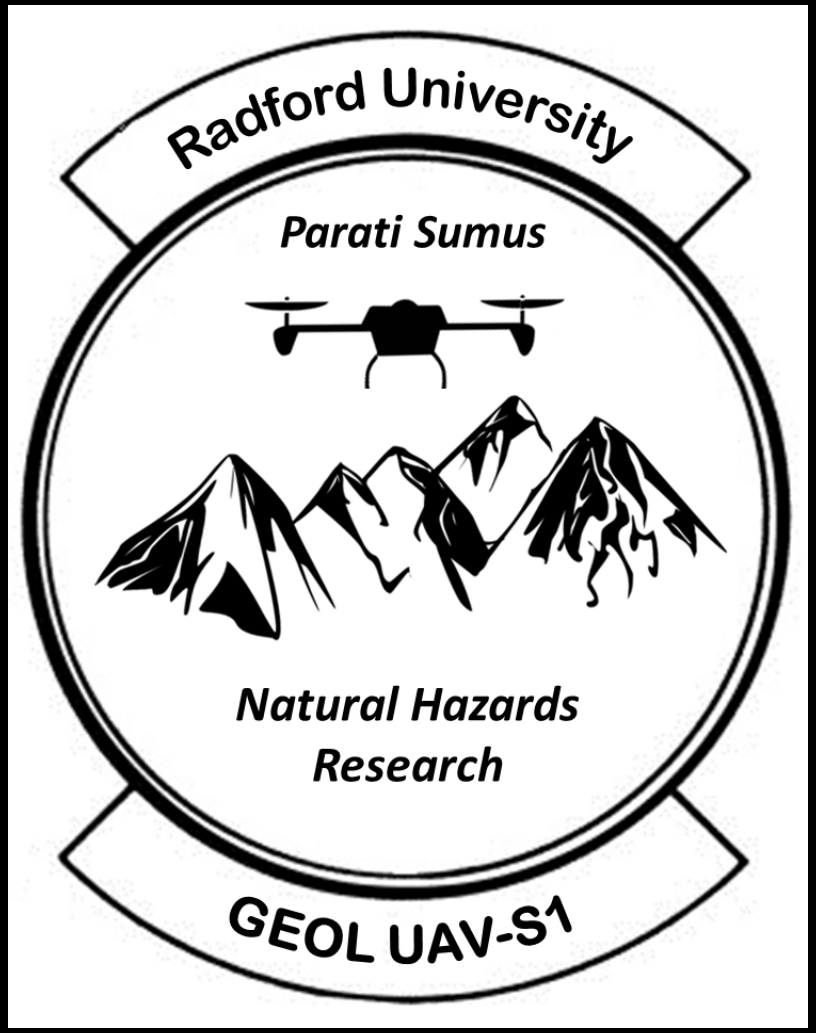


Skip Watts
UAS Geohazards Research Center
Radford University

16th Forum - Geohazards Impacting Transportation in Appalachia
August 3, 2016 - Knoxville, Tennessee

Acknowledgement to collaborators

- GeoStabilization International, Colby Barrett
- ATS-International, Ted Dean
- Kent State University, Abdul Shakoor
- Piedmont Virginia Community College, Darren Goodbar
- Many more…



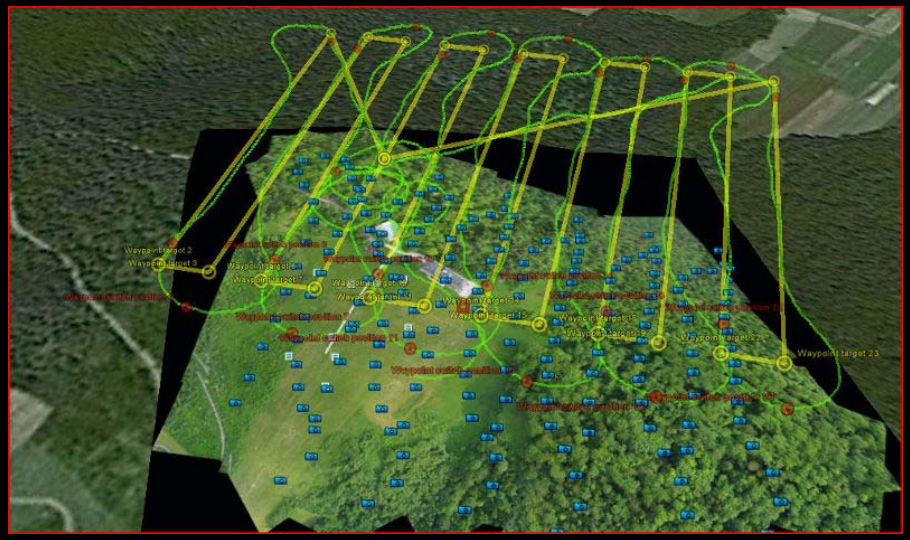
cwatts@radford.edu
(Skip Watts)

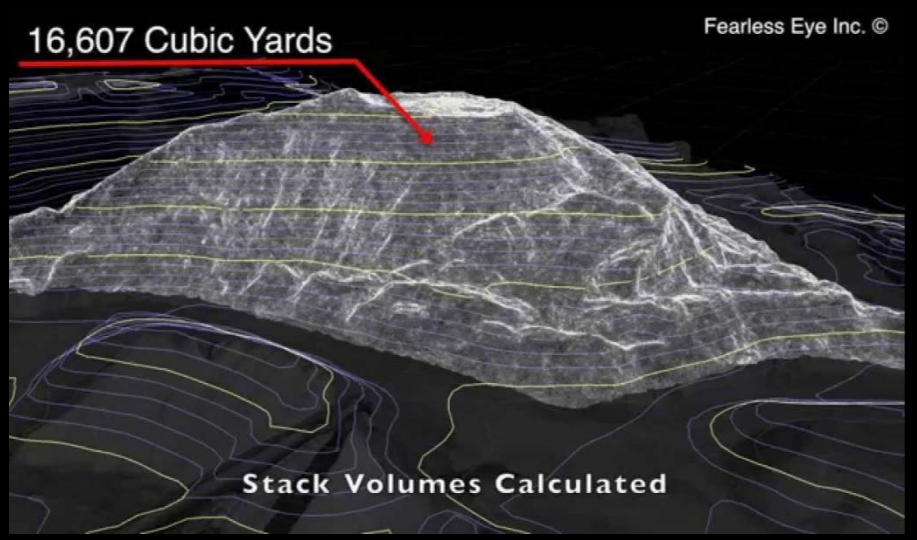
Unmanned Vehicles (UV's) are everywhere

Terminology: (Air, Land, & Sea)

1. UV or UVS – unmanned vehicle, systems
2. UAV – unmanned aerial vehicle
3. UAS – unmanned aerial system
4. ROV – remotely operated vehicle (submersible)
5. Drones – generally try to avoid that term

Applications of UAS's





1. Agriculture
2. Civil Engineering & Mining
3. Movie Production, Real Estate Sales, Televising & Recording Events
4. Emergency Management, Disaster Response, Situational Awareness for Police & Fire
5. More & more…

SEPTEMBER ● 2015

Civil Engineering

THE MAGAZINE OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS ASCE

PANAMA ICON

ALSO:

DRONE DEVELOPMENTS

FREIGHT TRAIN TRENCH

RISE OF THE DRONES

They're here, and although their use and regulation are still nascent, drones—or unmanned aerial vehicles—are becoming more appealing to the architecture, engineering, and construction industries as a means of gathering data more accurately, safely, and quickly.

By T.R. Witcher

The use of unmanned aerial vehicles is taking hold within the architecture, engineering, and construction sectors because of their usefulness in a variety of applications, including highway and bridge inspections.

IN JULY A BRUSH FIRE swept the stretch of Interstate 15 that runs through the Cajon Pass—the mountainous border between metropolitan Los Angeles and the Mojave Desert. The fire consumed 3,500 acres and demolished 20 cars. As panicked motorists fled to higher ground, five drones piloted by hobbyists took to the skies over the fire to record the mayhem. This interference delayed firefighting efforts for 20 minutes. In August a medical helicopter transporting a person who had been bitten by a snake to a Fresno, California, hospital nearly collided with a large drone. The pilot was able to turn the helicopter swiftly and avert a catastrophe, missing the drone by only about 20 ft.

While no injuries were sustained in either incident, these encounters are dramatic indicators that the widespread use of drones—small, unmanned aerial vehicles—is upon us. Whether it's your neighbor playing with one in the driveway or the retail giant Amazon floating the idea of deploying a fleet of drones to deliver packages right to your doorstep, drones are giving rise both to optimism about their potential to make our lives easier and to all sorts of concerns about air safety and invasions of privacy.

Until recently it was illegal to operate drones for commercial purposes. However, the Federal Aviation Administration (FAA) is slowly finalizing regulations covering drone use in commercial applications, and it has granted waivers for a variety of cases, among them real estate work, land surveying, the operation of oil and gas facilities, and the making of motion pictures.

The use of drones is taking hold within the architecture, engineering, and construction sectors as well. Of the 1,008 waivers allowing commercial drones that were granted by the FAA as of August 3, approximately 120 were related to construction or engineering companies or services. As technology makes drones increasingly affordable and practical for a range of uses in these industries, pressure is building on the FAA to decide how drones will be regulated and how to do so in a way that will ensure the safety of the national airspace and protect people and property on the ground.

According to federal law, aircraft operation in the national airspace requires a certificated and registered aircraft, a licensed pilot, and operational approval. However, under section 333 of the FAA Modernization and Reform Act of 2012, the secretary of transportation can authorize low-risk operations of commercial unmanned aircraft systems (UASs). The exemptions under section 333 are being used as a stopgap measure until new rules the agency has proposed for small UASs are finalized.

Since the FAA began issuing exemptions under section 333 last year, it has granted more than 1,000 waivers. It has denied another 300 or so applications, primarily because applicants failed to, according to the agency, "supply sufficient information to make a safety decision." As more companies propose operations that the FAA has already approved, the applications are being processed more quickly. Early applications were taking around six months to approve, whereas the most recent exemptions required only two. More applications are coming in, and the agency has a backlog of hundreds, although the incoming number has slowed.

THE FIRST THING you learn about drones is that many people who use them don't care for the term "drone," perhaps because it brings to mind pilotless planes attacking targets on the other side of

TRIMBLE

nes Are Becoming the Oil stry's Guardian Angels

m has become harder to find, it's become increasingly costly ous to extract. Could aerial data-collection bots create a new ssil fuels?

POINTS OF INTERE

Full Text View

Volume 25 Issue 7 (July 2015)

GSA TODAY

Article, pp. 42–43 | Abstract | PDF (219KB)

GROUNDWORK:

A bird's-eye view of geology: The use of micro drones/UAVs in geologic fieldwork and education

Benjamin R. Jordan
Brigham Young University–Hawaii, 55-220 Kulanui Street, Bldg. 5, Laie, Hawaii 96762, USA

INTRODUCTION

The past few years have seen the rapid development and availability of unmanned aerial vehicles (UAV). Popularly called "drones," they are remotely operated vehicles that can be fixed-wing aircraft or helicopters. UAVs are being developed for use in everything from product delivery (e.g., Albright, 2014) to farming (e.g., Papadopoulos et al., 2014).

Especially popular are micro UAV helicopters, which are usually in the form of small aerial platforms that have four or more propellers (Fig. 1). This configuration provides great maneuverability, stability, and control. Newer UAVs have built-in GPS systems that provide even greater control and make it easy for an inexperienced person to quickly learn the basics of flying. Their size also makes them easy to transport to even the most remote areas (Fig. 1). They require very little launch and recovery space, and the cost of a basic unit is such that even the total loss of a vehicle is not financially catastrophic (Carrivick et al., 2013). Their low cost also means that multiple UAVs can be used, providing for redundancy if one is lost or damaged.

Figure 1
An example of a micro UAV, a DJI Phantom 2. The drone has a GoPro camera mounted between the landing gear.

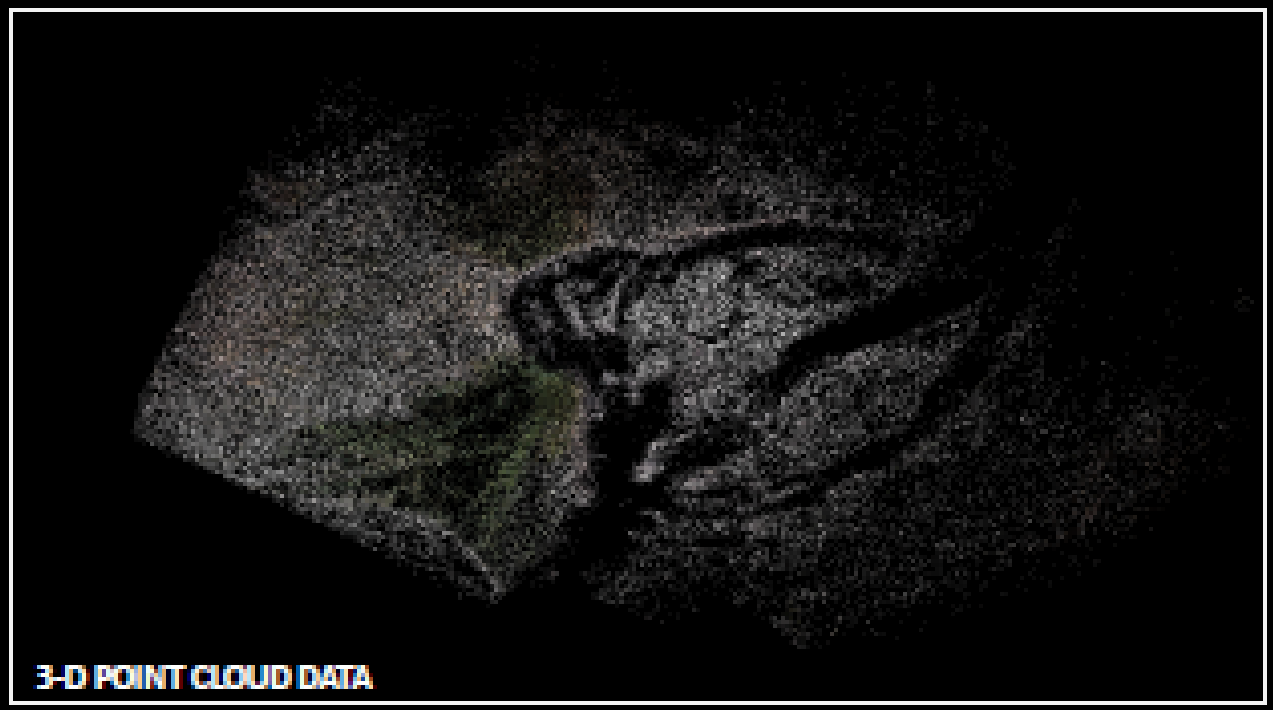
Examples of products

1. Full motion HD video (visual impact & able to extract 100's of overlapping stereo pairs)
2. High resolution still imagery (programmable overlapping pictures, embedded with meta-data)
3. 3-D Point Clouds (xyz locations in space, with attributes like color or temperature)
4. Elevation models (colored maps)
5. Contour maps (traditional topographic maps)
6. Orthoimagery (uniform scale across images and mosaics)
7. Segmentation & classification (pixel by pixel analysis to outline "like areas," then classify, such as vegetation or landuse)

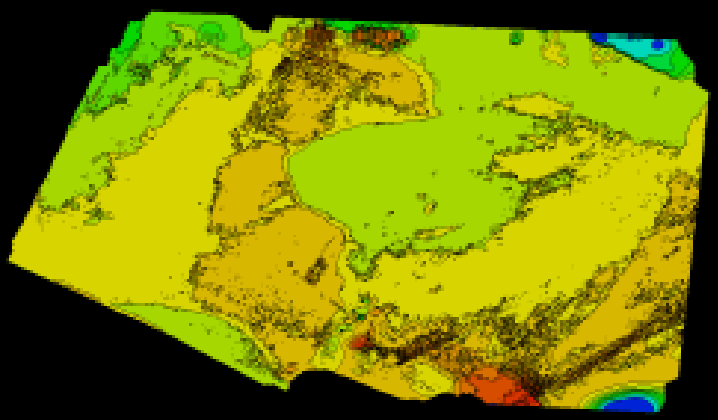
GEOSPATIAL PRODUCT CREATION WITH DATA ACQUIRED FROM UNMANNED AIRCRAFT SYSTEMS

FULL-MOTION VIDEO

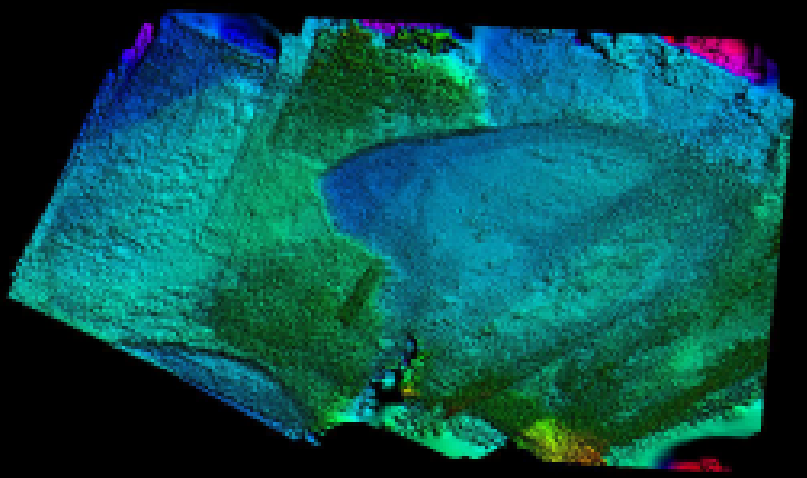
USGS



3-D POINT CLOUD DATA

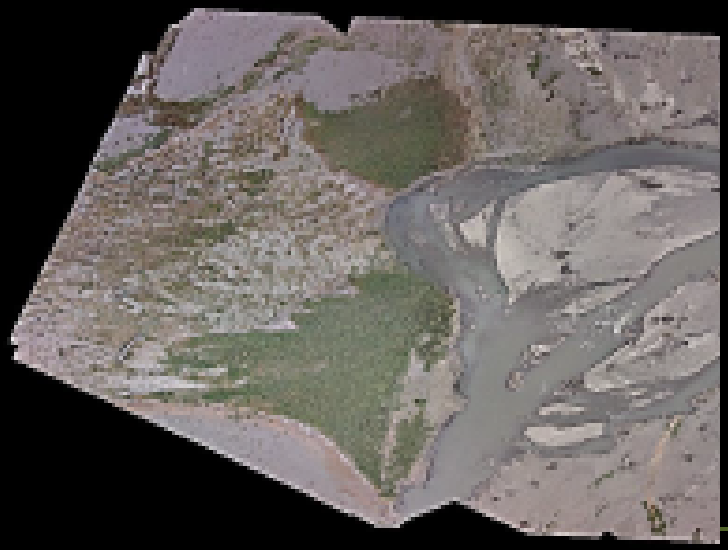


ELEVATION CONTOURS

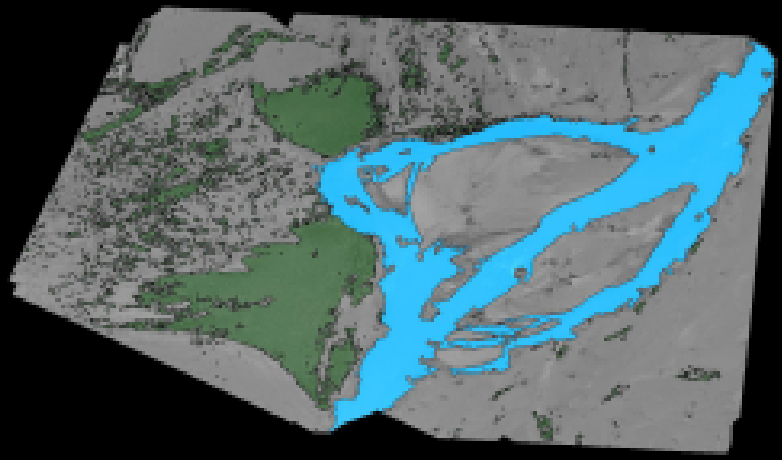


ELEVATION MODELS

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
January 2013



ORTHOIMAGERY



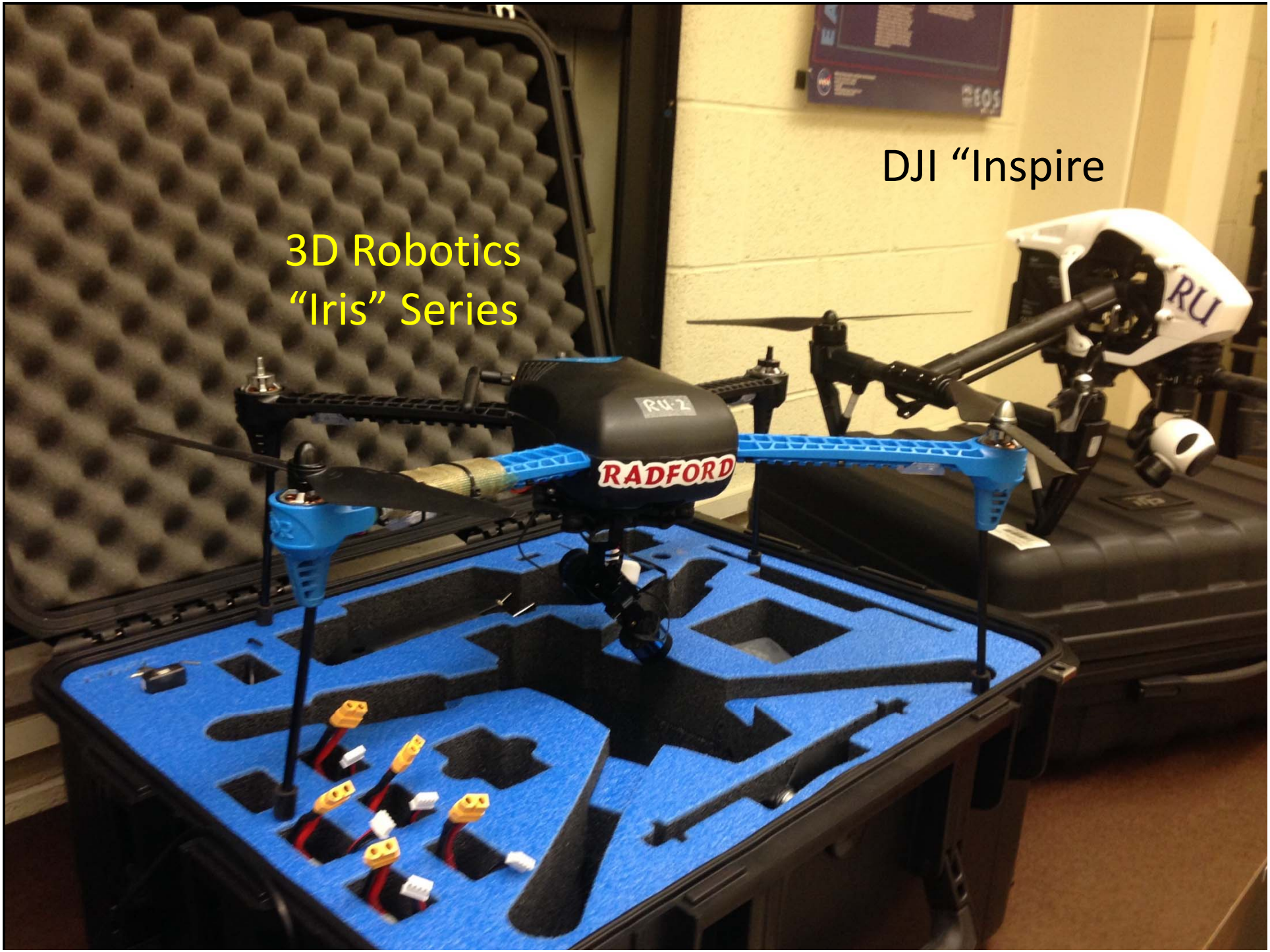
SEGMENTATION AND CLASSIFICATION

USGS

Aircraft & Payload Options:

1. Range from very expensive to very cheap
2. Most applications still involve photographic payloads
   a. Standard RGB cameras (red-green-blue)
   b. Infrared cameras
3. Structure from Motion (SFM) software makes 3D modeling possible
4. Popular packages also make orthophoto mosaic mapping possible
   a. Pix4D
   b. AgisSoft
5. Small LiDAR units are becoming available


"Trainers "
motor memory
development
DJI "Phantom"
Series
3D Robotics
"Iris" Series
DJI "Inspire"
EXTREME F-22
THE HUBSAN X4
THE HUBSAN X4


3D Robotics
"Iris" Series
DJI "Inspire
RADFORD

DJI Inspire
Quadcopter

Pix4D Mapper
Software

albris

senseFly

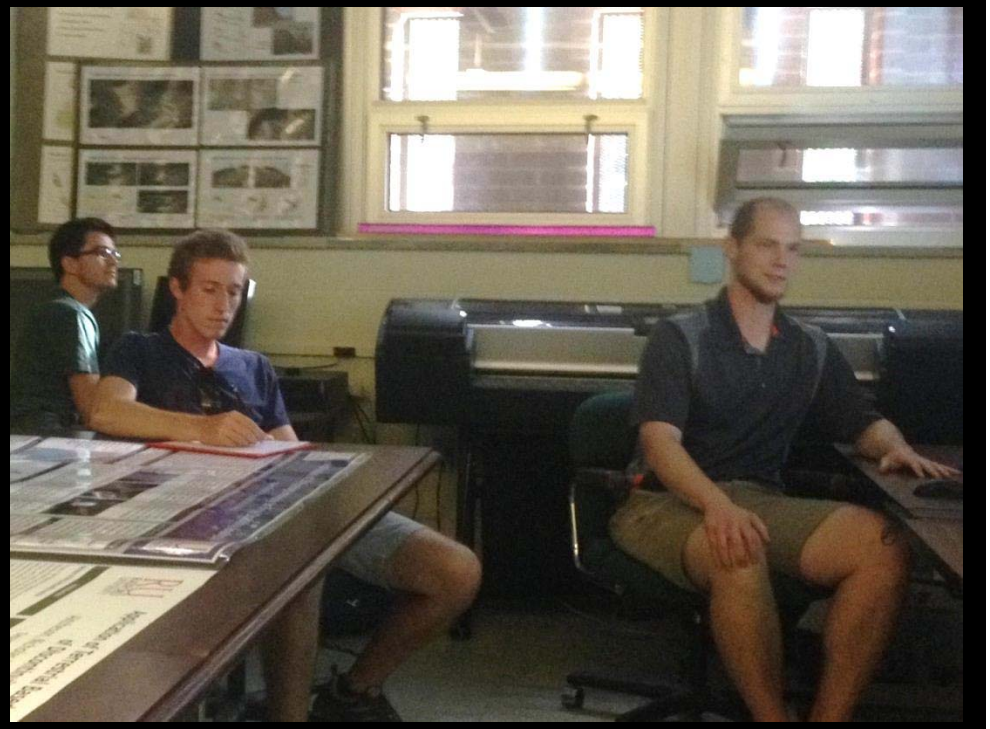
albris

The intelligent mapping & inspection drone

Infrared on the fly…

Some of the uses of UAS's in Geologic Mapping

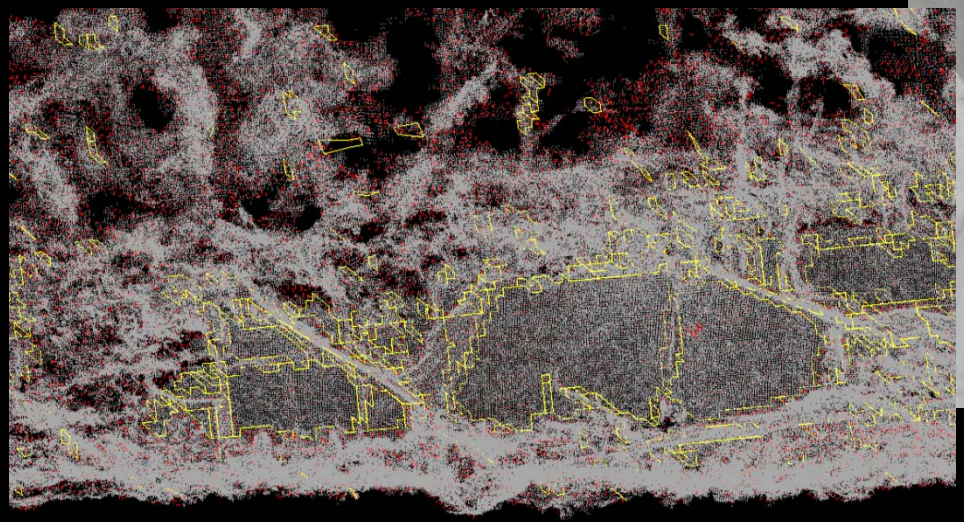
- Gaining an elevation advantage during reconnaissance
- Locating outcrops
- Producing scaled orthophoto mosaics for base maps
- Creating contoured topographic maps
- Generating 3D computer models for manipulation, analysis, and 3D printing
- All of the above are useful for both qualitative and quantitative analyses of potential hazards
- All of the above are useful for assessing damage after-the-fact: landslides, floods, earthquakes, extreme weather events



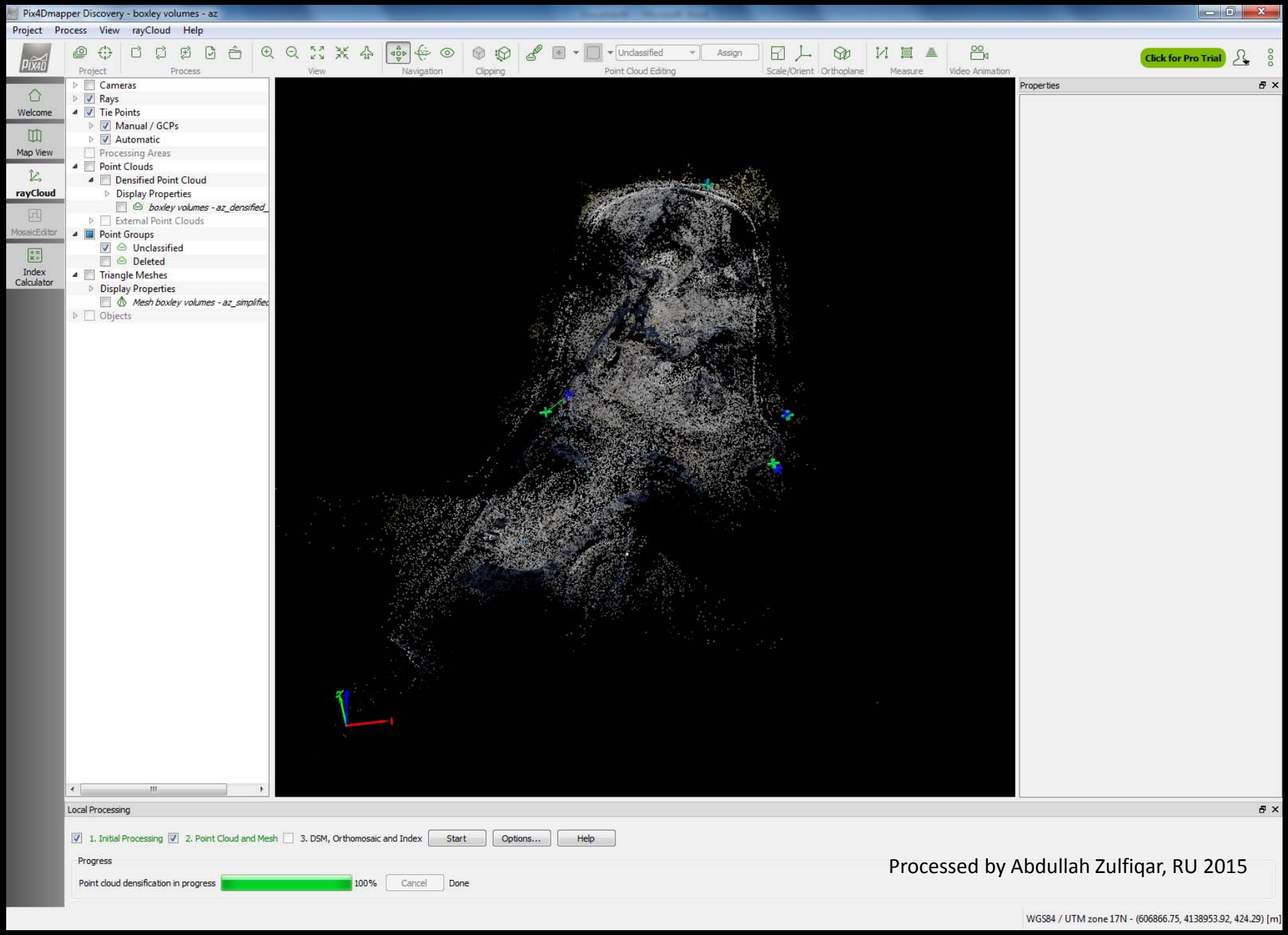
Radford University

UAV GeoHazards Research Group

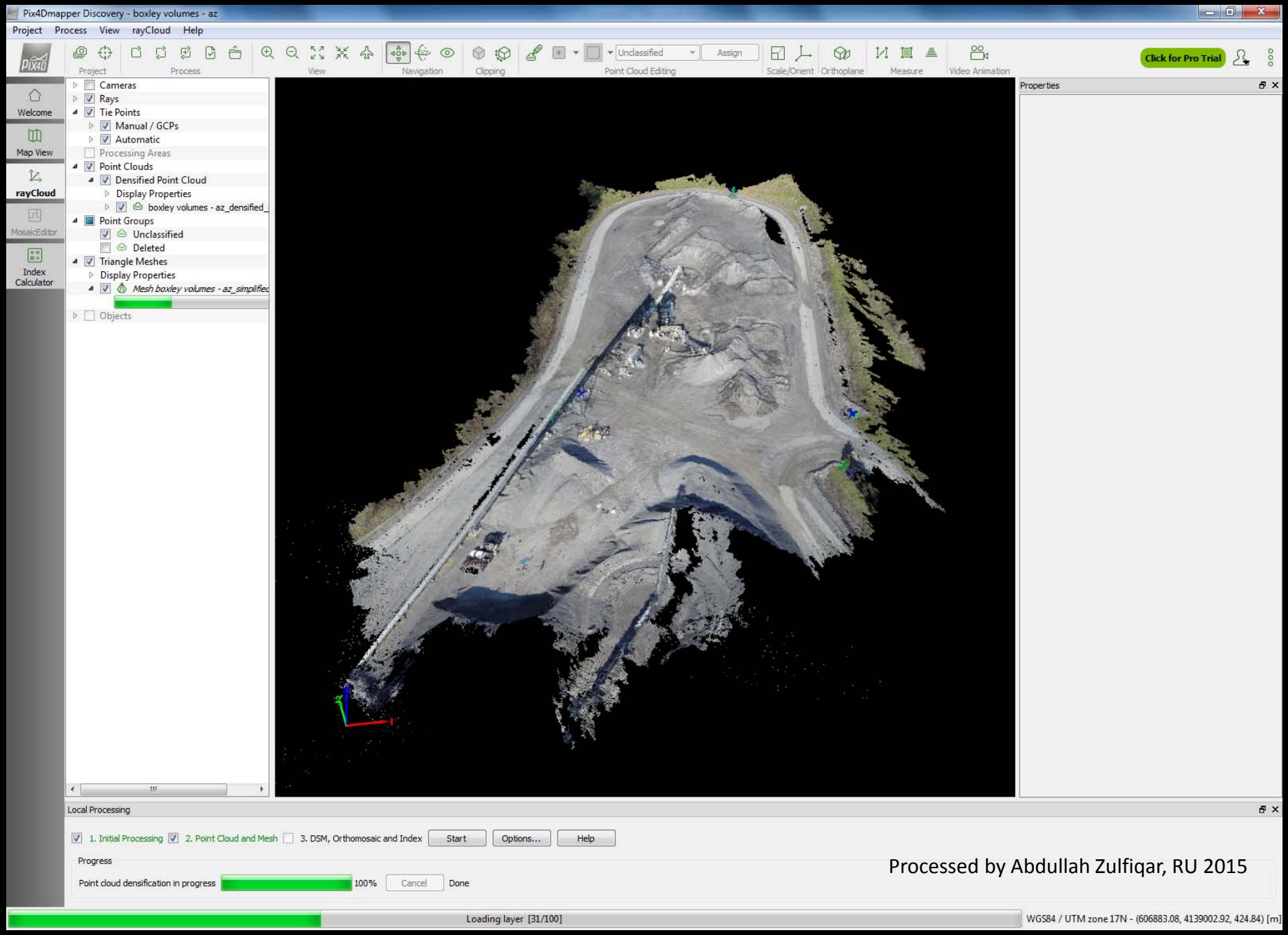
RU Examples:



1. Extraction of geologic structure data
2. Areas & Volumetrics
3. Actual surface areas for treatment (mesh, shotcrete, etc.)
4. Landslide volumes
5. Stockpile volumes
6. Flood reconnaissance



Processed by Abdullah Zulfiqar, RU 2015



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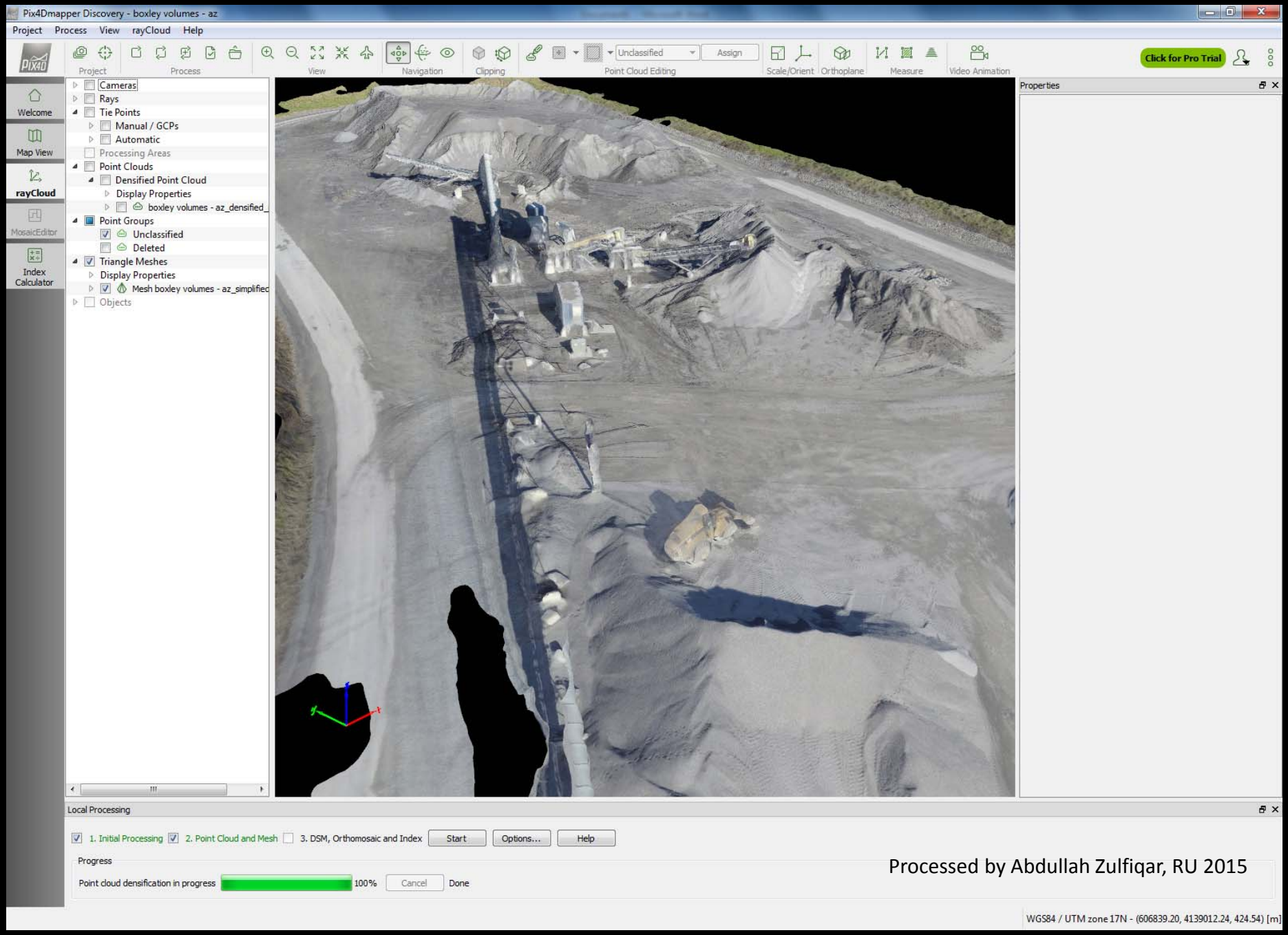

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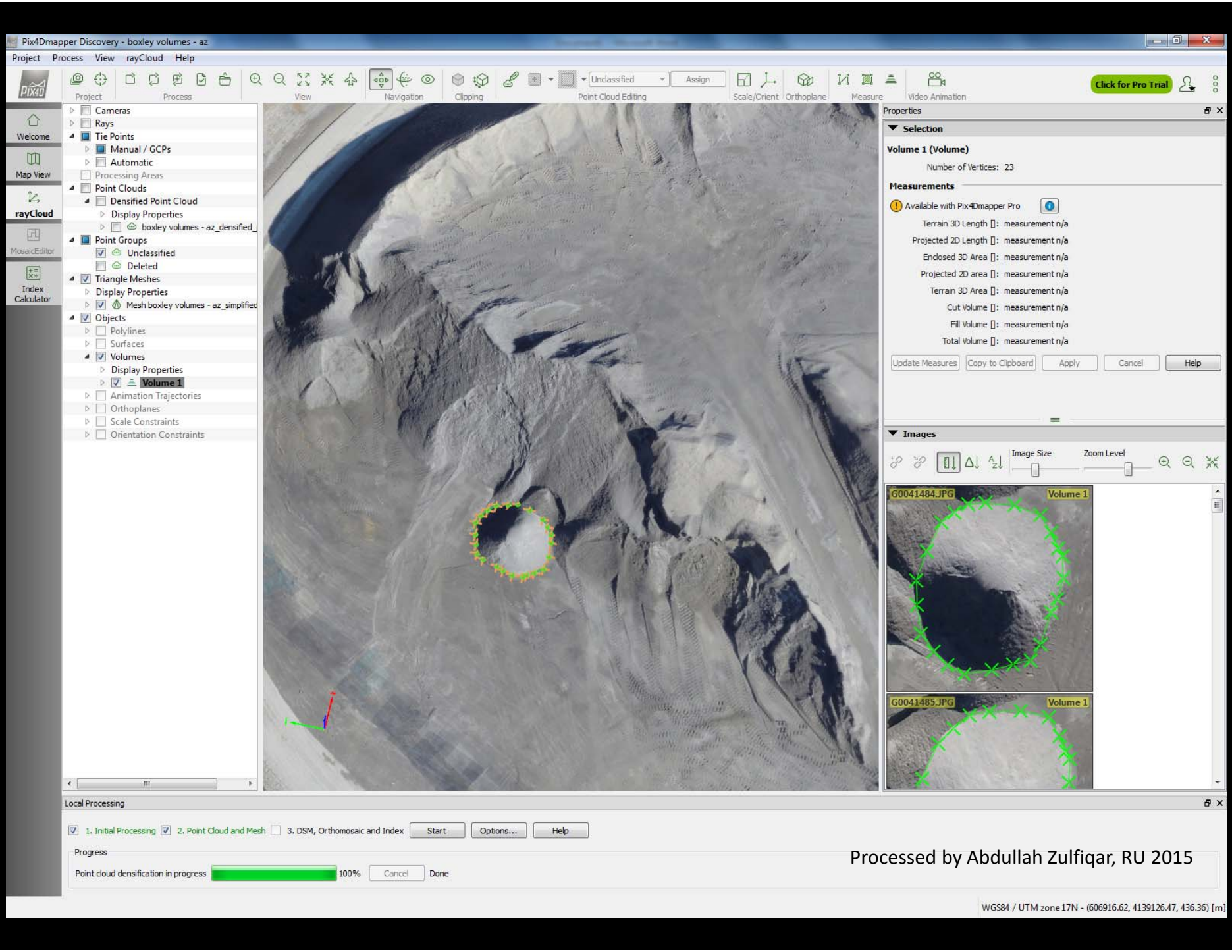
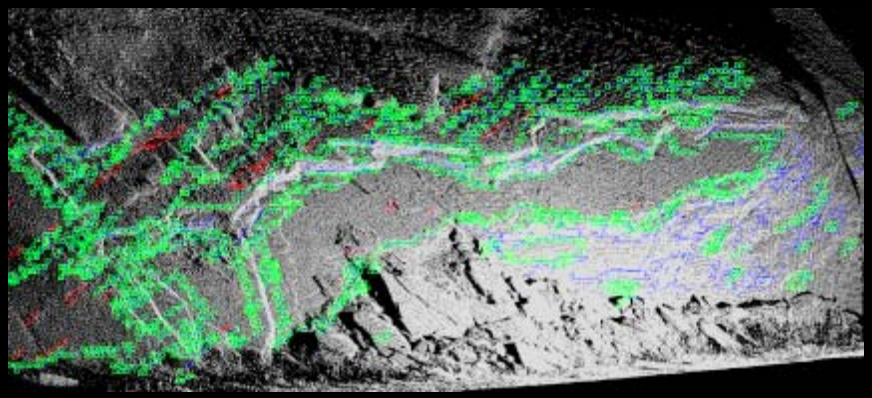
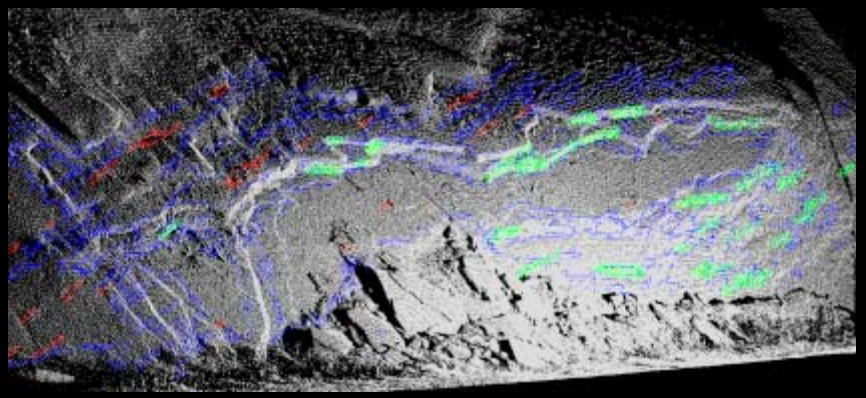
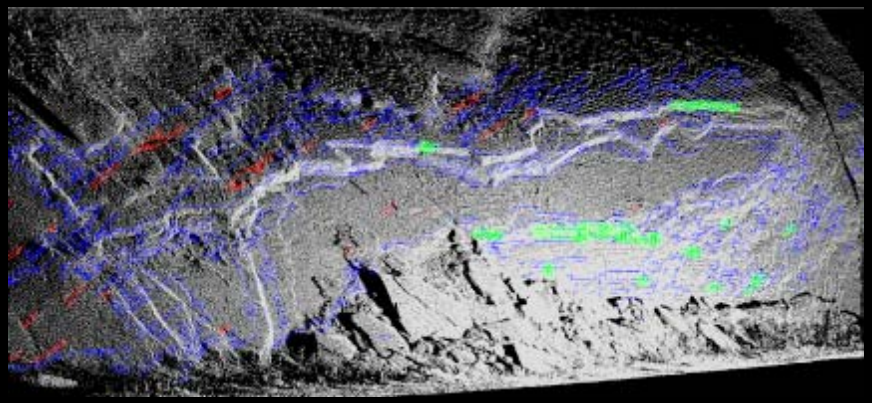


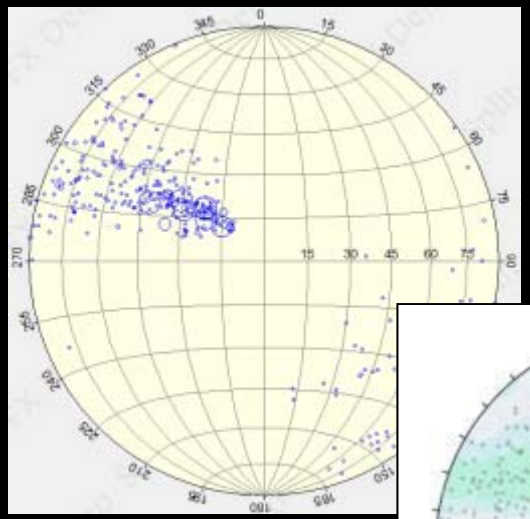
Processed by Abdullah Zulfiqar, RU 2015

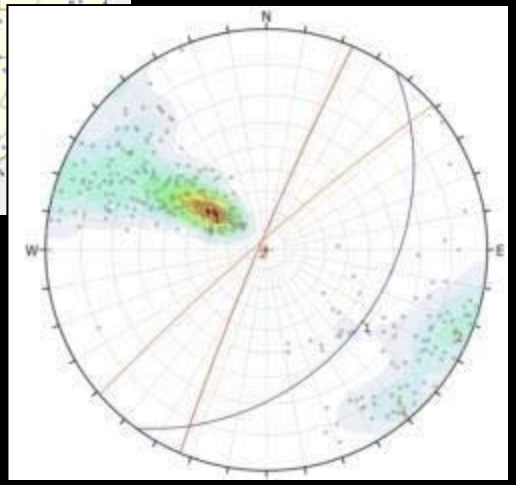
Extraction of discontinuity orientation data using Split-FX software…







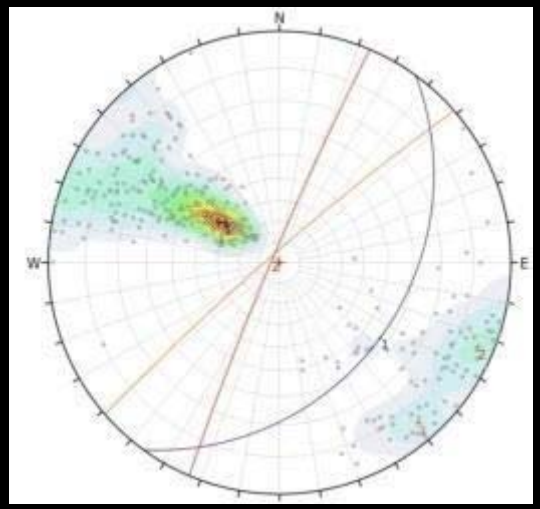




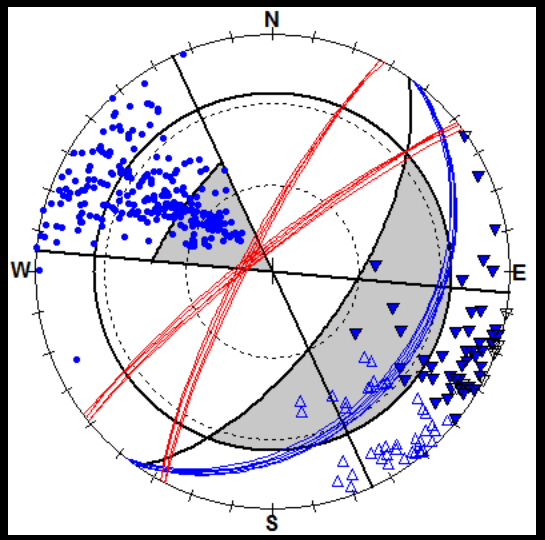
Various steps in processing point cloud data to obtain structure data for stereonets using Split-FX

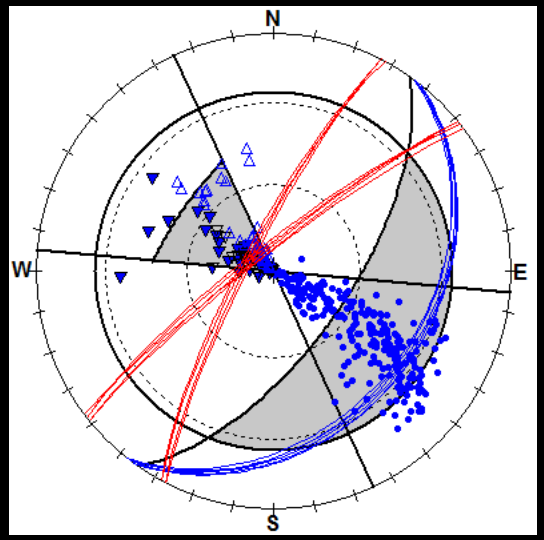
Point Cloud - Stereonet stability analyses

Rt 629 Deerfield, VA



Plotted in *Dips*





Plotted in *RockPack III*

UAV Surveys

Quadcopter used for terrain mapping and aerial reconnaisance

Winter 2014 – Landslide Dam Study

Suspicious holes in the ice sheet

What do you need to know about UAV's ?

There are at least 4 different learning curves

1. Understanding and working within government regulations (FAA)
    a. Still evolving (exemptions, tail numbers, pilot requirements)
    b. Next big change expected summer 2016
2. Choosing appropriate aircraft for your mission
    a. Rotor wing v. fixed wing
    b. Large or small
3. Choosing appropriate payloads for your mission
    a. RGB Cameras
    b. Infrared
    c. Laser Sensors ?

What do you need to know continued…

4. Processing your data
   a. There is so much good software out there !
   b. This talk is focused on the stability of rock slopes
5. "Modern Photogrammetry" (SFM – Structure From Motion)
   a. Hollywood Style Computer Generated Imagery (CGI)
   b. Continuous stereopairs, 10k's of "key" points each, enabling dense point clouds
   c. Like used by Industrial Light & Magic Company

INDUSTRIAL LIGHT & MAGIC

VisualSFM (free)
(Changchang Wu, Google)

PIX4D
simply powerful

Understanding and working within government regulations (FAA)

"*Know before you fly*" pamphlet describes the three types of UAS operators

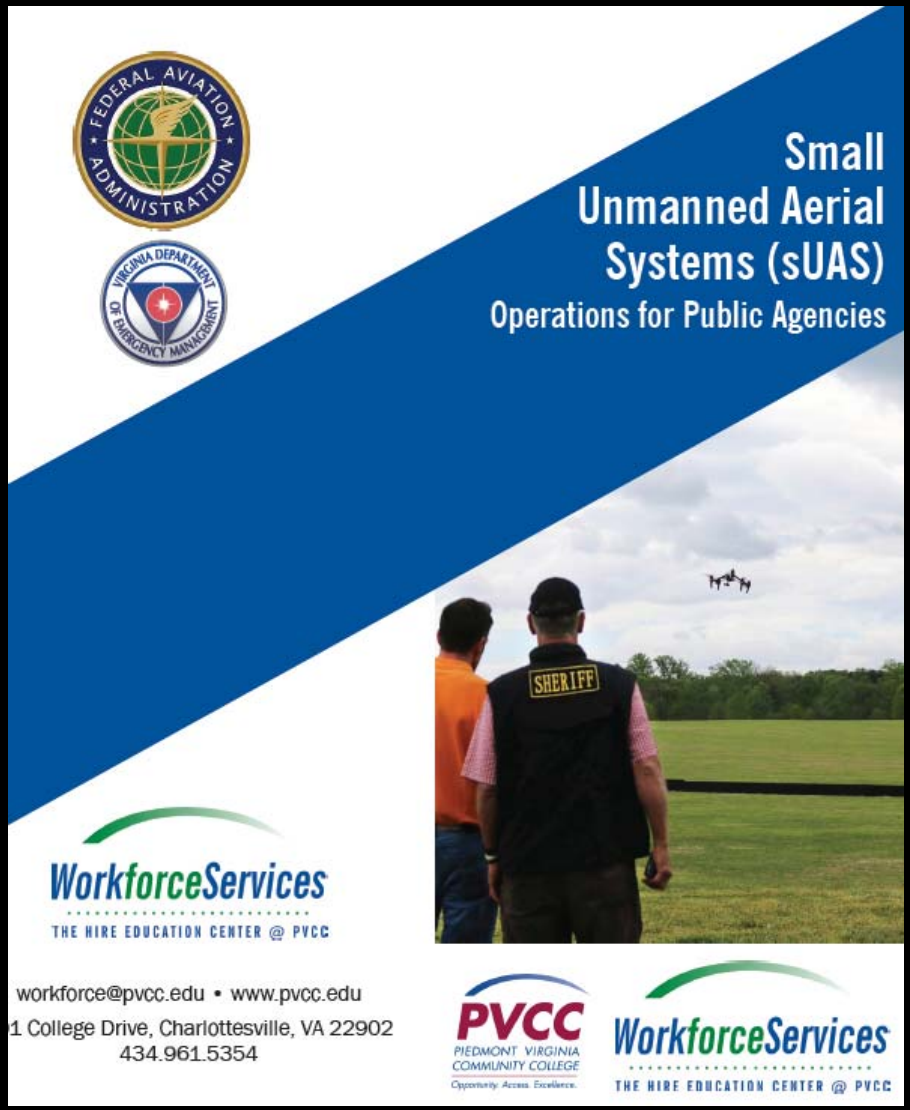
1. Recreational (hobbyist) rules & regulations:
    a. Must register yourself as UAV operator
    b. Use your number on multiple aircraft
    c. Cannot receive compensation for your flights, including incidental YouTube advertising
2. Commercial 333 Exemption or now follow Part 107 rules:
    a. Need exemption or new Part 107 certificate, online training & testing starting August 29, 2016
    b. Aircraft must be registered & marked with "tail number"
    c. Also still need Certificate of Authorization (COA) for some missions, beyond line-of-sight, night flights, near airports
3. Public Entities (like universities & state DOT's):

(next page)

Understanding and working within government regulations (FAA)

"*Know before you fly*" pamphlet describes the three types of UAS operators

3. Public Entities (like universities & state DOT's):
   a. Rules eased on teaching use, but not operational use
   b. COA's from the FAA are required for operational public use
   c. Difficult to obtain COA's, but gives the agency broader operational freedom
   d. Agencies become self-regulating in many ways…



Training is available…

For more information visit

WWW.KNOWBEFOREYOUFLY.ORG

Founding Members

AMA

AUVSI

Campaign Partner

About Know Before You Fly

"Know Before You Fly" is an educational campaign that provides prospective unmanned aircraft users with the information and guidance they need to fly safely and responsibly.

About AUVSI

The Association for Unmanned Vehicle Systems International (AUVSI)—the world's largest nonprofit organization dedicated to the advancement of unmanned systems and robotics—represents more than 7,500 members from 60+ allied countries involved in the fields of government, industry and academia. AUVSI members work in the defense, civil and commercial markets.

AUVSI

For more information, go to www.auvsi.org.

GENERAL RESTRICTIONS

- Follow community-based safety guidelines, as developed by organizations such as the Academy of Model Aeronautics.
- Fly no higher than 400 feet and remain below any surrounding obstacles when possible.
- Keep your sUAS in eyesight at all times, and use an observer to assist if needed.
- Remain well clear of and do not interfere with manned aircraft operations, and you must see and avoid other aircraft and obstacles at all times.
- Do not intentionally fly over unprotected persons or moving vehicles, and remain at least 25 feet away from individuals and vulnerable property.
- Contact the airport or control tower before flying within five miles of an airport.
- Do not fly in adverse weather conditions such as in high winds or reduced visibility.
- Do not fly under the influence of alcohol or drugs.

- Ensure the operating environment is safe and that the operator is competent and proficient in the operation of the sUAS.
- Do not fly near or over sensitive infrastructure or property such as power stations, water treatment facilities, correctional facilities, heavily traveled roadways, government facilities, etc.
- Check and follow all local laws and ordinances before flying over private property.
- Do not conduct surveillance or photograph persons in areas where there is an expectation of privacy without the individual's permission (see AMA's privacy policy).

Coal Hollow Area Test Site

Montgomery County, Virginia

using

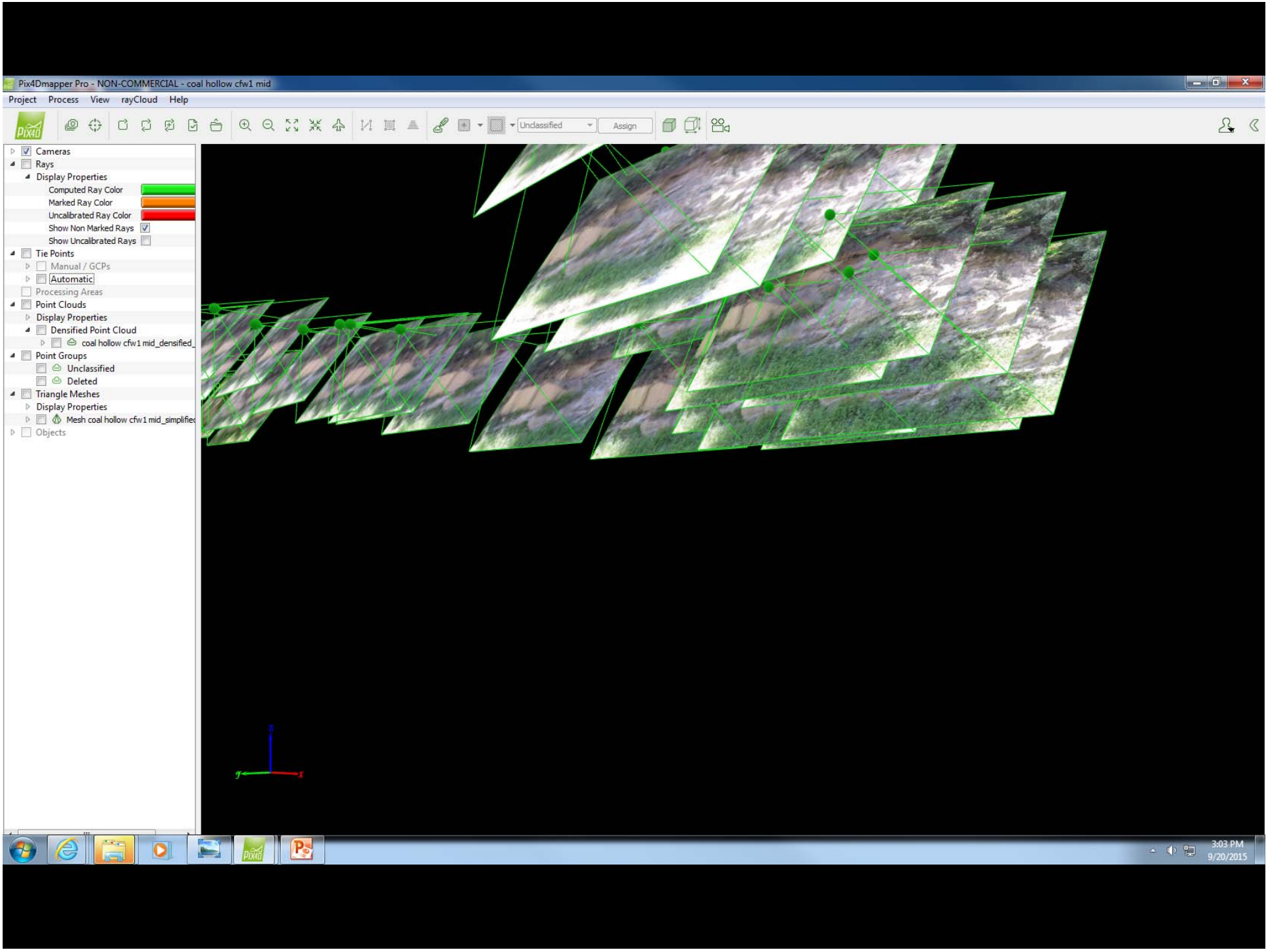
PIX4D
simply powerful!

3D Robotics “Iris” Series - UAV

&

Pix4D Mapper

East End Details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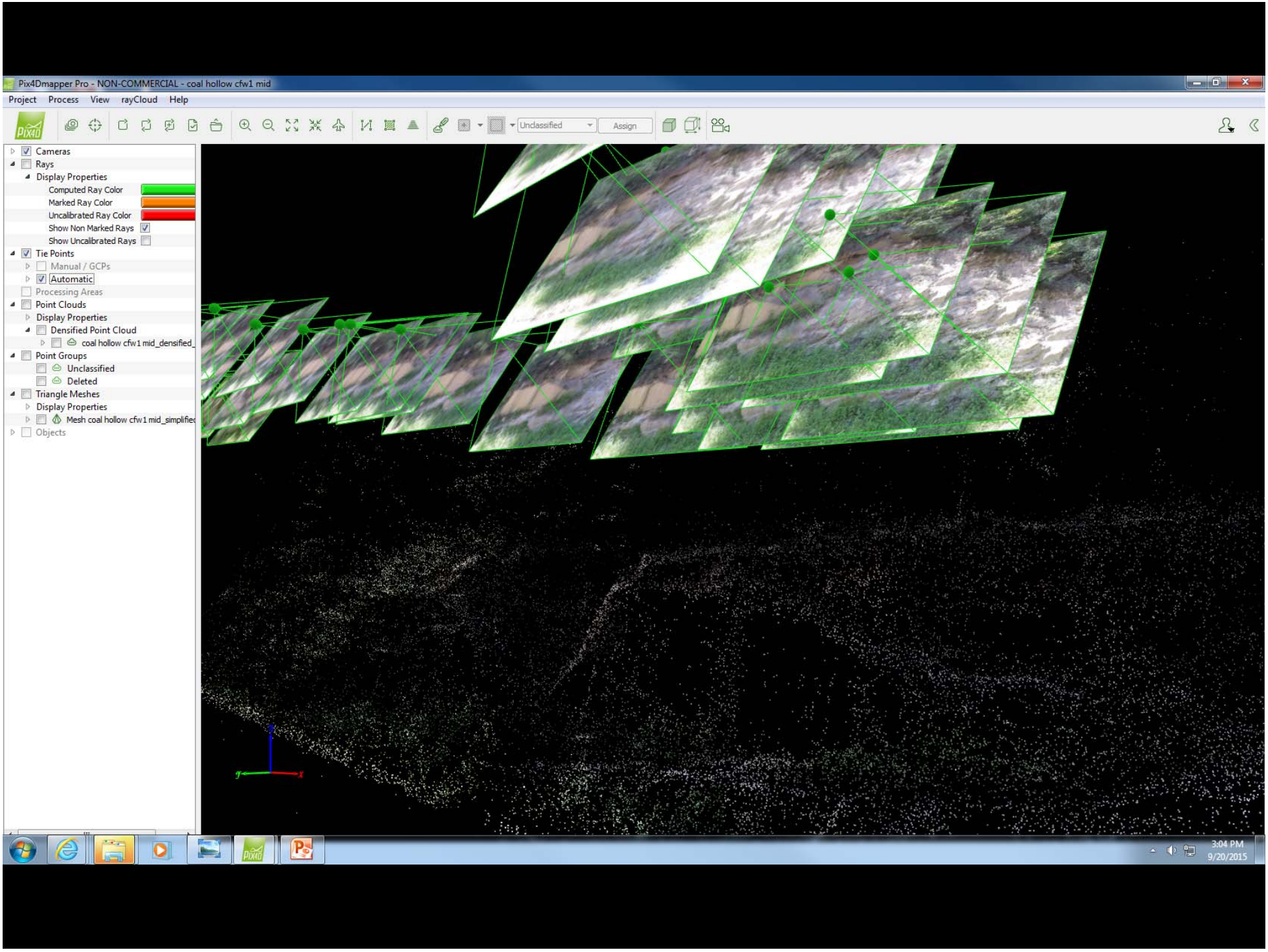
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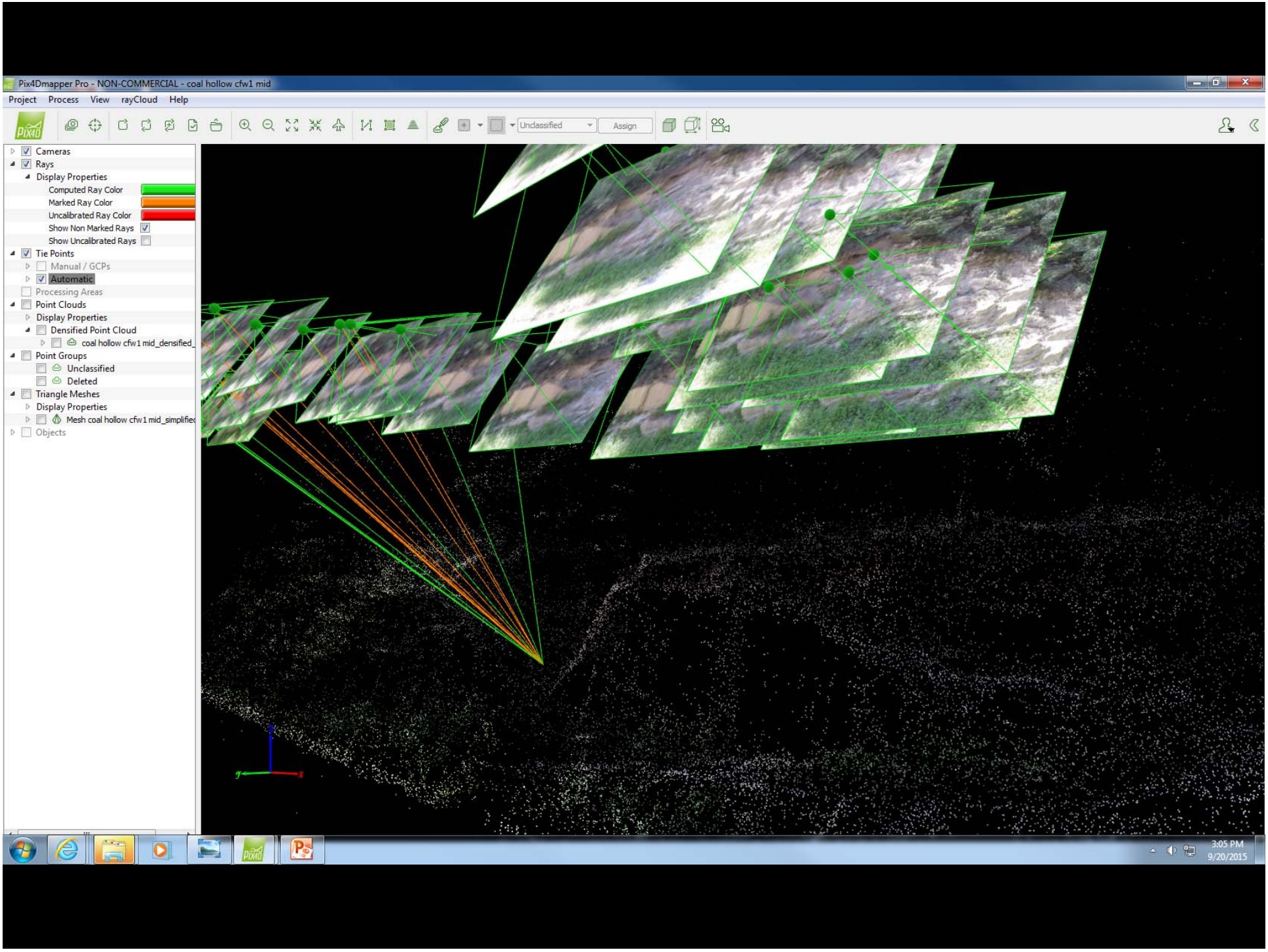
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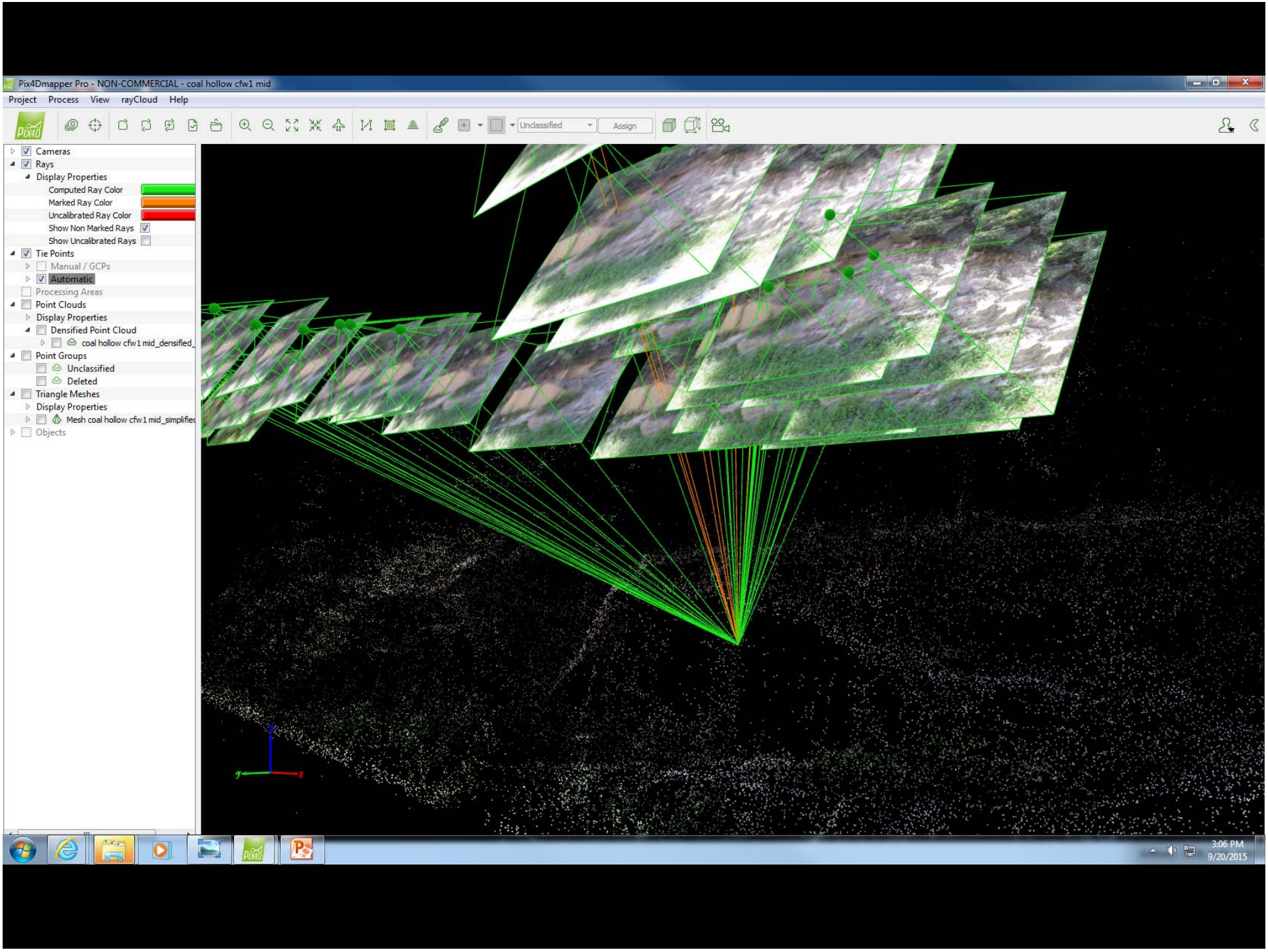
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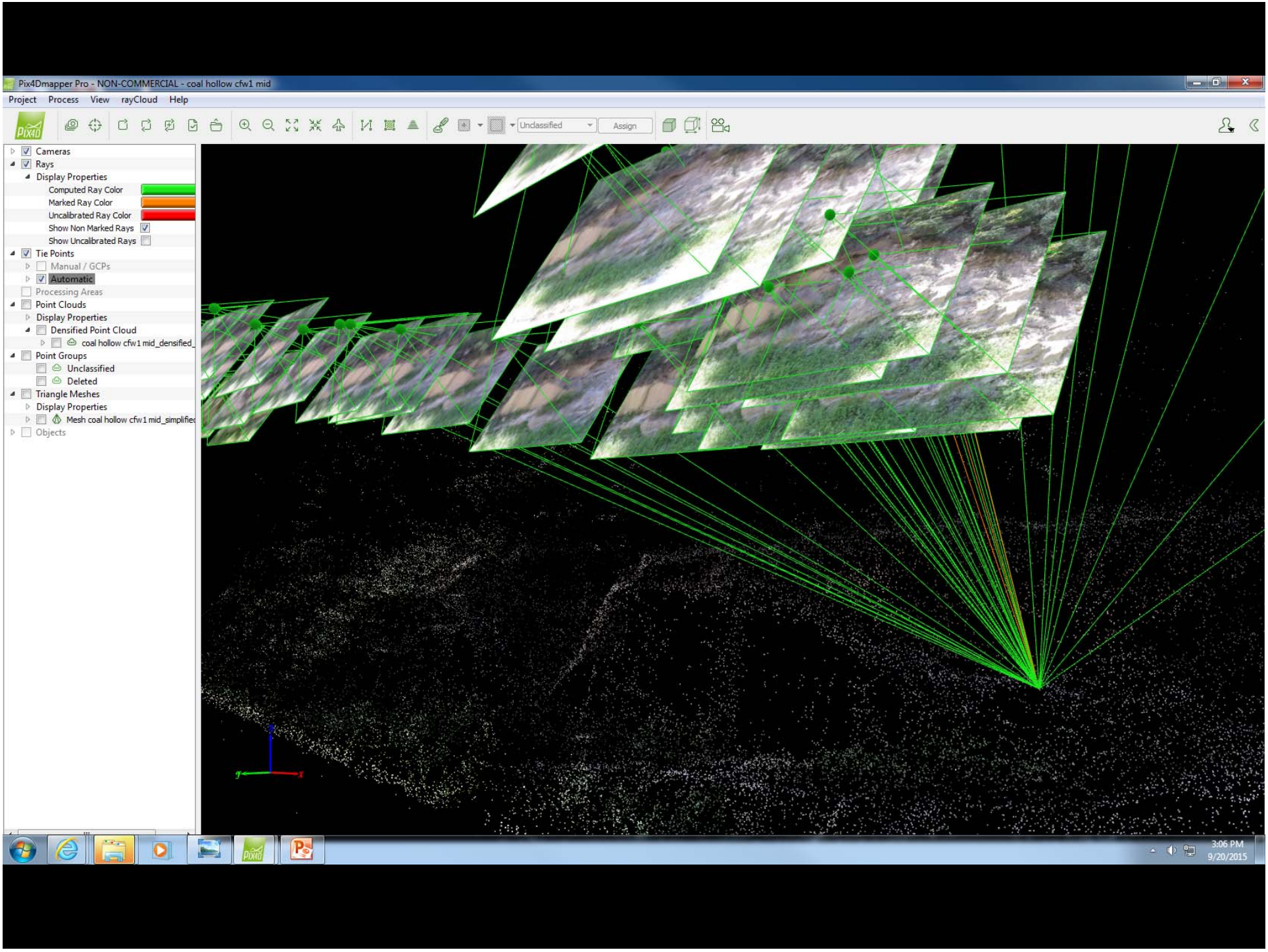
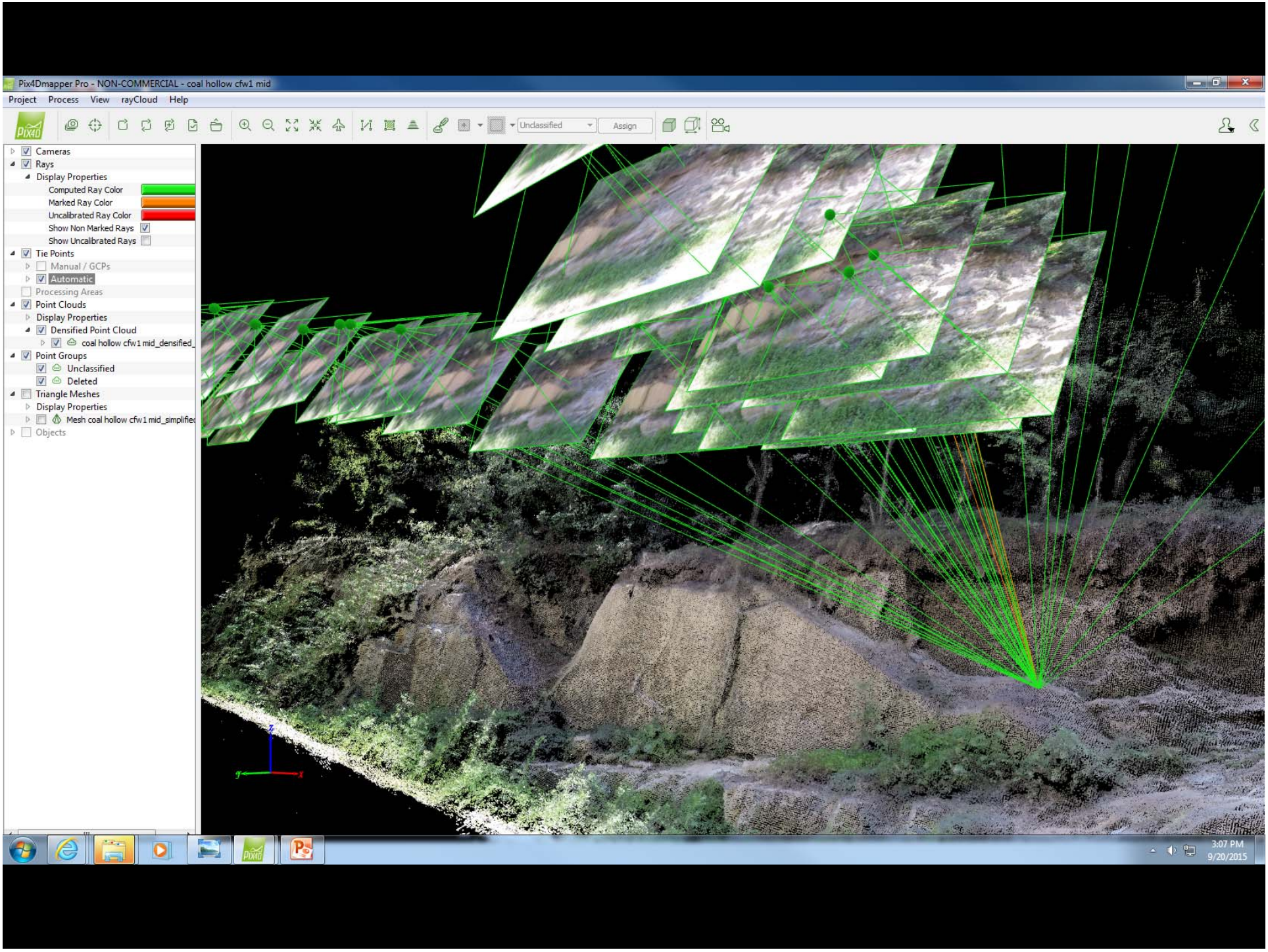

Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project
Process
View
rayCloud
Help
Unclassified
Assign
Cameras
Rays
Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
Show Non Marked Rays
Show Uncalibrated Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
Unclassified
Deleted
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:06 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
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rayCloud
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Unclassified
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Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
Show Non Marked Rays
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Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
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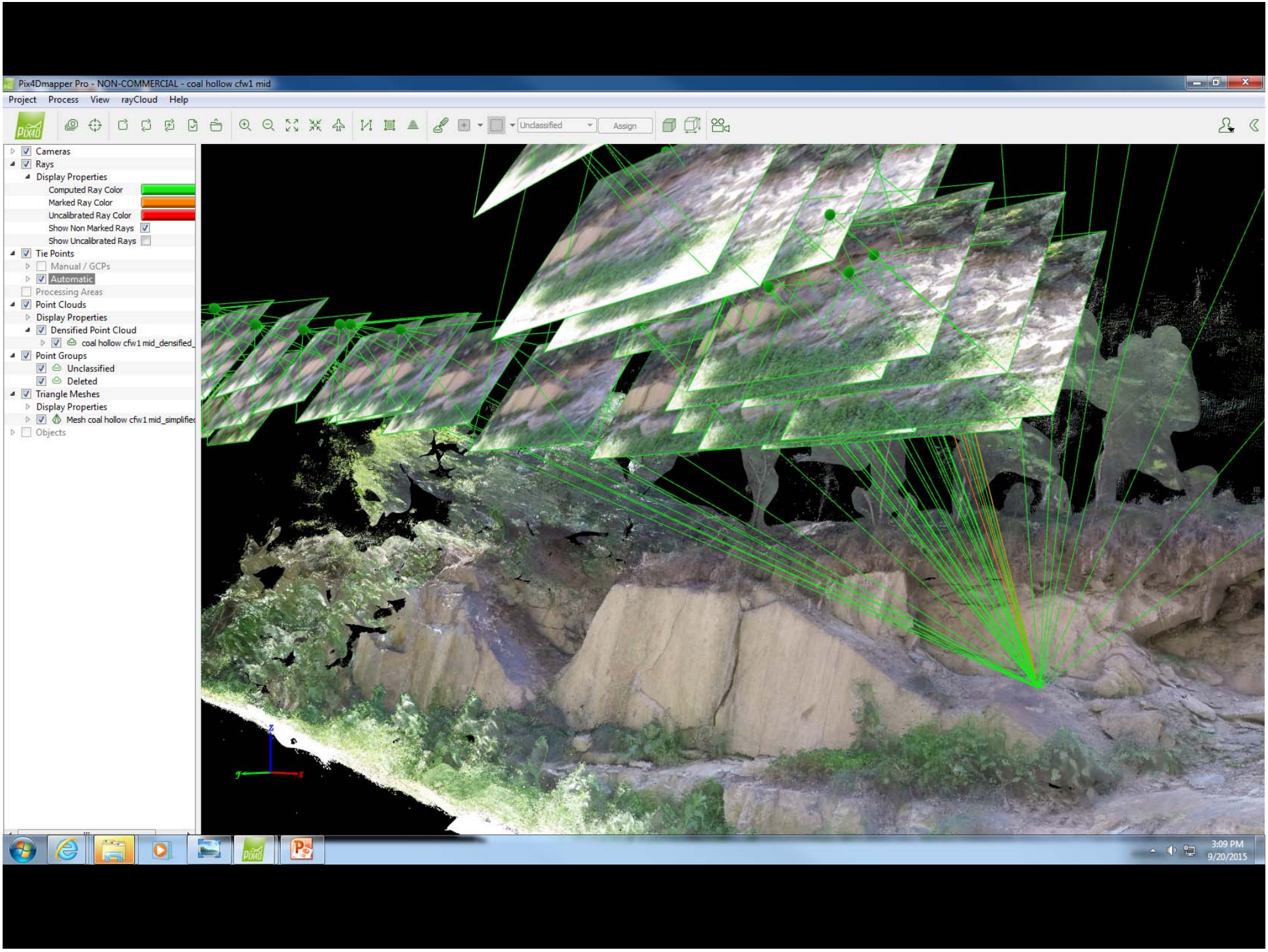
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:07 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project Process View rayCloud Help
Unclassified
Assign
Cameras
Rays
Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
Show Non Marked Rays
Show Uncalibrated Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
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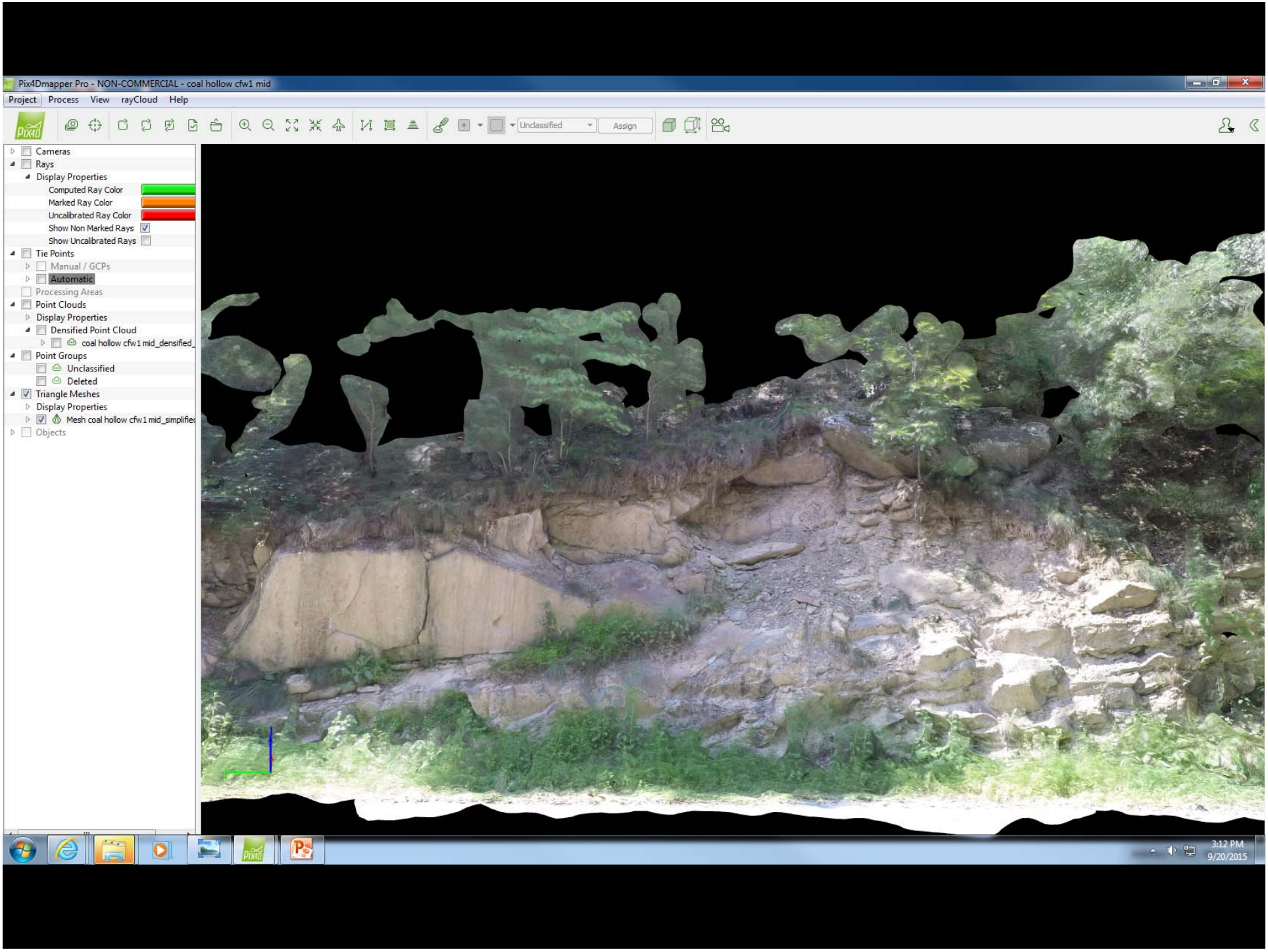
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:09 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project
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Unclassified
Assign
Cameras
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Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
Show Non Marked Rays
Show Uncalibrated Rays
Tie Points
Manual / GCPs
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Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
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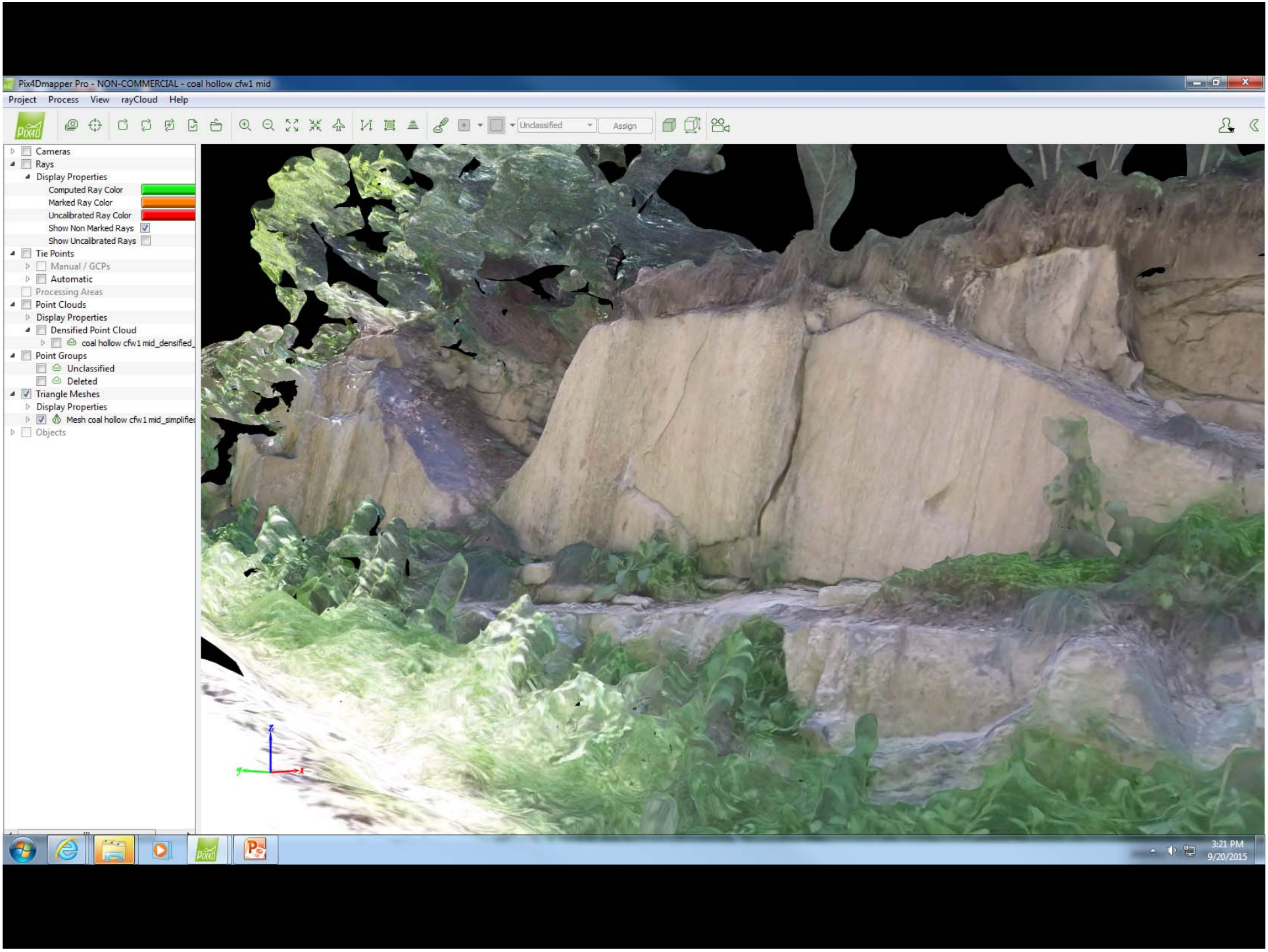
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:12 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project Process View rayCloud Help
Unclassified
Assign
Cameras
Rays
Display Properties
Computed Ray Color
Marked Ray Color
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Show Non Marked Rays
Show Uncalibrated Rays
Tie Points
Manual / GCPs
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Processing Areas
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Display Properties
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Point Groups
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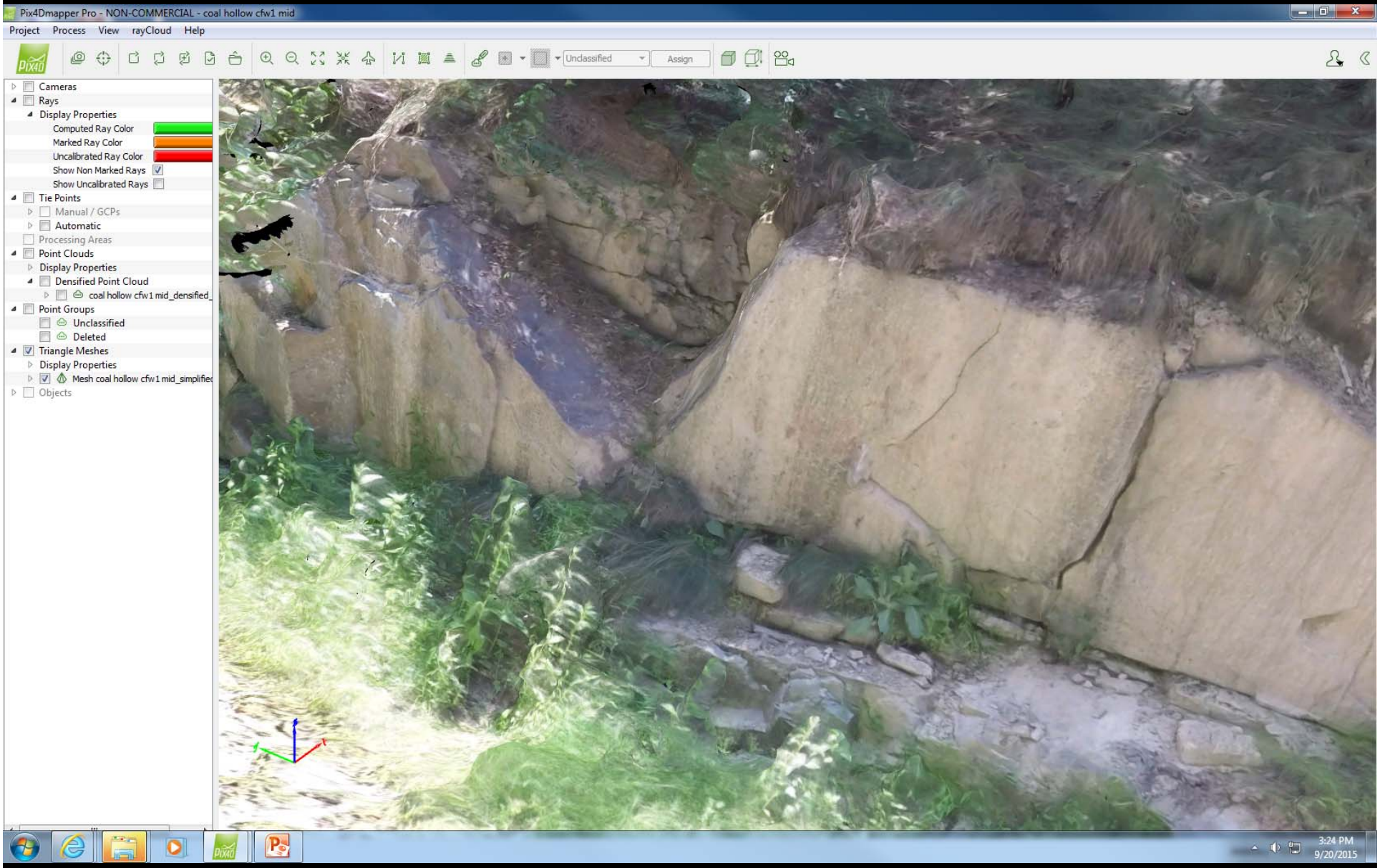
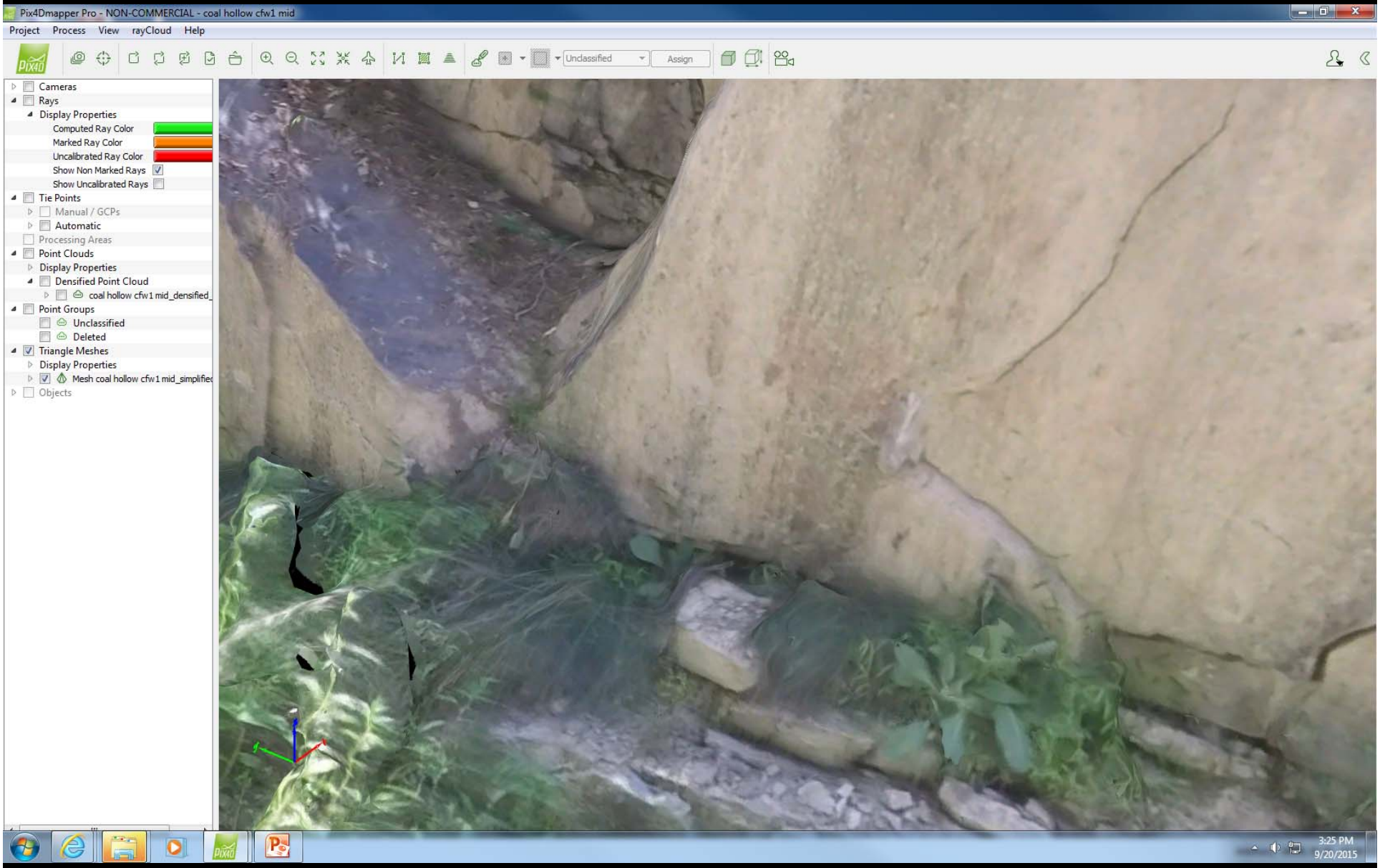
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:21 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project Process View rayCloud Help
Unclassified
Assign
Cameras
Rays
Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
Show Non Marked Rays
Show Uncalibrated Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
Unclassified
Deleted
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:24 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project
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rayCloud
Help
Unclassified
Assign
Cameras
Rays
Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
Show Non Marked Rays
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Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
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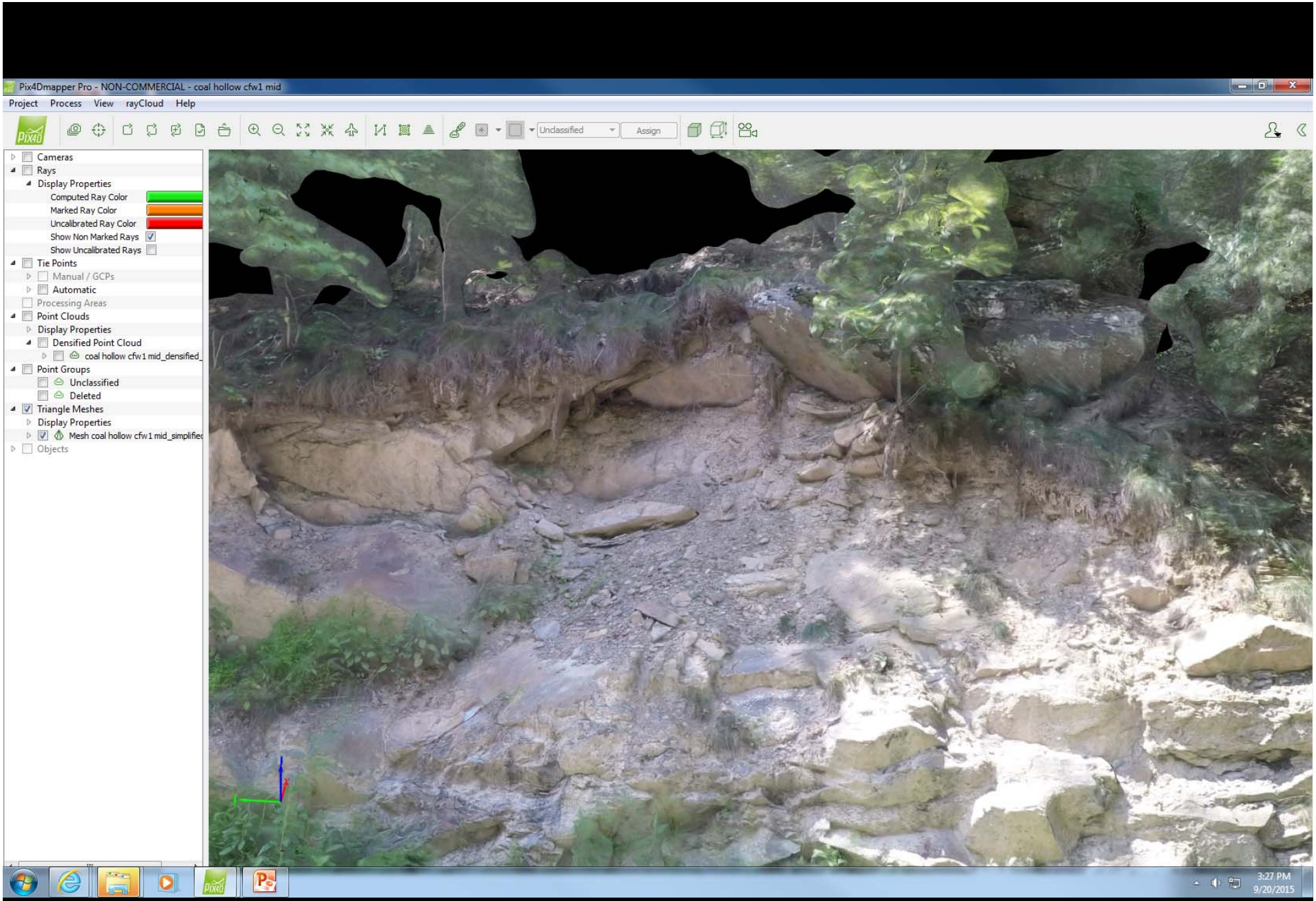
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:25 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project Process View rayCloud Help
Unclassified
Assign
Cameras
Rays
Display Properties
Computed Ray Color
Marked Ray Color
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Show Uncalibrated Rays
Tie Points
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Processing Areas
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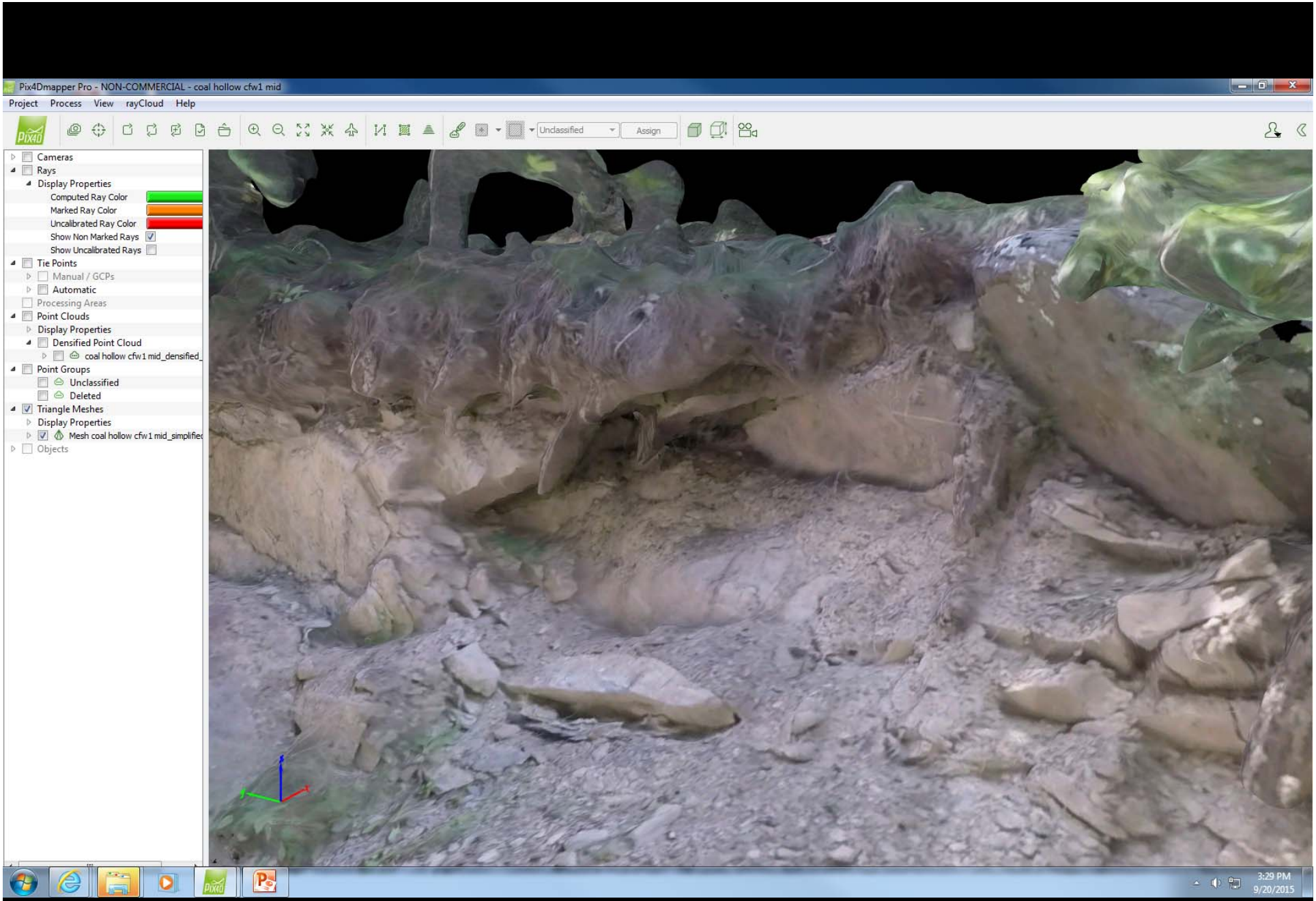
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
Unclassified
Deleted
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:27 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project Process View rayCloud Help
Unclassified
Assign
Cameras
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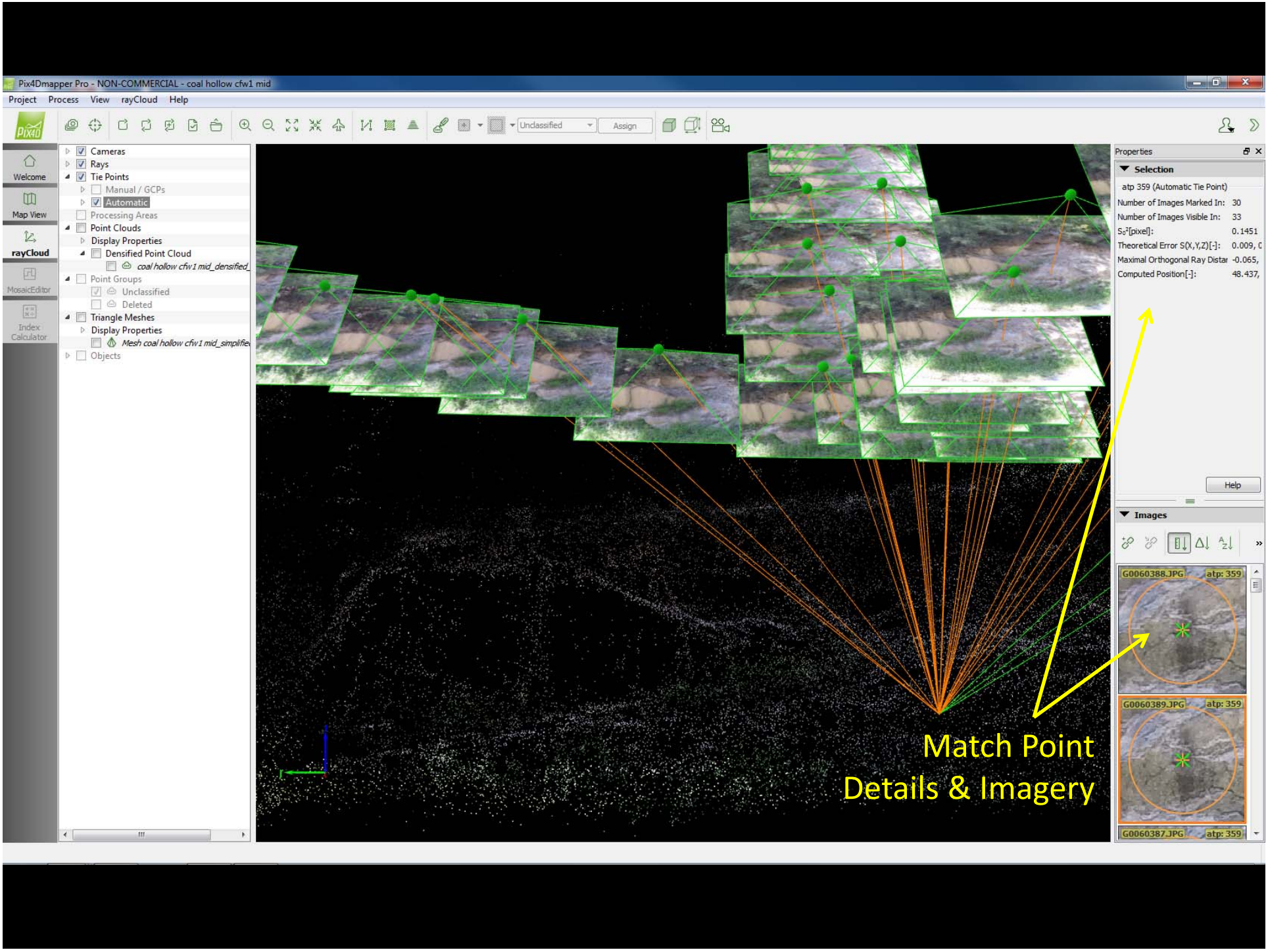
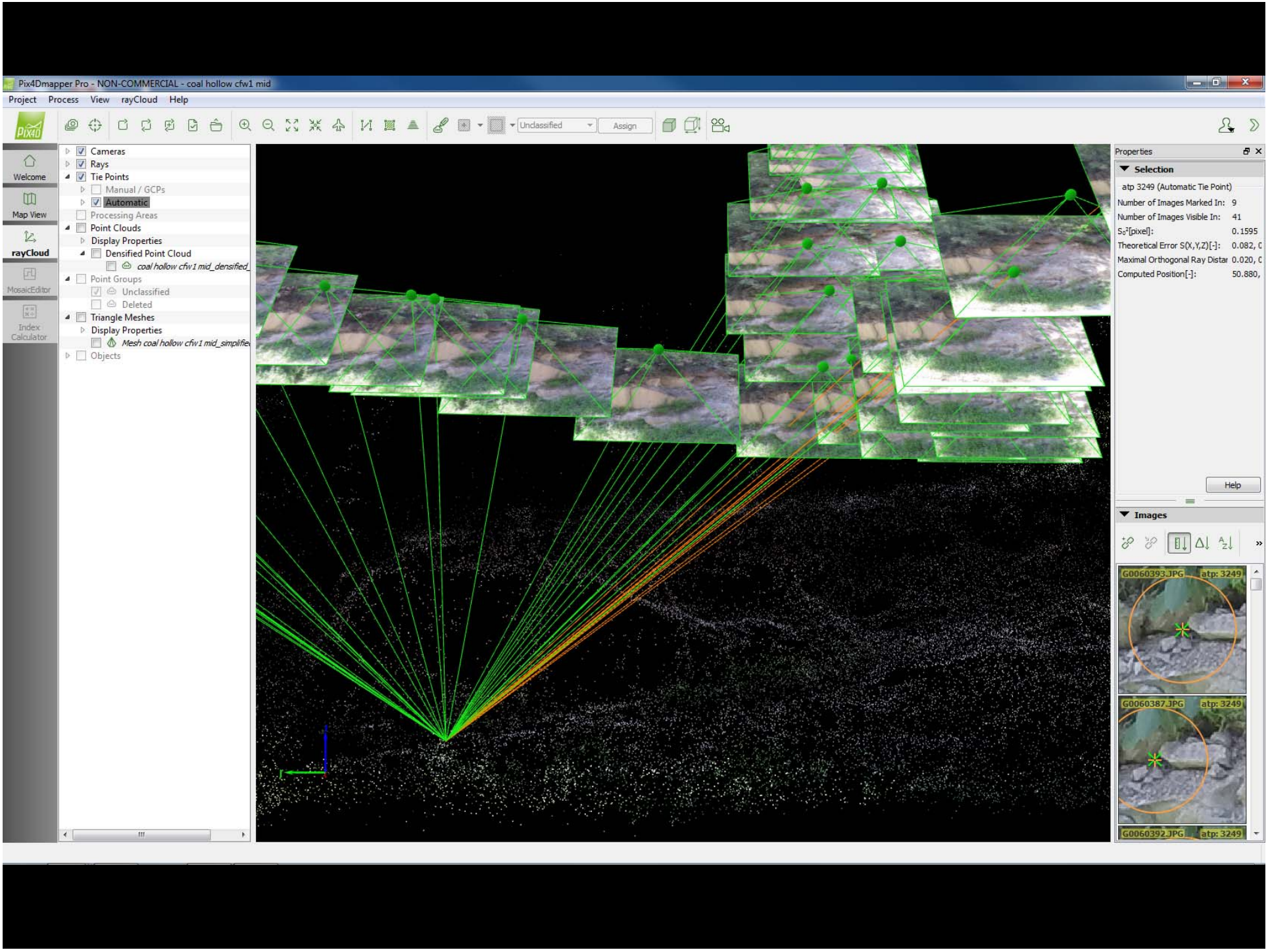
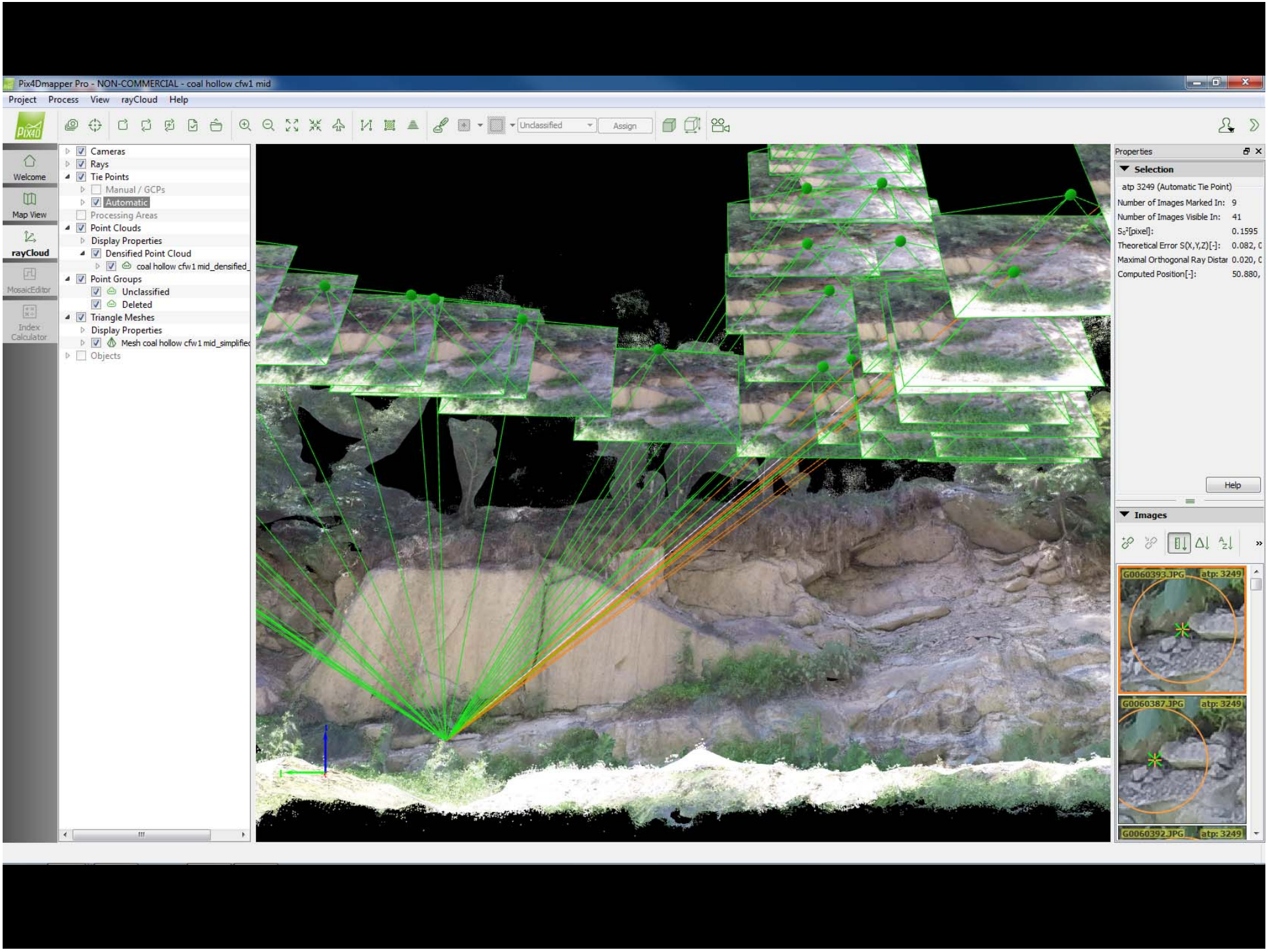
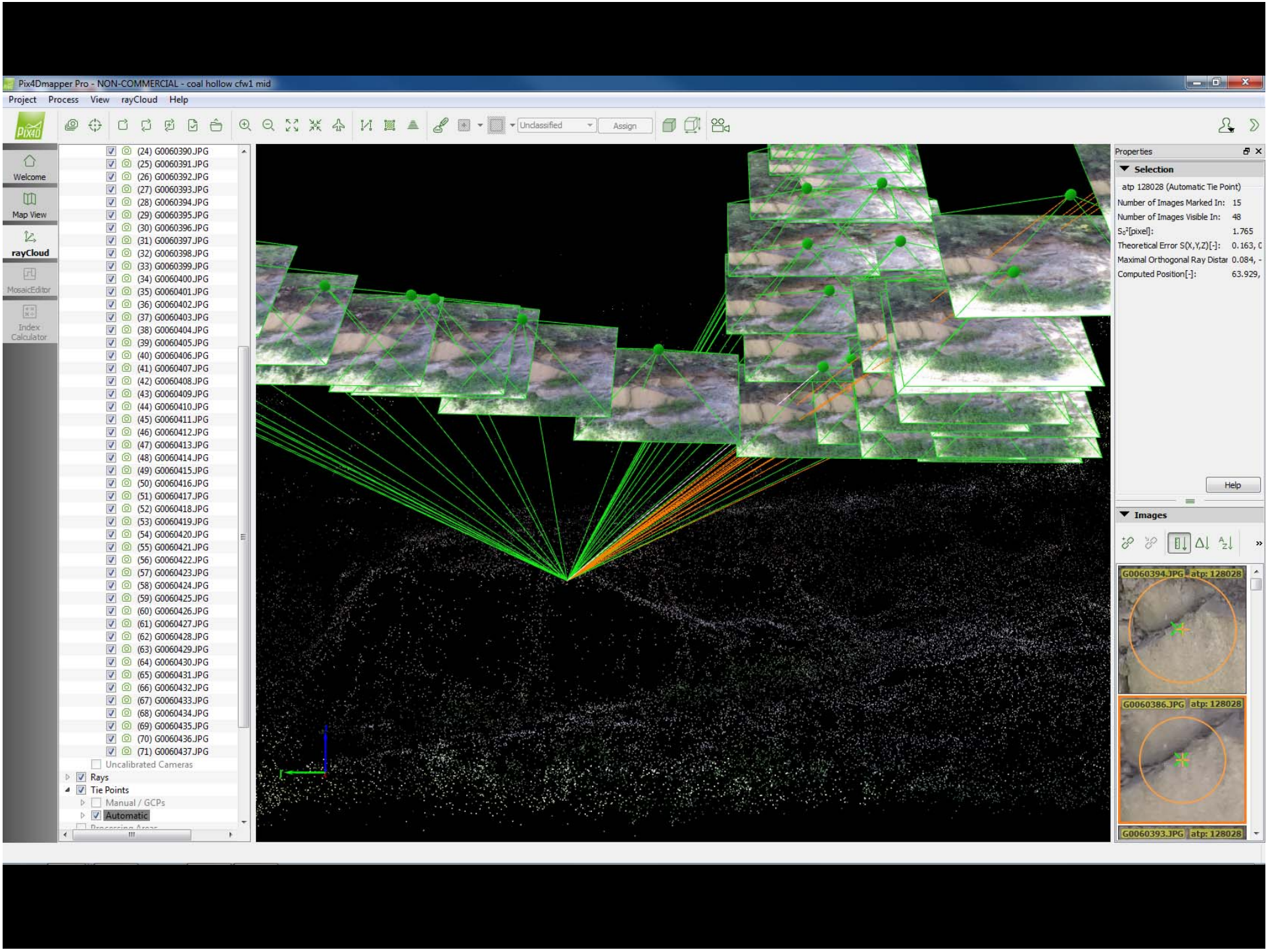
Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
Show Non Marked Rays
Show Uncalibrated Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
Unclassified
Deleted
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:29 PM
9/20/2015

Match Point Details & Imagery


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project
Process
View
rayCloud
Help
Unclassified
Assign
Welcome
Map View
rayCloud
MosaicEditor
Index Calculator
Cameras
Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
Unclassified
Deleted
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
Properties
Selection
atp 359 (Automatic Tie Point)
Number of Images Marked In: 30
Number of Images Visible In: 33
Theoretical Error S(X,Y,Z)[-]: 0.009, 0
Maximal Orthogonal Ray Distar -0.065,
Computed Position[-]: 48.437,
Help
Images
G0060388.JPG atp: 359
G0060389.JPG atp: 359
G0060387.JPG atp: 359
Match Point
Details & Imagery


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project
Process
View
rayCloud
Help
Unclassified
Assign
Welcome
Map View
rayCloud
MosaicEditor
Index Calculator
Cameras
Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
Unclassified
Deleted
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
Properties
Selection
atp 3249 (Automatic Tie Point)
Number of Images Marked In: 9
Number of Images Visible In: 41
Theoretical Error S(X,Y,Z)[-]: 0.082, 0
Maximal Orthogonal Ray Distar 0.020, 0
Computed Position[-]: 50.880,
Help
Images
G0060393.JPG atp: 3249
G0060387.JPG atp: 3249
G0060392.JPG atp: 3249


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project
Process
View
rayCloud
Help
Unclassified
Assign
Welcome
Map View
rayCloud
MosaicEditor
Index Calculator
Cameras
Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
Unclassified
Deleted
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
Properties
Selection
atp 3249 (Automatic Tie Point)
Number of Images Marked In: 9
Number of Images Visible In: 41
Theoretical Error S(X,Y,Z)[-]: 0.082, 0
Maximal Orthogonal Ray Distar 0.020, 0
Computed Position[-]: 50.880,
Help
Images
G0060393.JPG atp: 3249
G0060387.JPG atp: 3249
G0060392.JPG atp: 3249


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project
Process
View
rayCloud
Help
Unclassified
Assign
Welcome
Map View
rayCloud
MosaicEditor
Index Calculator
(24) G0060390.JPG
(25) G0060391.JPG
(26) G0060392.JPG
(27) G0060393.JPG
(28) G0060394.JPG
(29) G0060395.JPG
(30) G0060396.JPG
(31) G0060397.JPG
(32) G0060398.JPG
(33) G0060399.JPG
(34) G0060400.JPG
(35) G0060401.JPG
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(40) G0060406.JPG
(41) G0060407.JPG
(42) G0060408.JPG
(43) G0060409.JPG
(44) G0060410.JPG
(45) G0060411.JPG
(46) G0060412.JPG
(47) G0060413.JPG
(48) G0060414.JPG
(49) G0060415.JPG
(50) G0060416.JPG
(51) G0060417.JPG
(52) G0060418.JPG
(53) G0060419.JPG
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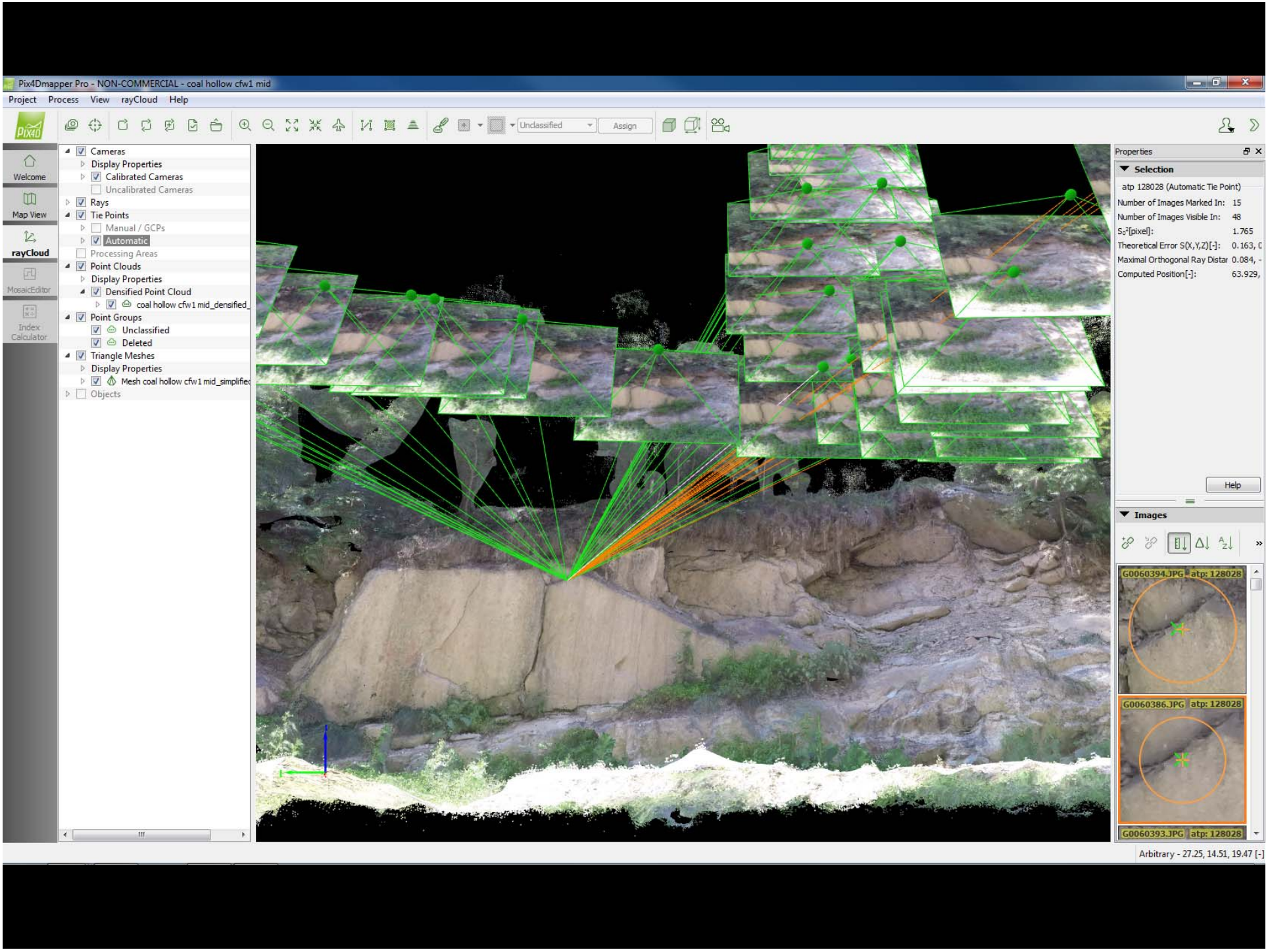
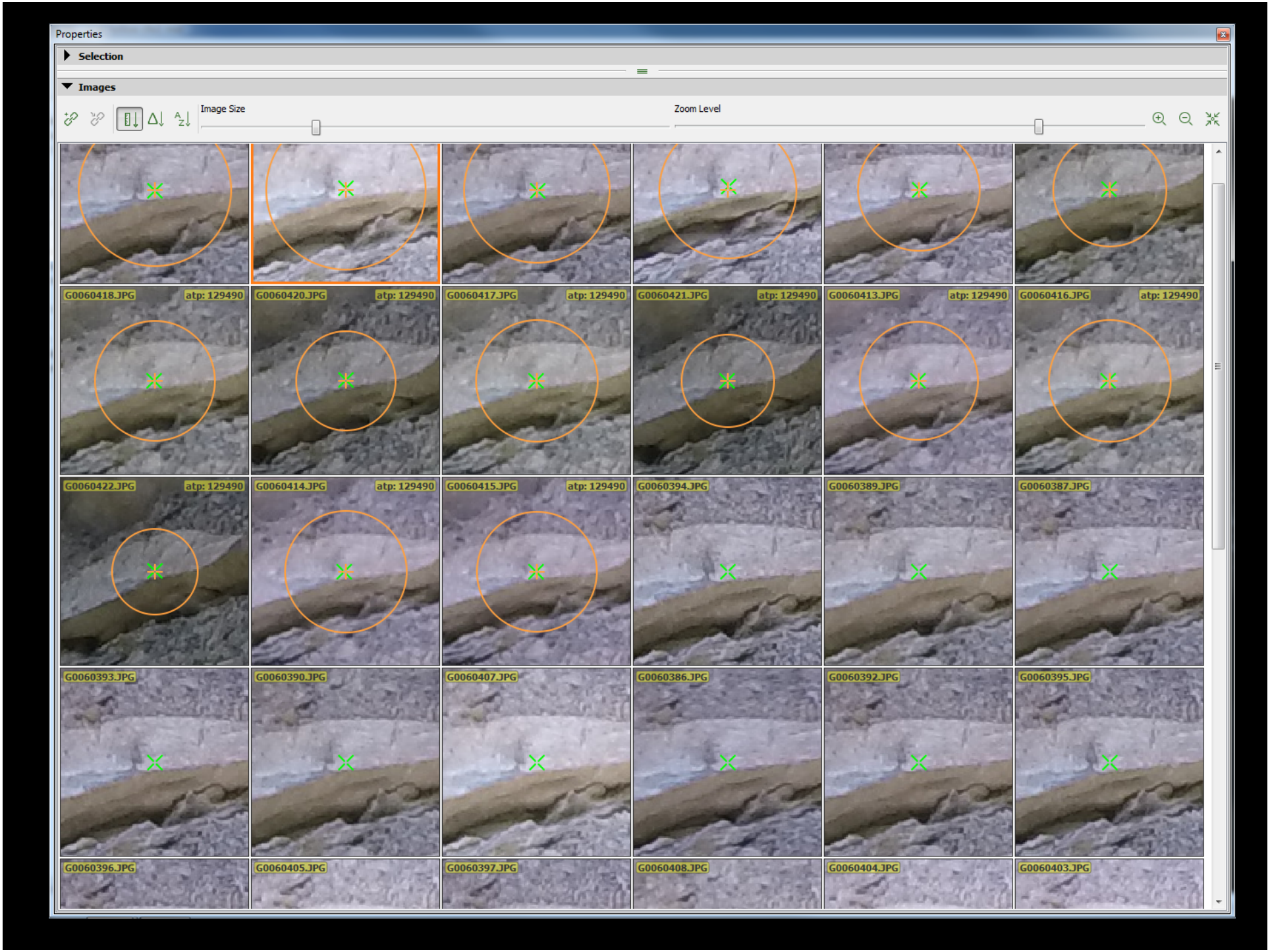
(55) G0060421.JPG
(56) G0060422.JPG
(57) G0060423.JPG
(58) G0060424.JPG
(59) G0060425.JPG
(60) G0060426.JPG
(61) G0060427.JPG
(62) G0060428.JPG
(63) G0060429.JPG
(64) G0060430.JPG
(65) G0060431.JPG
(66) G0060432.JPG
(67) G0060433.JPG
(68) G0060434.JPG
(69) G0060435.JPG
(70) G0060436.JPG
(71) G0060437.JPG
Uncalibrated Cameras
Rays
Tie Points
Manual / GCPs
Automatic
Properties
Selection
atp 128028 (Automatic Tie Point)
Number of Images Marked In: 15
Number of Images Visible In: 48
S_0^2[pixel]: 1.765
Theoretical Error S(X,Y,Z)[-]: 0.163, 0
Maximal Orthogonal Ray Distar 0.084, -
Computed Position[-]: 63.929,
Help
Images
G0060394.JPG atp: 128028
G0060386.JPG atp: 128028
G0060393.JPG atp: 128028


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project
Process
View
rayCloud
Help
Unclassified
Assign
Welcome
Map View
rayCloud
MosaicEditor
Index Calculator
Cameras
Display Properties
Calibrated Cameras
Uncalibrated Cameras
Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
coal hollow cfw1 mid_densified_
Point Groups
Unclassified
Deleted
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
Properties
Selection
atp 128028 (Automatic Tie Point)
Number of Images Marked In: 15
Number of Images Visible In: 48
Theoretical Error S(X,Y,Z)[-]: 0.163, 0
Maximal Orthogonal Ray Distar 0.084, -
Computed Position[-]: 63.929,
Help
Images
G0060394.JPG atp: 128028
G0060386.JPG atp: 128028
G0060393.JPG atp: 128028
Arbitrary - 27.25, 14.51, 19.47 [-]


Properties
Selection
Images
Image Size
Zoom Level
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G0060417.JPG atp: 129490
G0060421.JPG atp: 129490
G0060413.JPG atp: 129490
G0060416.JPG atp: 129490
G0060422.JPG atp: 129490
G0060414.JPG atp: 129490
G0060415.JPG atp: 129490
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G0060387.JPG
G0060393.JPG
G0060390.JPG
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G0060386.JPG
G0060392.JPG
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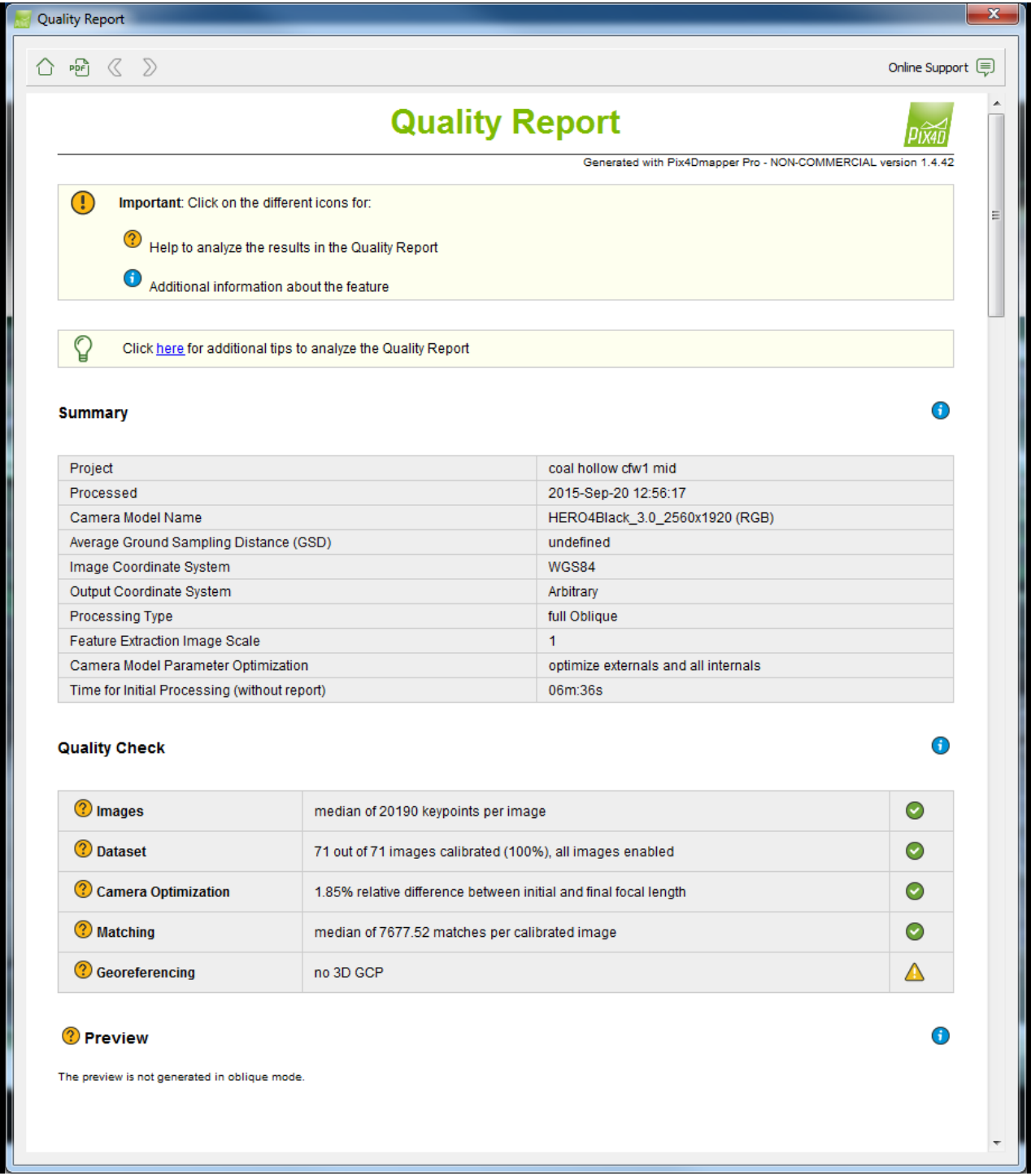
G0060397.JPG
G0060408.JPG
G0060404.JPG
G0060403.JPG


Quality Report
Online Support
Quality Report
Generated with Pix4Dmapper Pro - NON-COMMERCIAL version 1.4.42
Important: Click on the different icons for:
Help to analyze the results in the Quality Report
Additional information about the feature
Click here for additional tips to analyze the Quality Report
Summary
Project coal hollow cfw1 mid
Processed 2015-Sep-20 12:56:17
Camera Model Name HERO4Black_3.0_2560x1920 (RGB)
Average Ground Sampling Distance (GSD) undefined
Image Coordinate System WGS84
Output Coordinate System Arbitrary
Processing Type full Oblique
Feature Extraction Image Scale 1
Camera Model Parameter Optimization optimize externals and all internals
Time for Initial Processing (without report) 06m:36s
Quality Check
Images median of 20190 keypoints per image
Dataset 71 out of 71 images calibrated (100%), all images enabled
Camera Optimization 1.85% relative difference between initial and final focal length
Matching median of 7677.52 matches per calibrated image
Georeferencing no 3D GCP
Preview
The preview is not generated in oblique mode.

Quality Report

Online Support

Calibration Details

Number of Calibrated Images	71 out of 71
Number of Geolocated Images	0 out of 71

Initial Image Positions

The preview is not generated for images without geolocation.

Computed Image/GCPs/Manual Tie Points Positions

The preview is not generated for images without geolocation. The preview is not generated in oblique mode.

Bundle Block Adjustment Details

Number of 2D Keypoint Observations for Bundle Block Adjustment	560695
Number of 3D Points for Bundle Block Adjustment	149529
Mean Reprojection Error [pixels]	0.2016

Internal Camera Parameters

HERO4Black_3.0_2560x1920 (RGB). Sensor Dimensions: 3.968 [mm] x 2.976 [mm]

EXIF ID: HERO4Black_3.0_2560x1920

	Poly[0]	Poly[1]	Poly[2]	Poly[3]	c	f	d	e	Principal Point x	Principal Point y
Initial Values	0.000145	1.0	-0.007731	0.150831	2342.40	2342.40	0	0	1280.00	960.00
Optimized Values	-0.000121	1.0	-0.020732	0.167218	2385.95	2385.95	0	0	1176.67	967.34

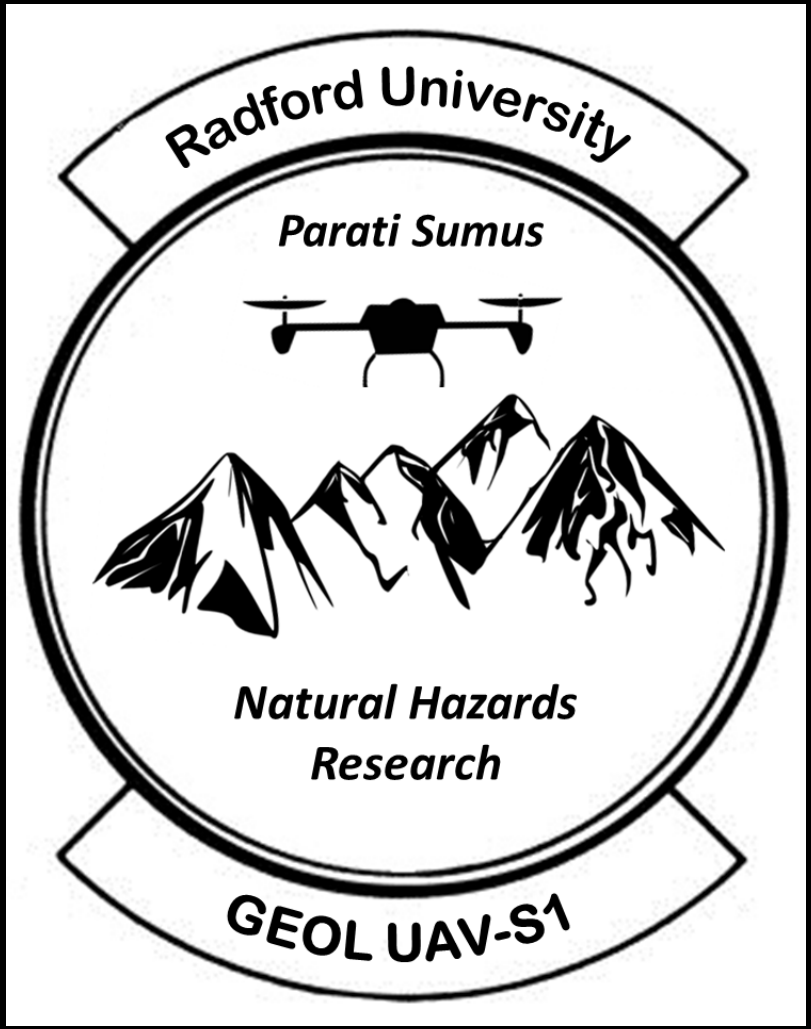
2D Keypoints Table

	Number of 2D Keypoints per Image	Number of Matched 2D Keypoints per Image
Median	20190	7678
Min	18114	3800
Max	24249	12120
Mean	20315	7897

We are looking for collaborators !!

To work alongside our Center for UAV GeoHazards Research

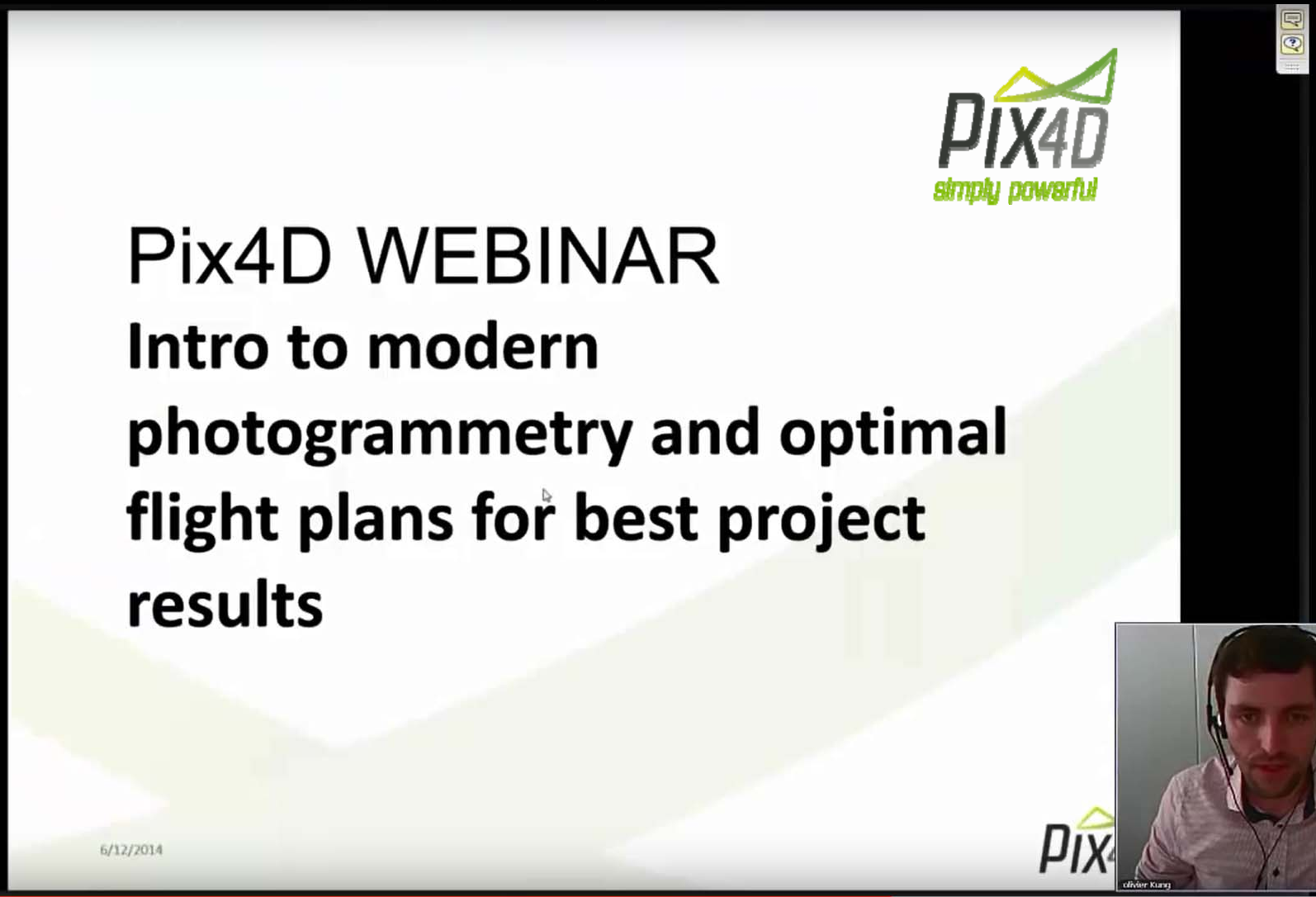
- Confidence Testing
- Technology Transfer & Training
- Research Test Sites & Funding
- Responsible coordinated emergency response protocols



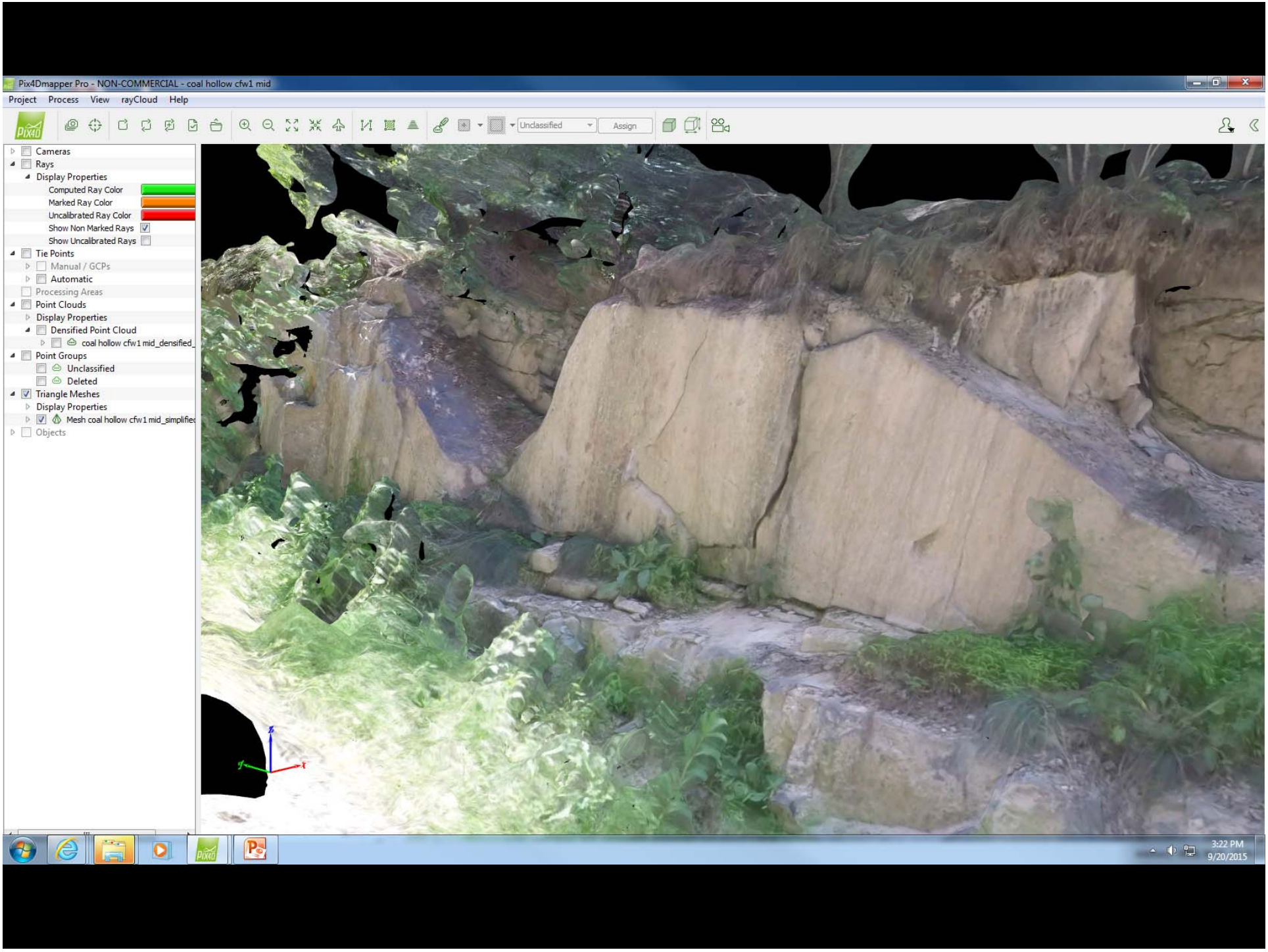
cwatts@radford.edu
(Skip Watts)

E N D

Pix4D Webinar 1: Introduction to Modern Photogrammetry and Optimal Flight Plans



48:11 / 1:16:02


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project Process View rayCloud Help
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Cameras
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Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
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Show Uncalibrated Rays
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coal hollow cfw1 mid_densified_
Point Groups
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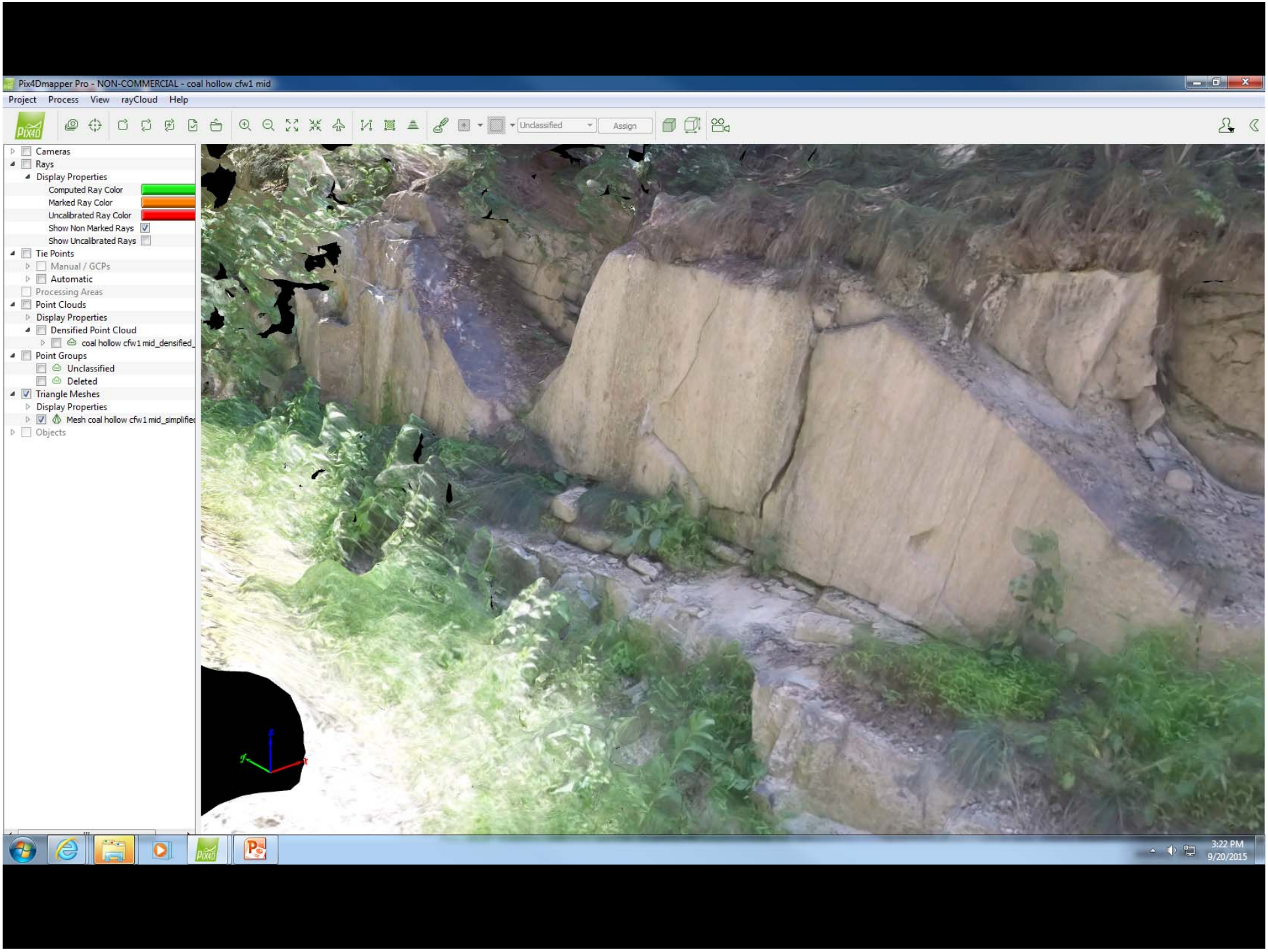
Triangle Meshes
Display Properties
Mesh coal hollow cfw1 mid_simplifie
Objects
3:22 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project Process View rayCloud Help
Unclassified
Assign
Cameras
Rays
Display Properties
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Display Properties
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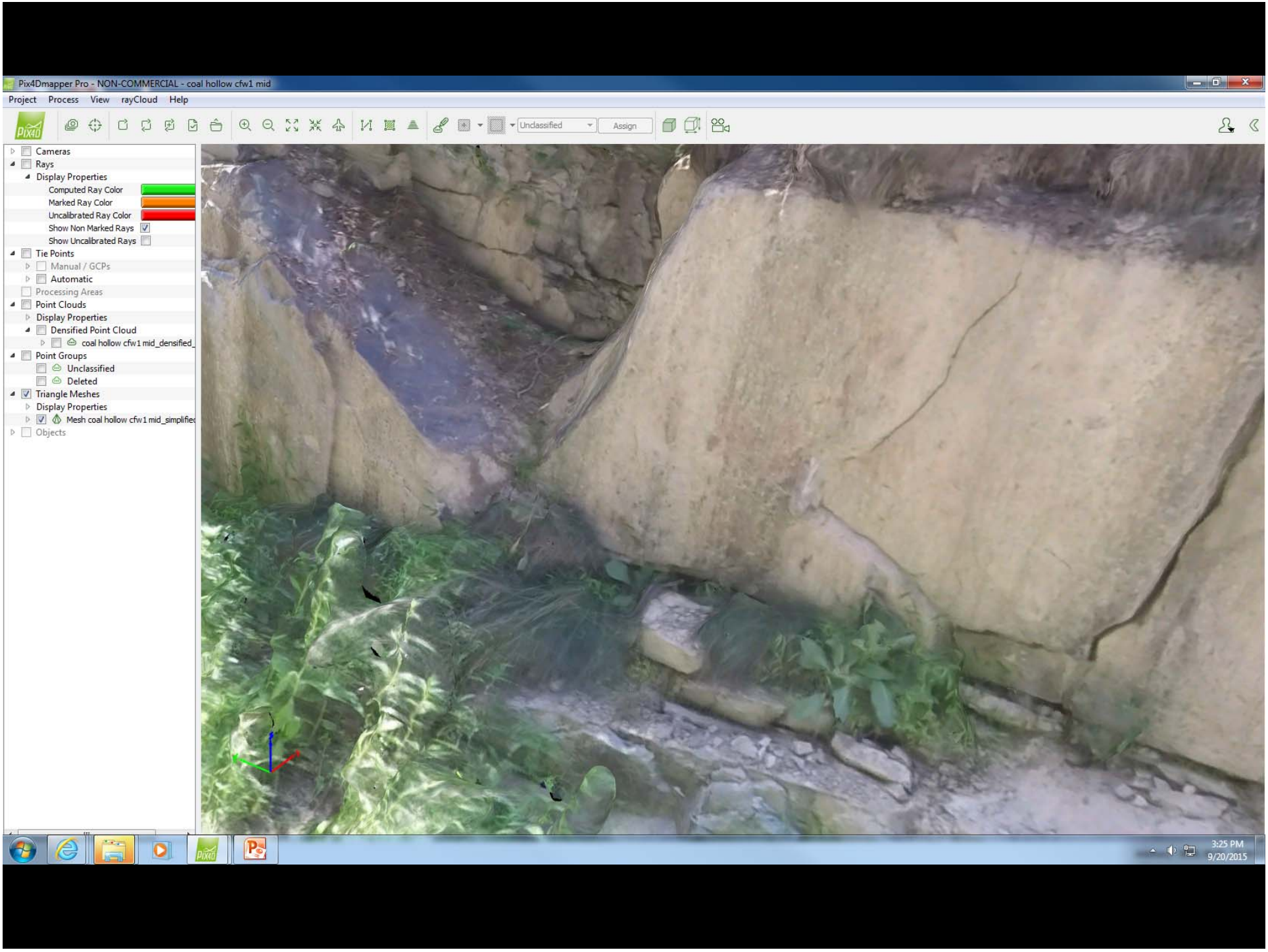
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
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Triangle Meshes
Display Properties
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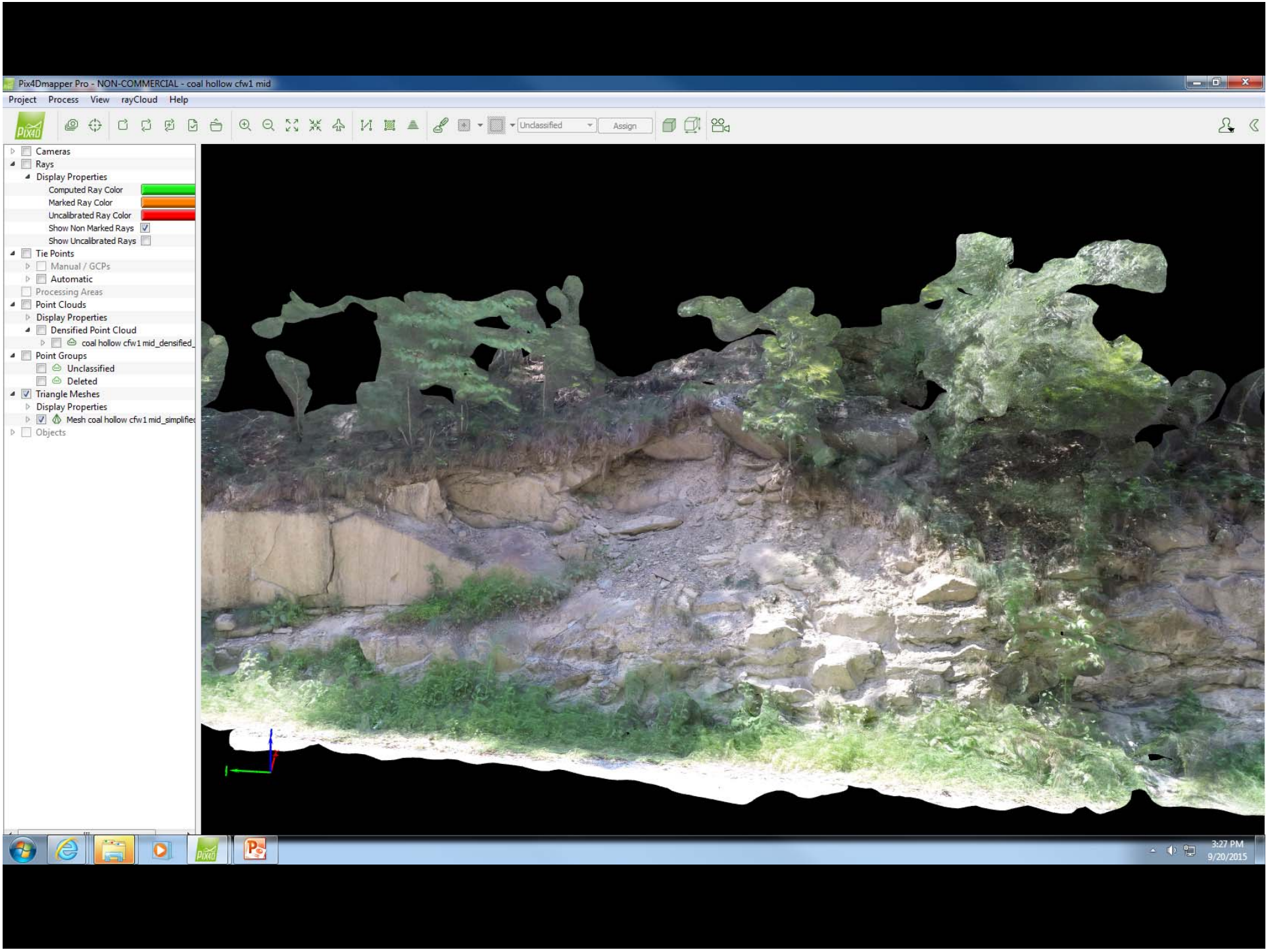
Objects
3:25 PM
9/20/2015


Pix4Dmapper Pro - NON-COMMERCIAL - coal hollow cfw1 mid
Project Process View rayCloud Help
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Display Properties
Computed Ray Color
Marked Ray Color
Uncalibrated Ray Color
Show Non Marked Rays
Show Uncalibrated Rays
Tie Points
Manual / GCPs
Automatic
Processing Areas
Point Clouds
Display Properties
Densified Point Cloud
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Triangle Meshes
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Objects
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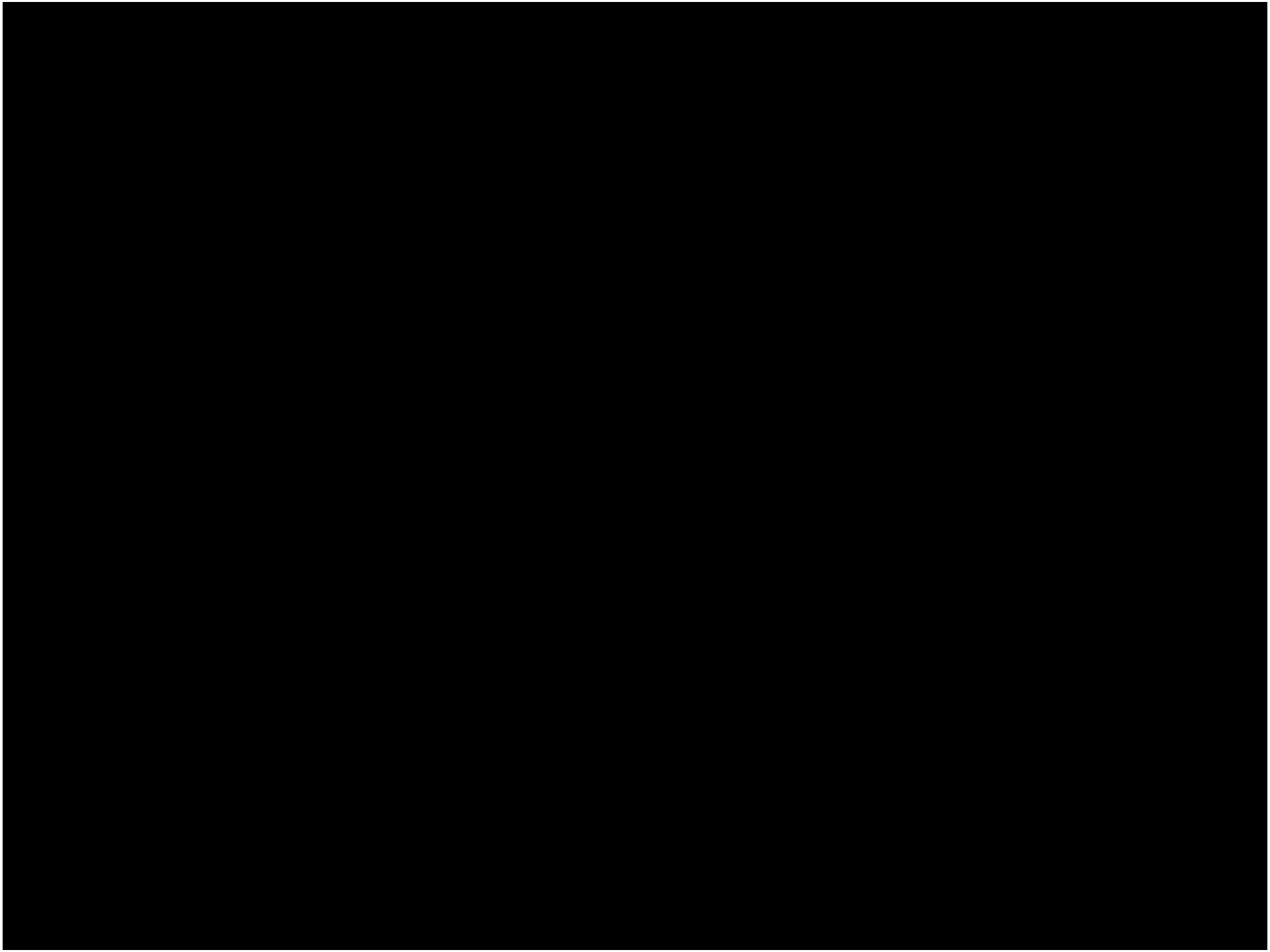
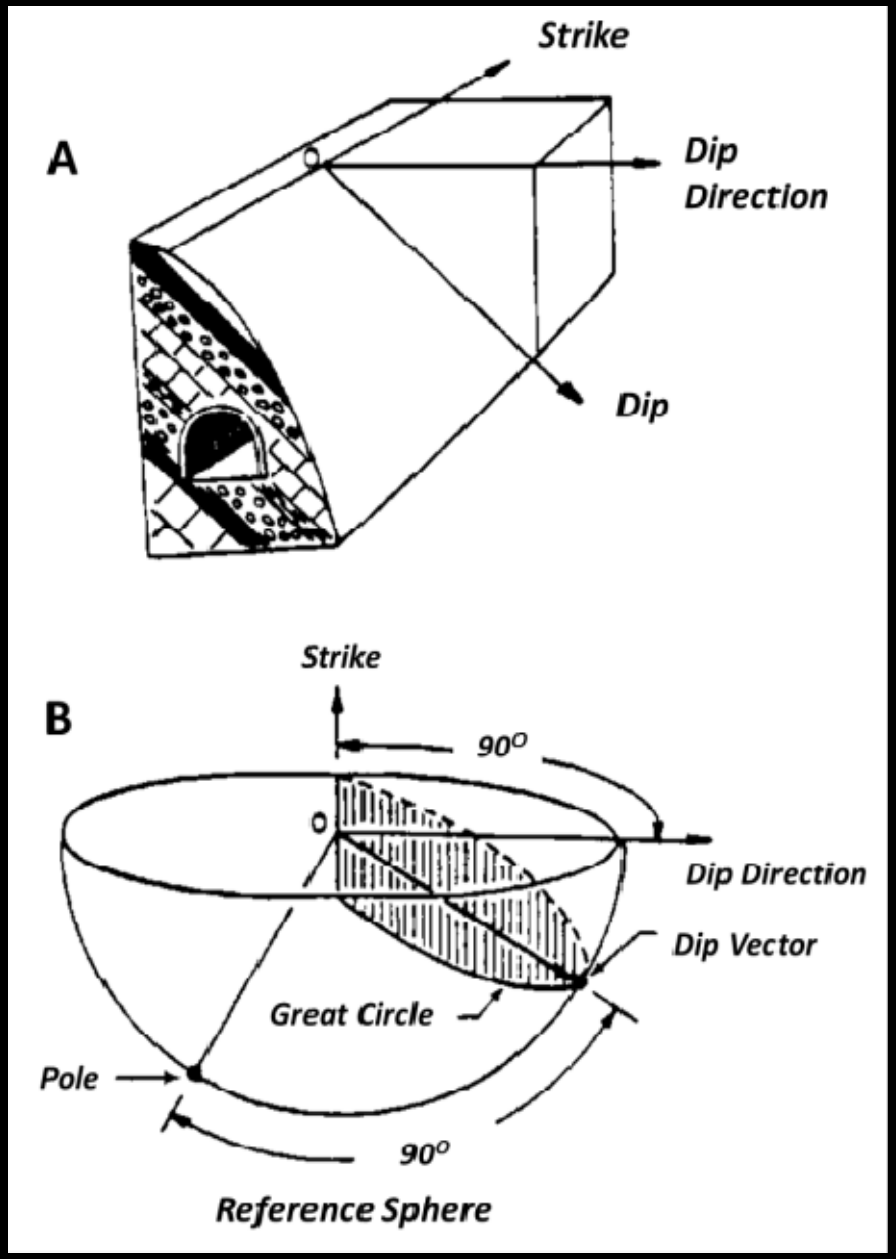
9/20/2015



Remote Data Acquisition Systems

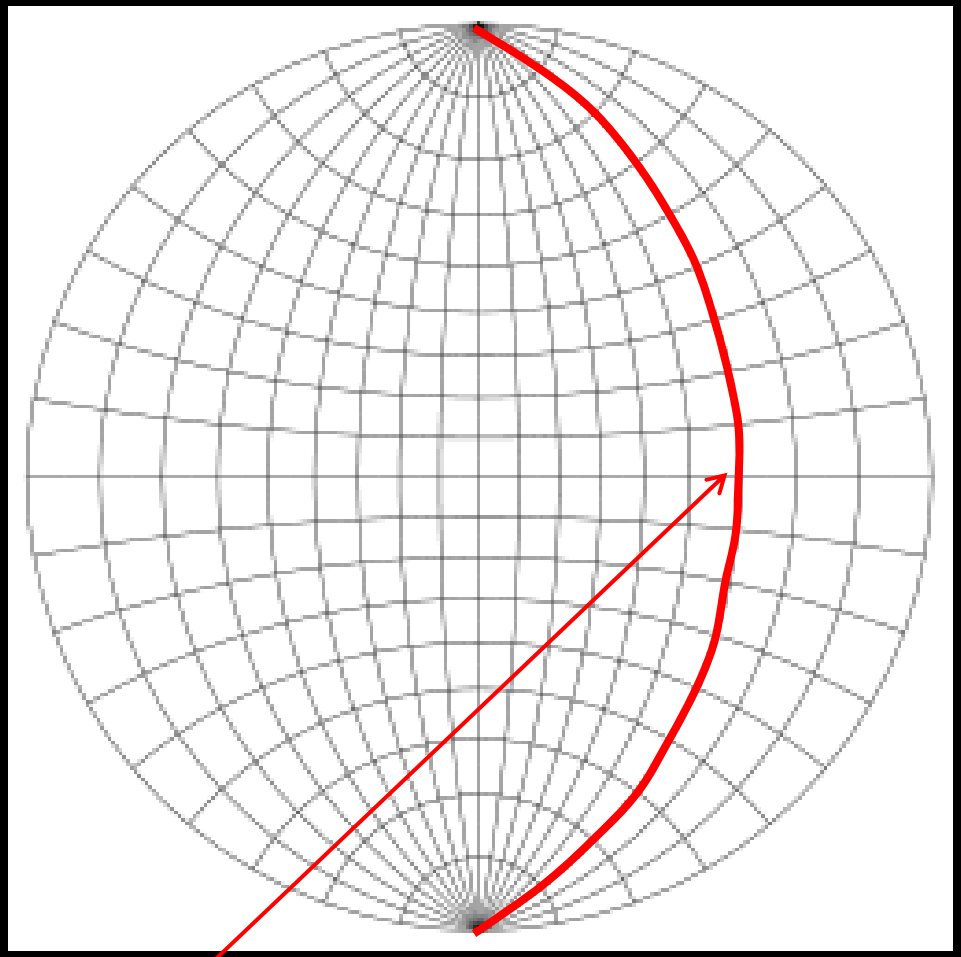
- LiDAR scanning
  - Optec
  - Leica Geosystems
  - Split-FX software
- 3D photogrammetry
  - Sirovision
  - Adam Technology
  - 3G Joint Metrix

Orientations of planes in space

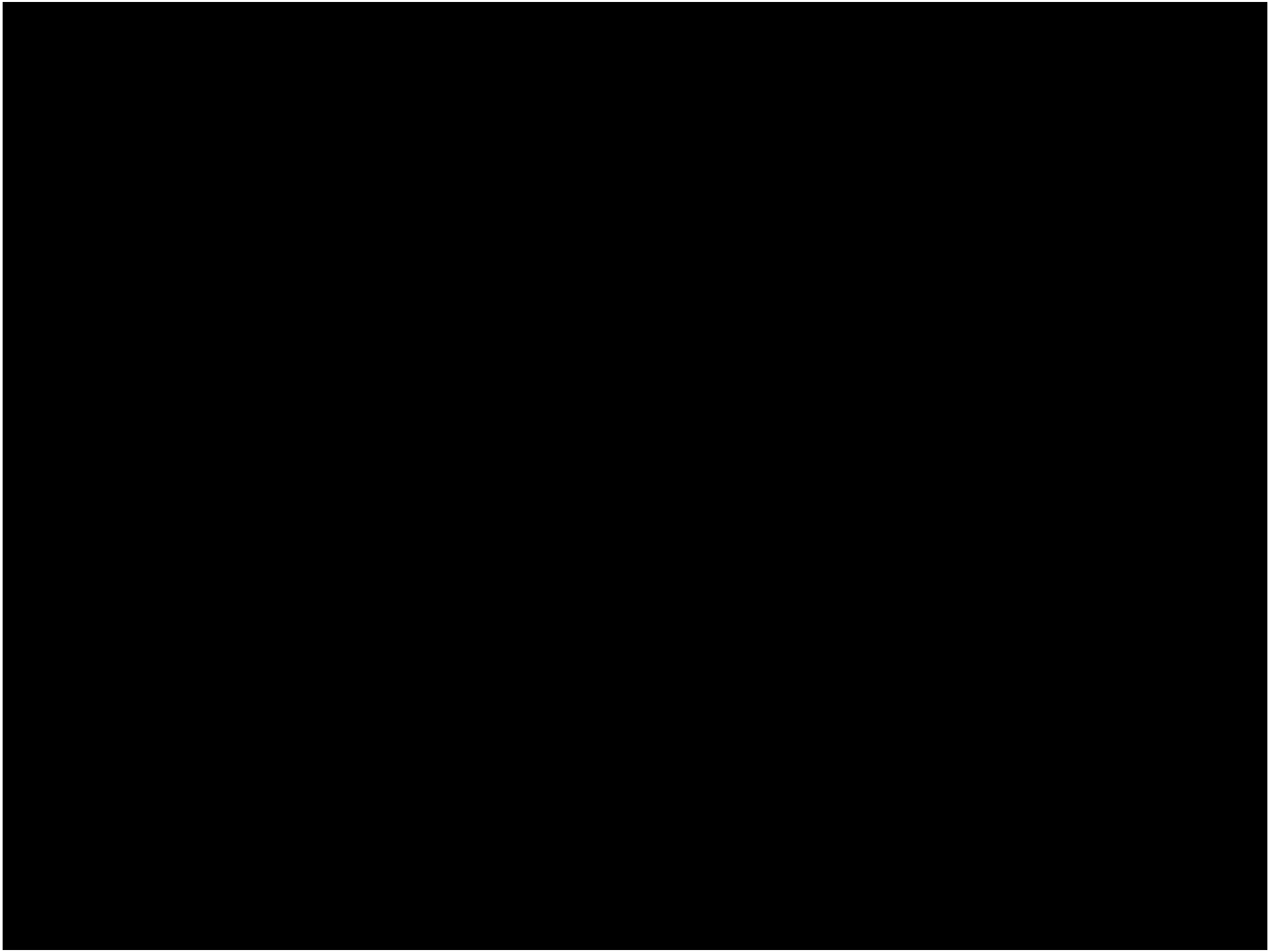


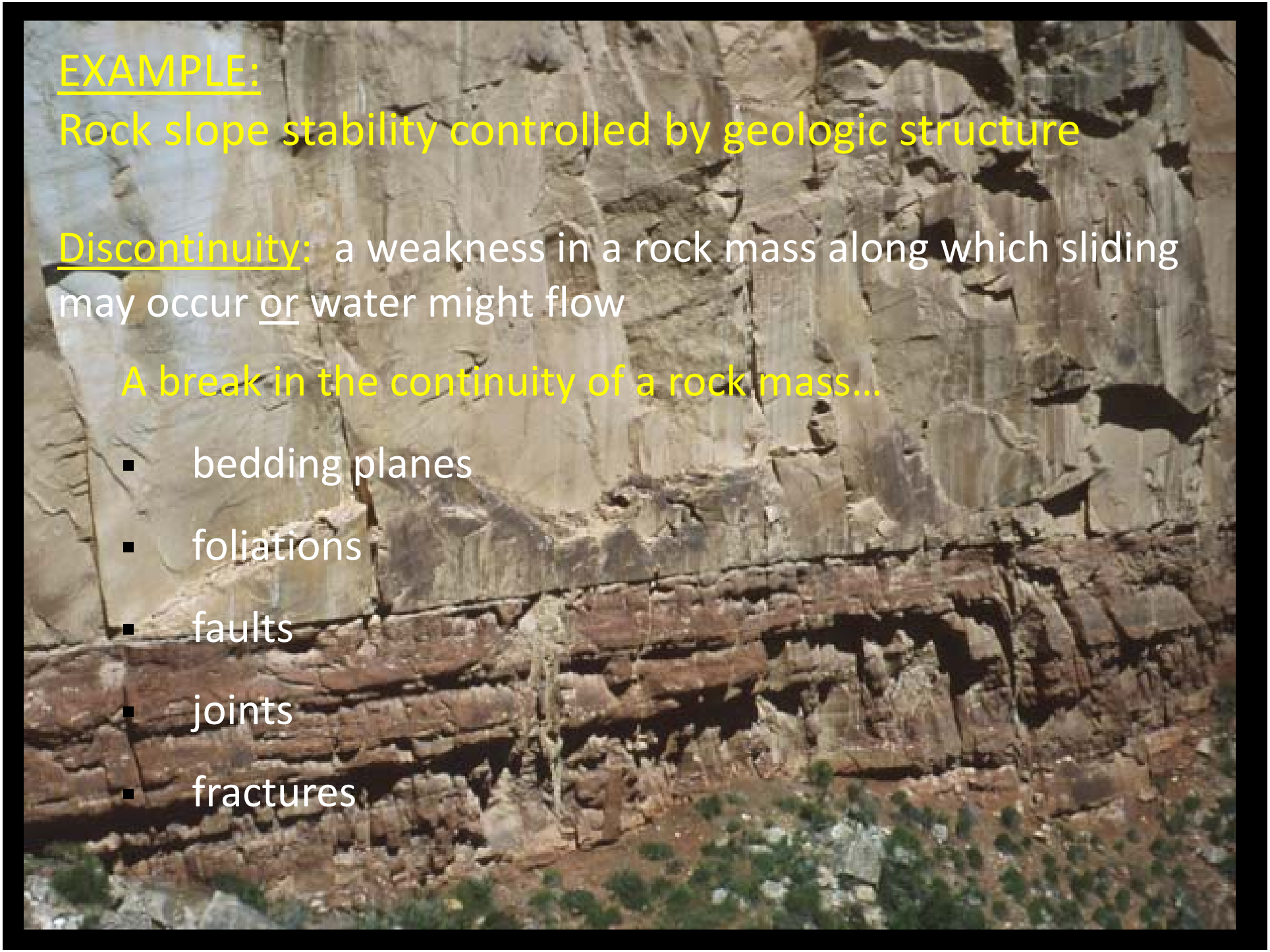
STEREONET ANALYSES

Equatorial projection



Great Circle for a plane dipping east at 30 degrees





EXAMPLE:

Rock slope stability controlled by geologic structure

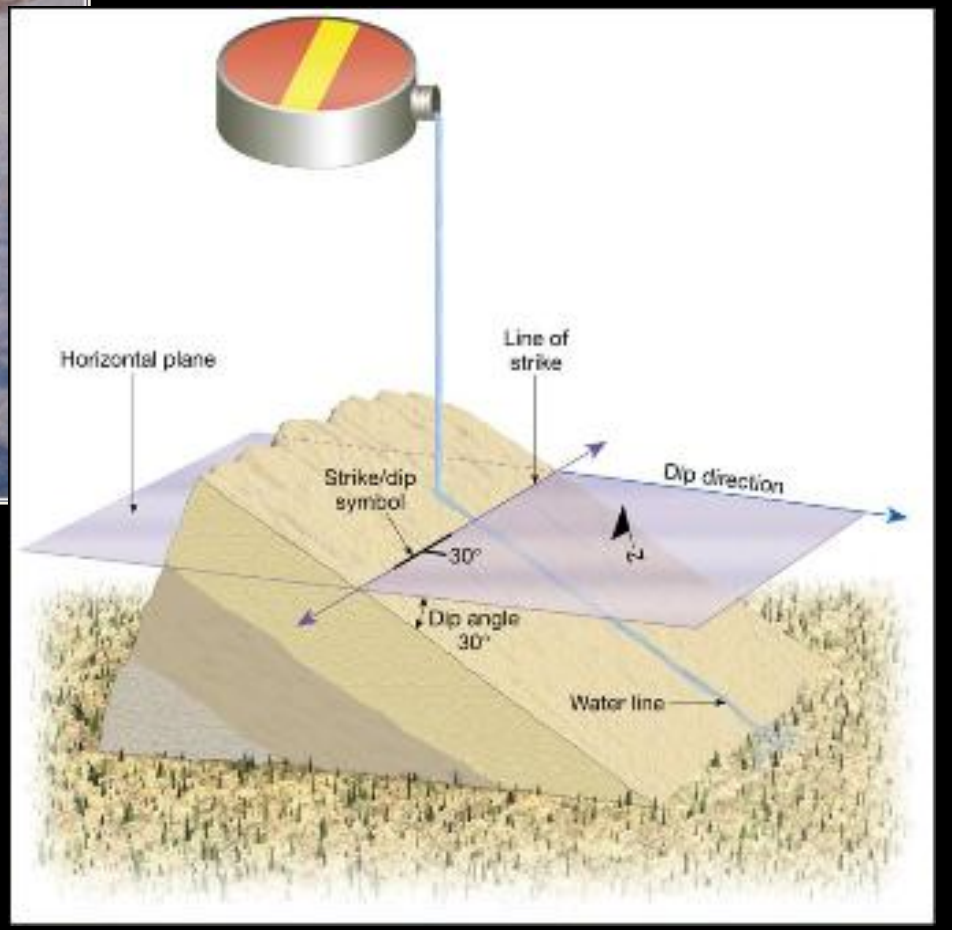
Discontinuity: a weakness in a rock mass along which sliding may occur or water might flow

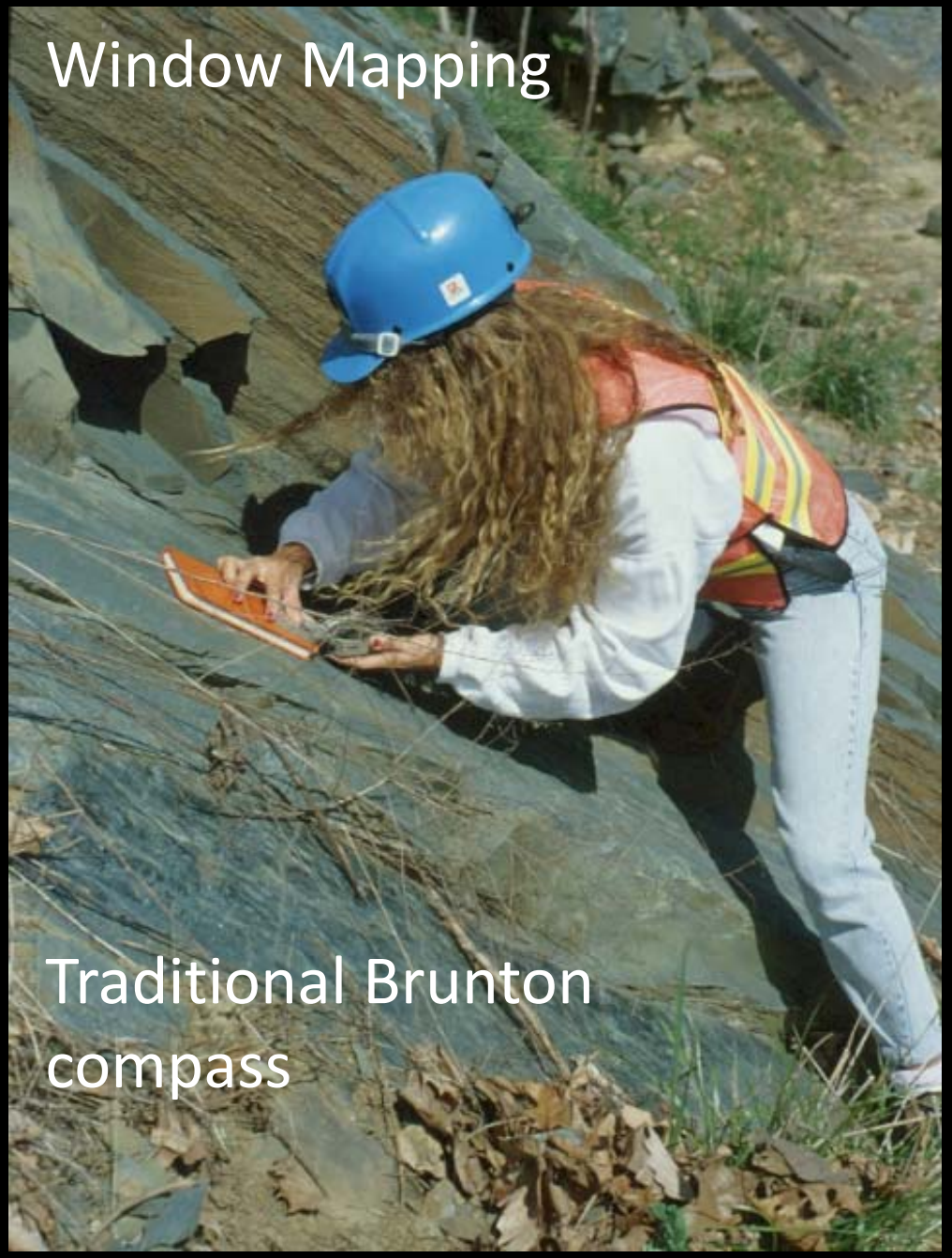
A break in the continuity of a rock mass…

- bedding planes
- foliations
- faults
- joints
- fractures

Rock slope stability controlled by geologic structure

Orientation: strike, dip, dip direction…




Window Mapping
Traditional Brunton compass

Enhanced Brunton compass

TruPulse 360b Laser

Now there's even…

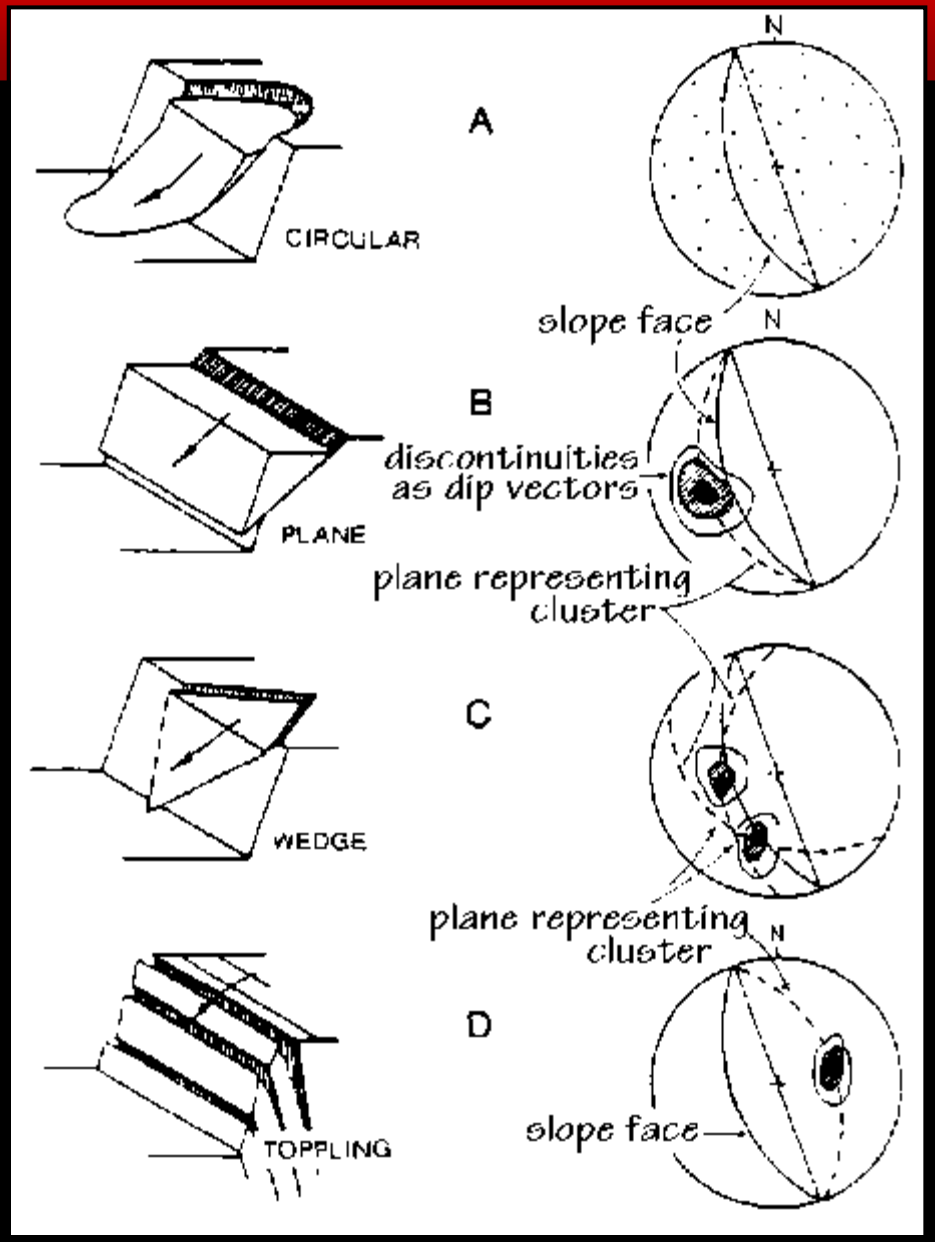
"an app for that…"

Types of rock slope failures

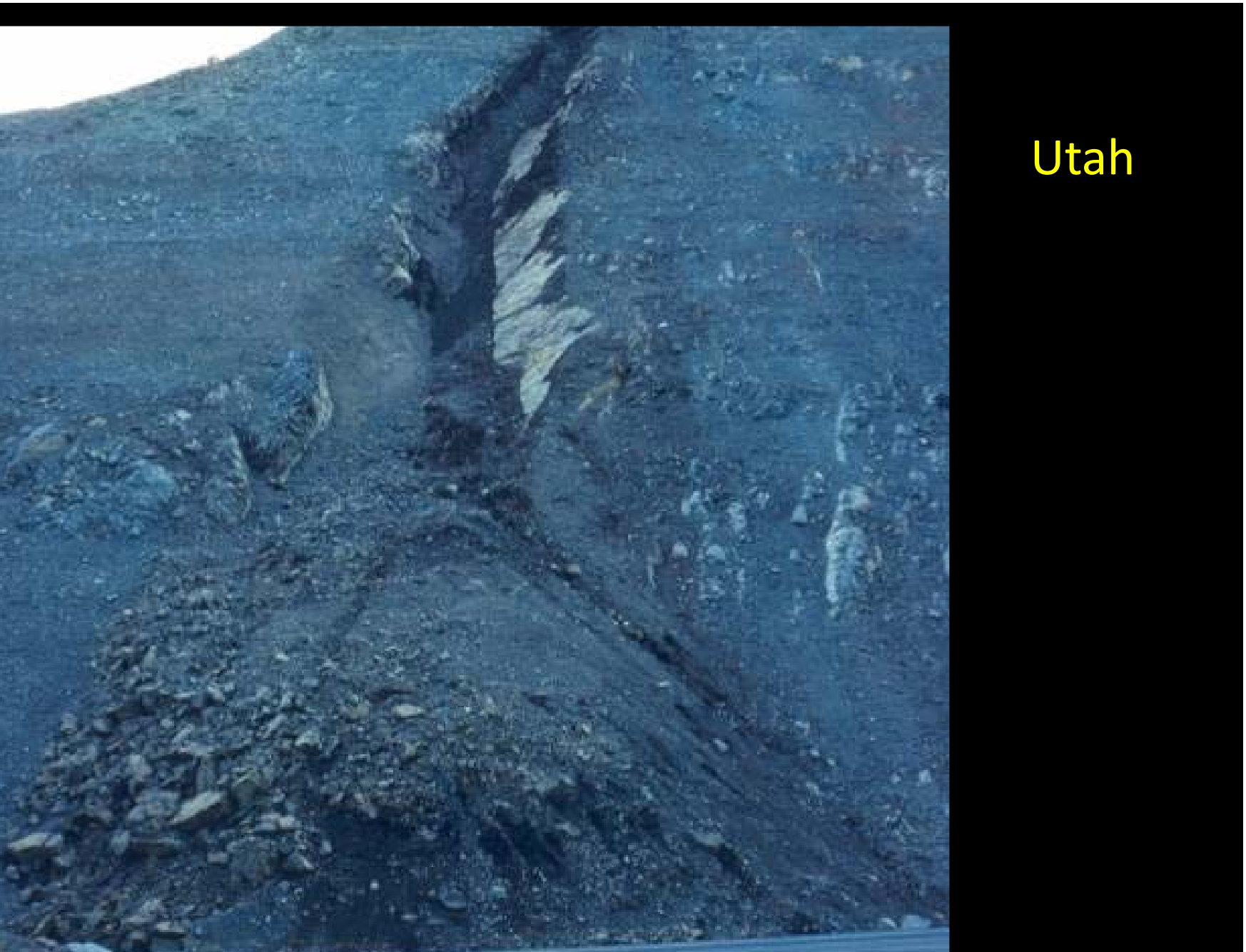
Failure Types

- Circular
- Planar
- Wedge
- Toppling

Different types of slope failures plot differently on dip-vector stereonets.




I-77 southwest Virginia



Utah

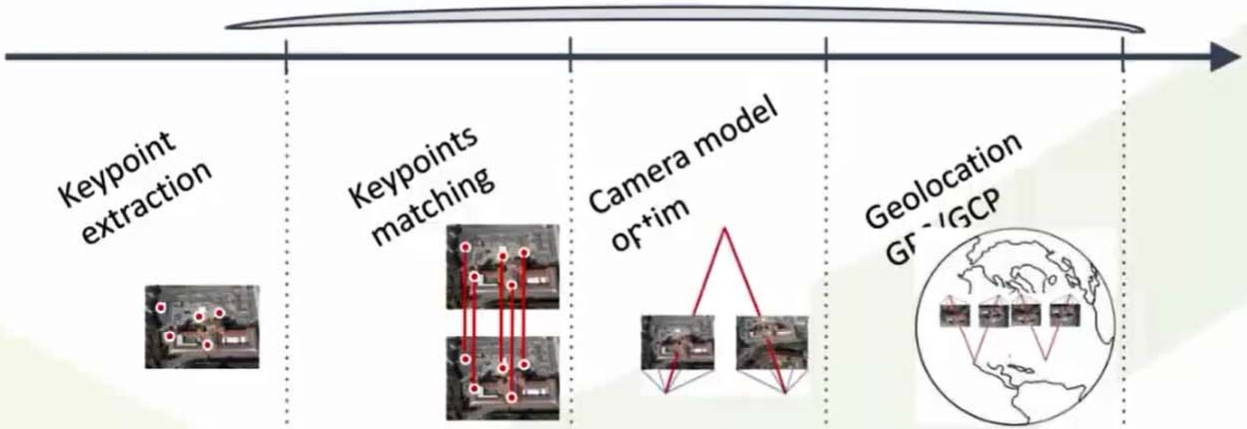
r 1: Introduction to Modern Photogrammetry and Optimal Flight Plans

Camera calibration + Exterior Orientation

PIX4D

Step 1: initial processing

Images => calibration + exterior orientation

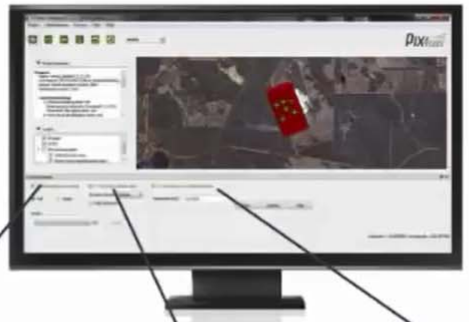


xample 14MP, 00 nages)	60'000 keypoints per image	Average of 6'000 matches per pair of images	600'000 matches => 150'000 3D Points for 100 images	Average of GPS OR Min 3 GCP

9:09 / 1:16:02

r 1: Introduction to Modern Photogrammetry and Optimal Flight Plans

3 main processing steps



Step 1: initial processing

Images
=> calibrate cameras + exterior orientation

Step 2: point densification

Calibrated cameras => point clouds

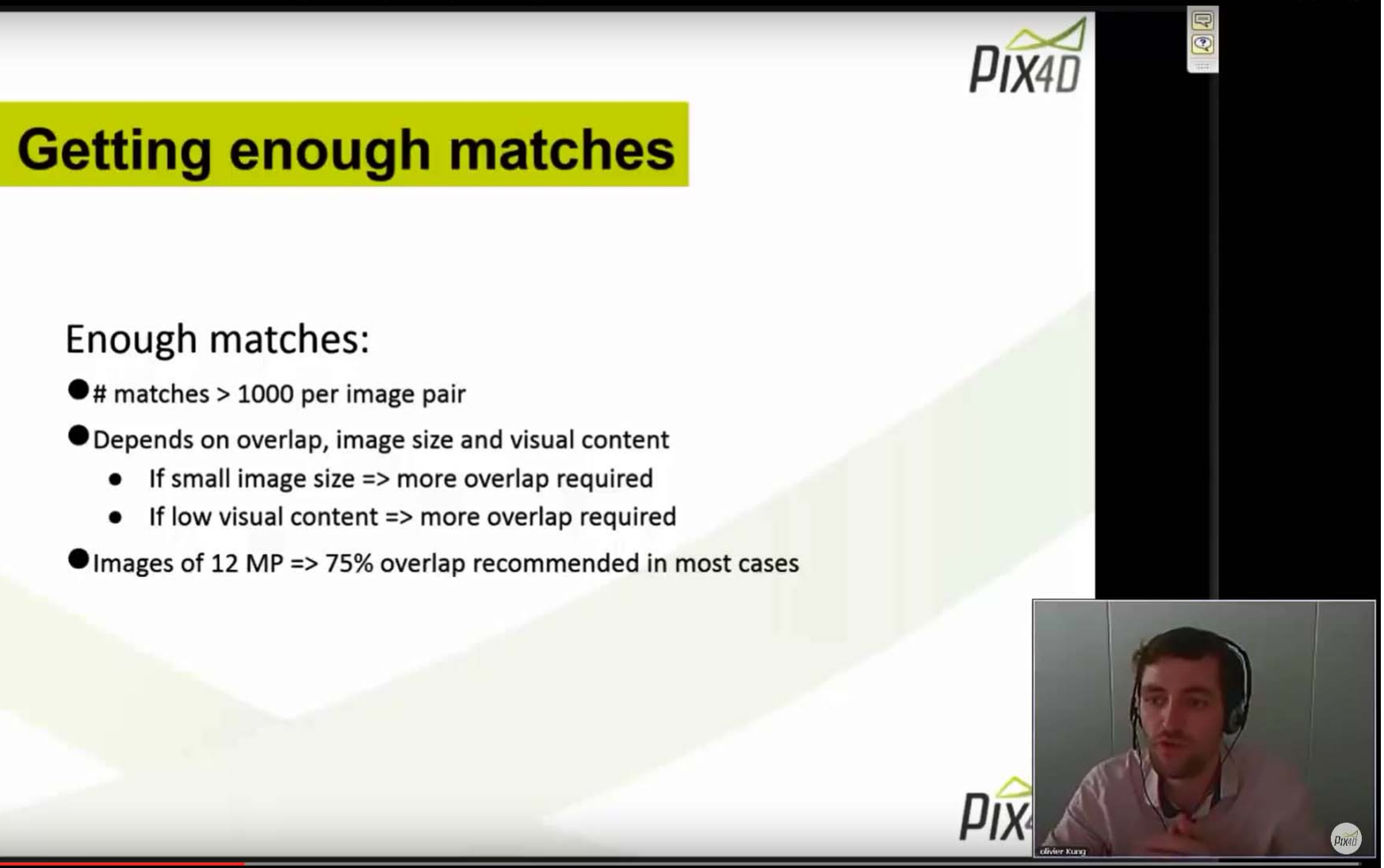
Step 3: DSM and orthomosaic

Point clouds
=> DSM and orthomosaic

Keypoint extraction
Keypoints matching
Camera model optim.
Geolocation GPS/GCP
Point densification
Point filtering
DSM generation
Orthomosaic images
Orthomosaic blending

8:31 / 1:16:02

r 1: Introduction to Modern Photogrammetry and Optimal Flight Plans



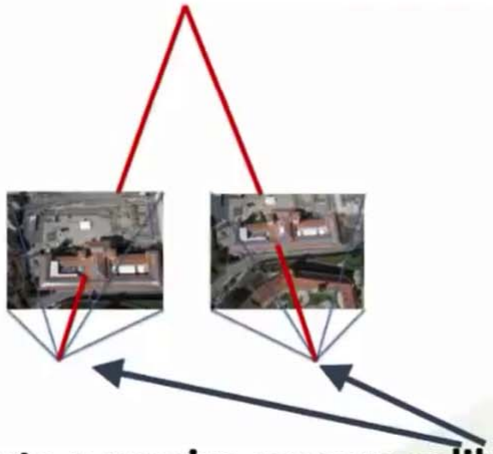
18:47 / 1:16:02

ing an optimal flight plan is all about getting enough matches. Small image requires

r 1: Introduction to Modern Photogrammetry and Optimal Flight Plans

PIX4D

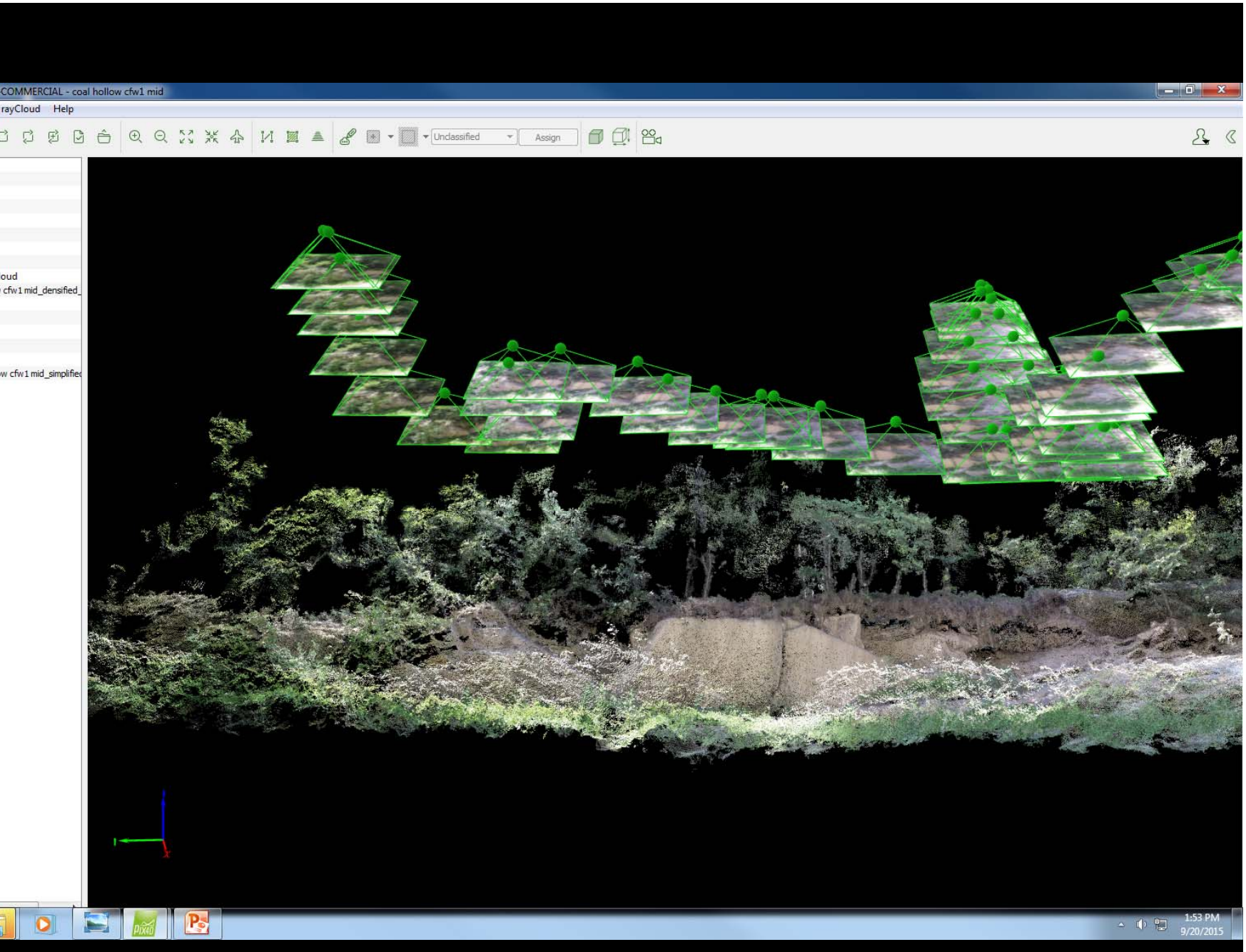
Relative exterior orientation



Pix4D is able to compute a precise camera calibration and relative model from image content only!

7:27 / 1:16:02

Typical Flight Paths for the
Coal Hollow Test Site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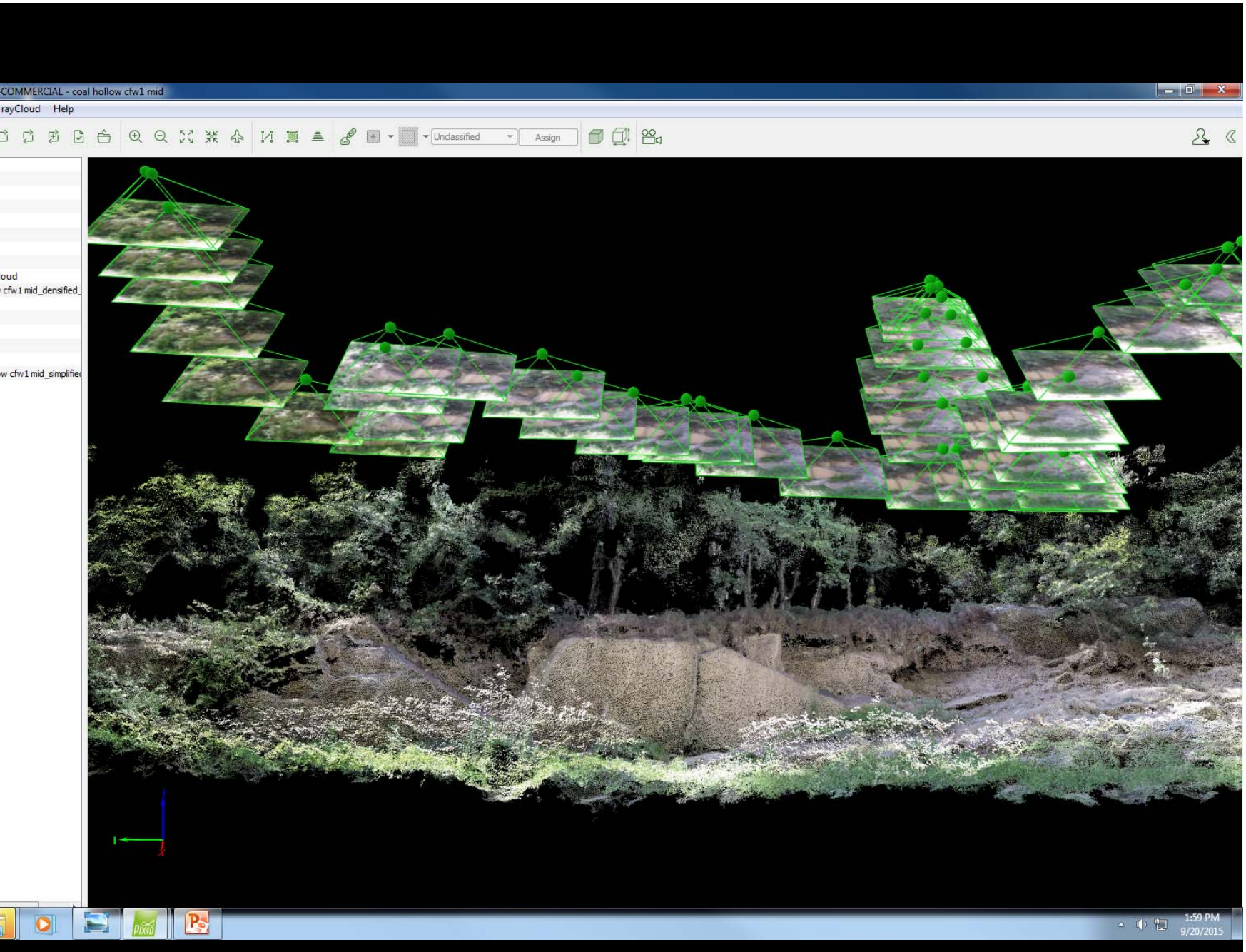
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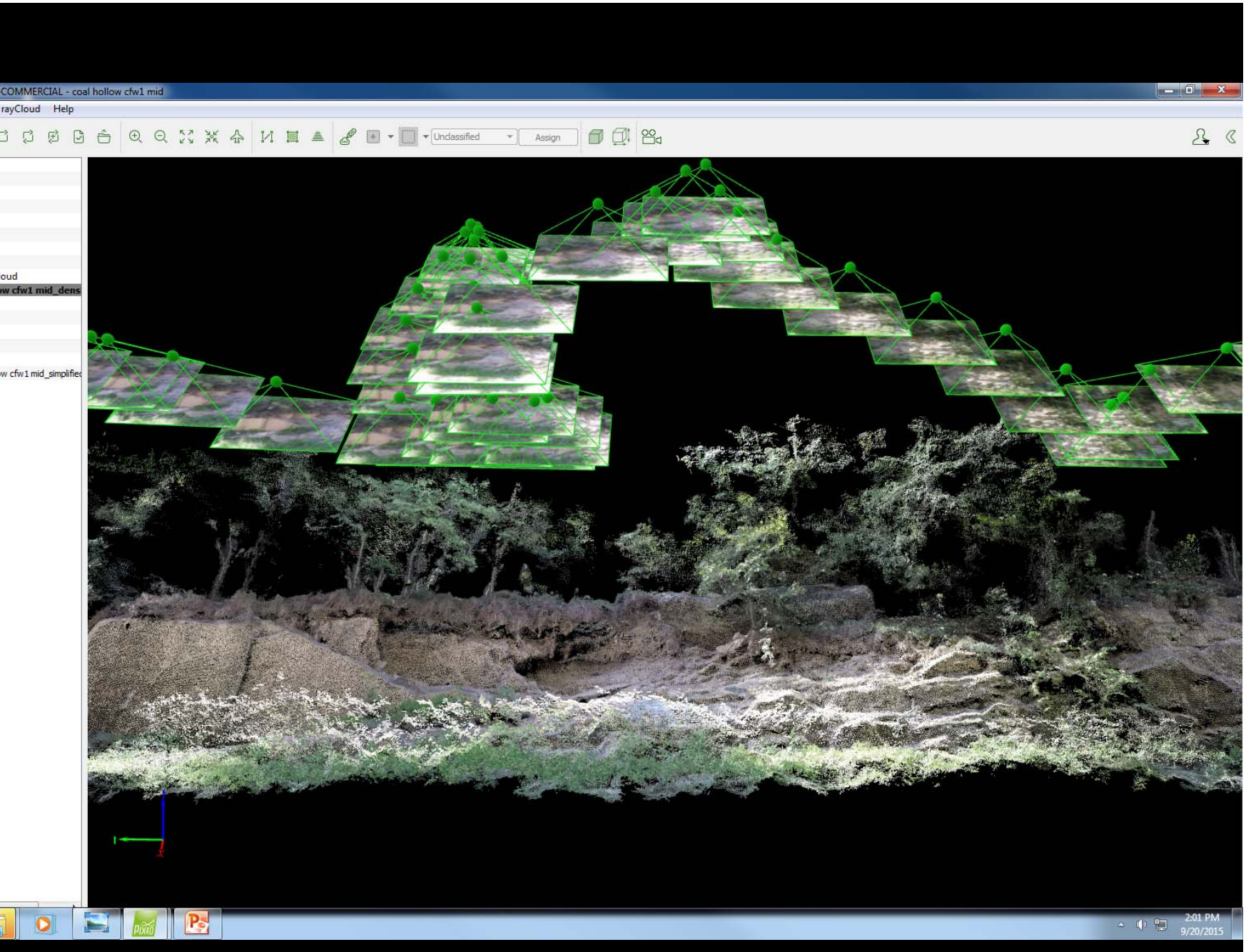
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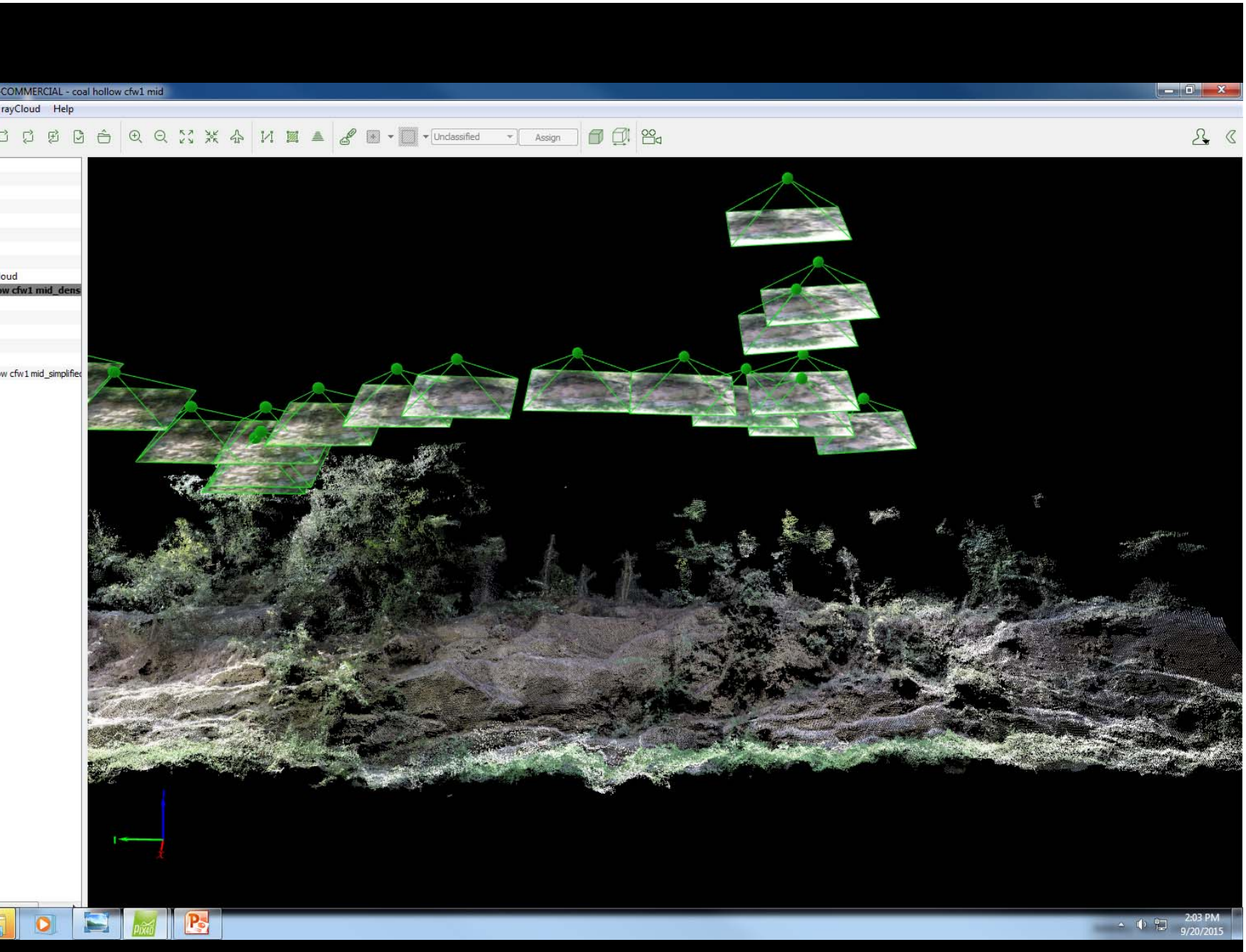
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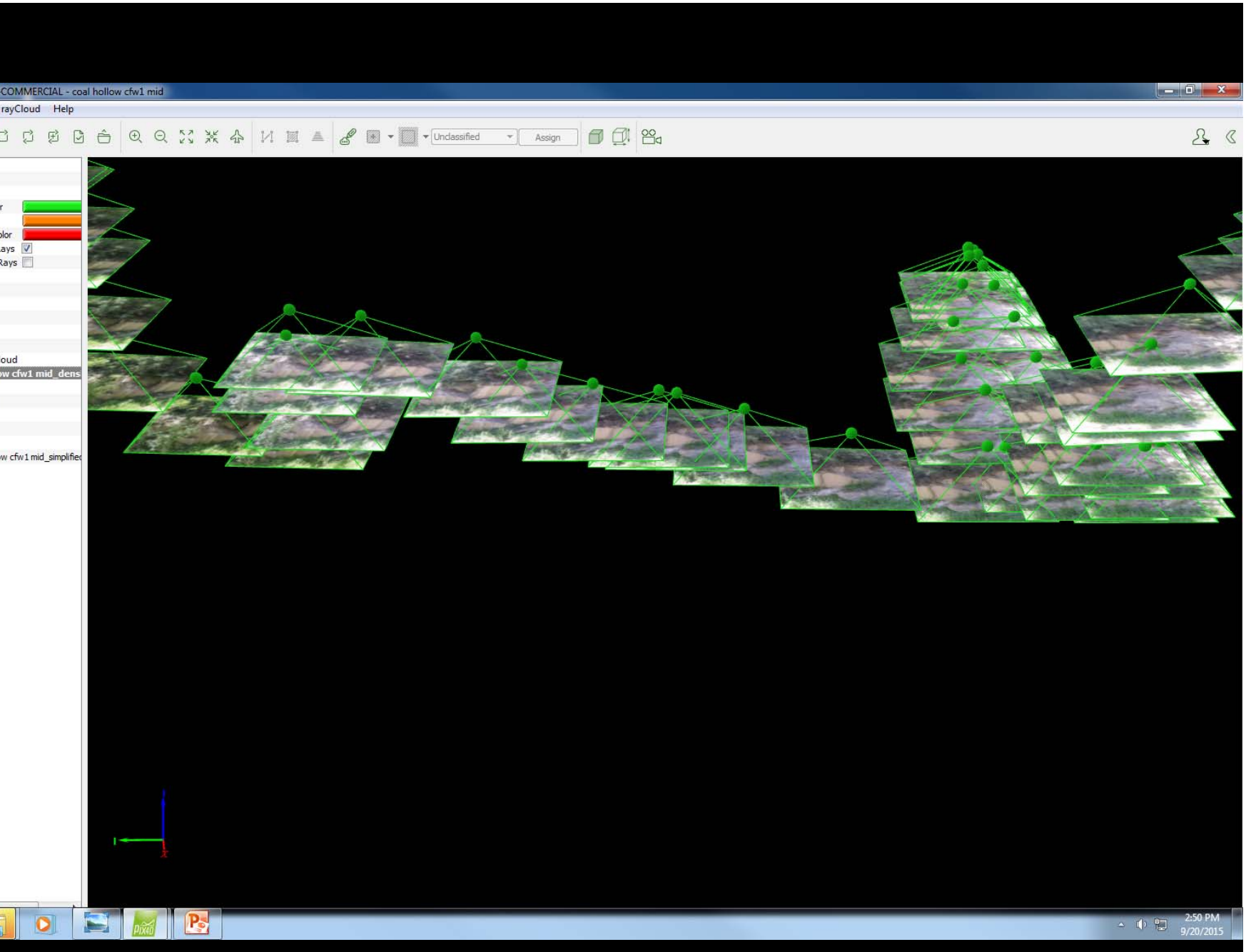
West End Details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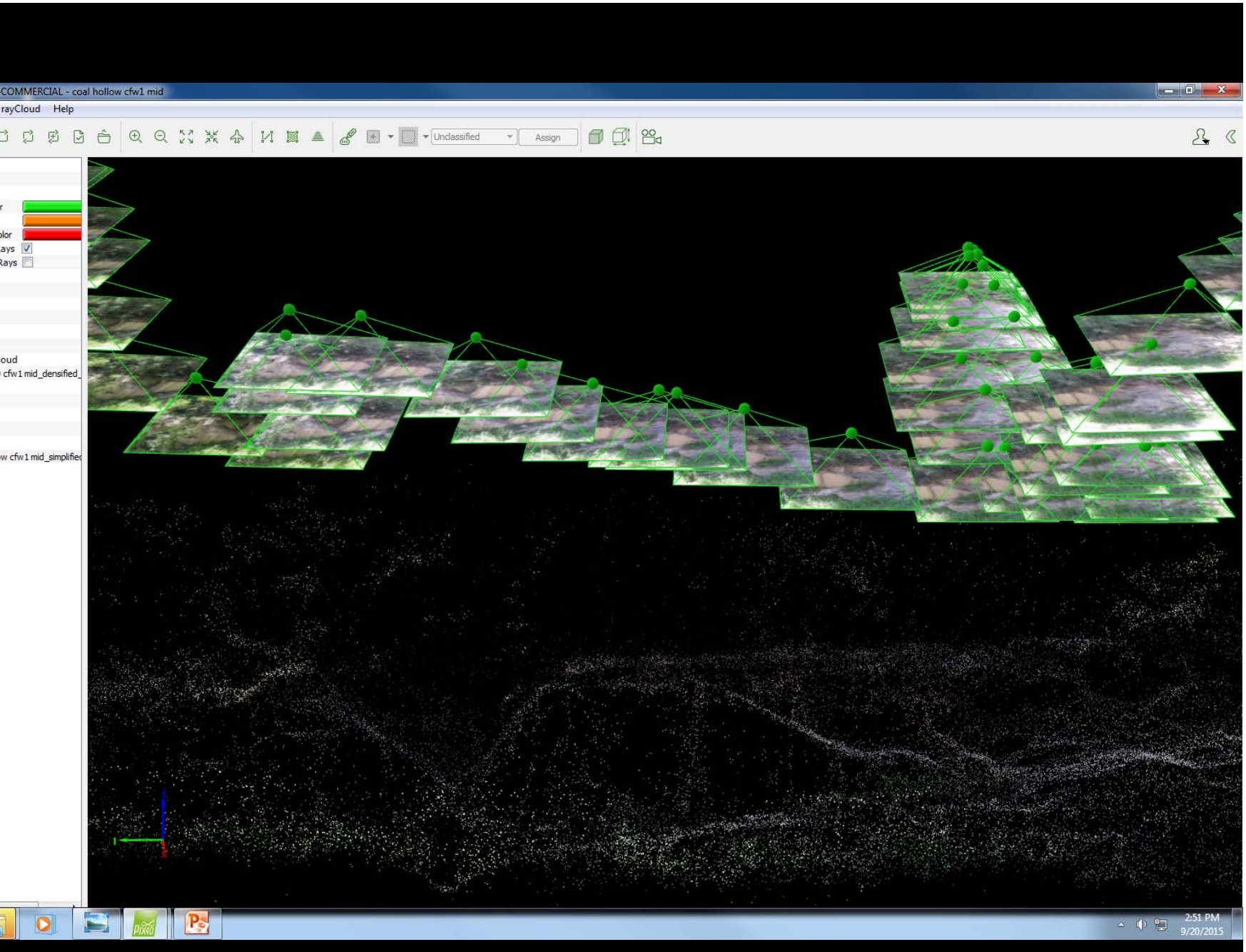
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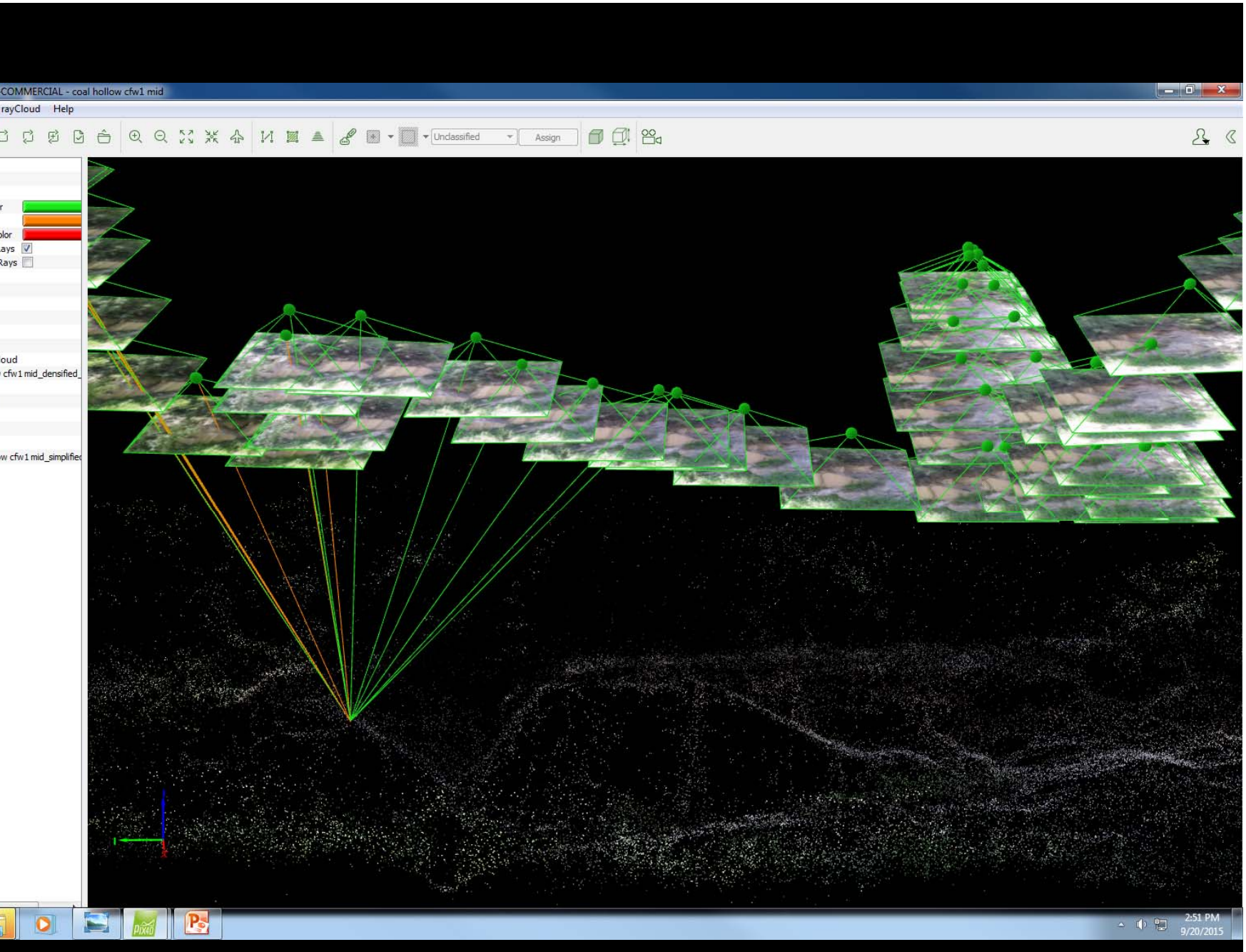
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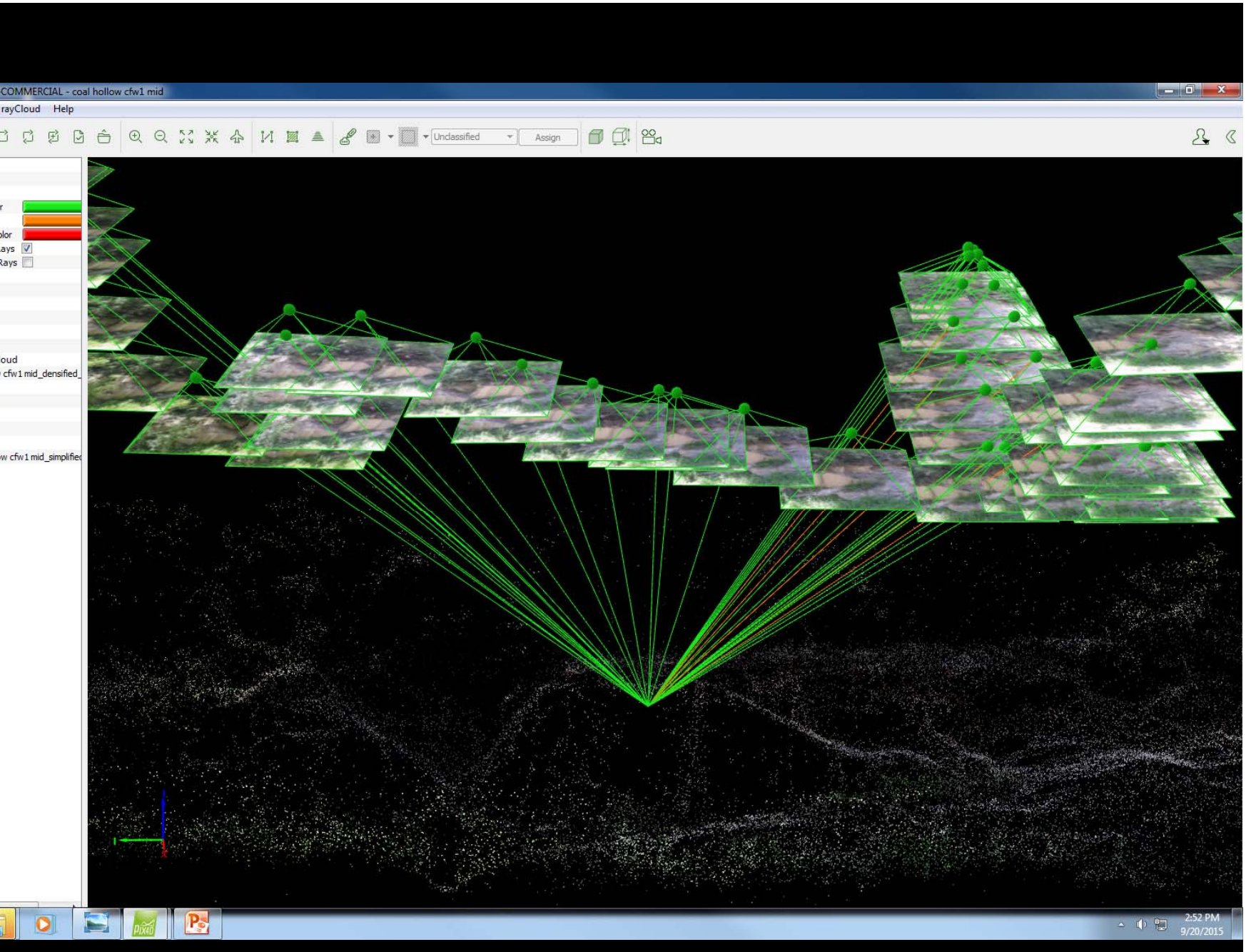
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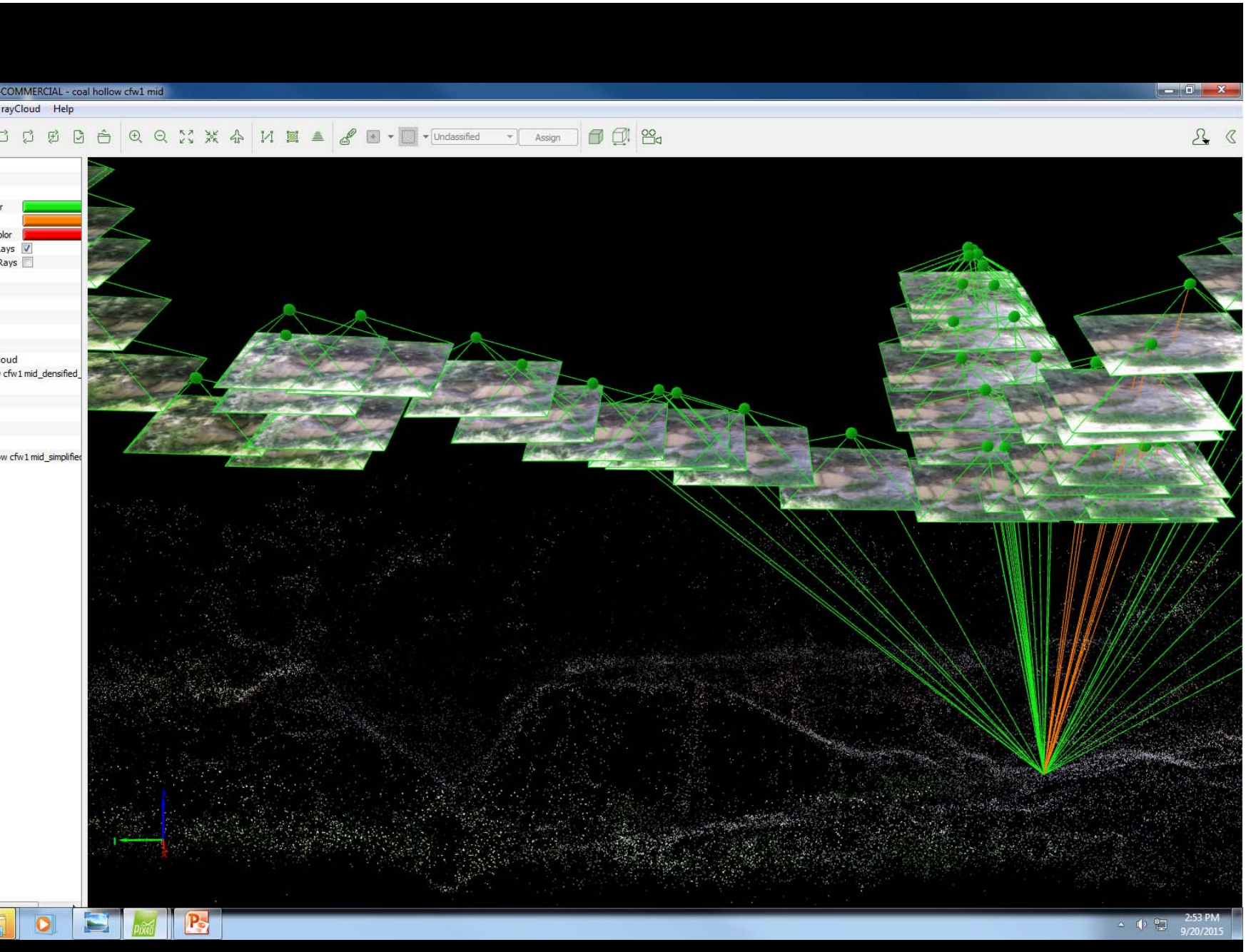
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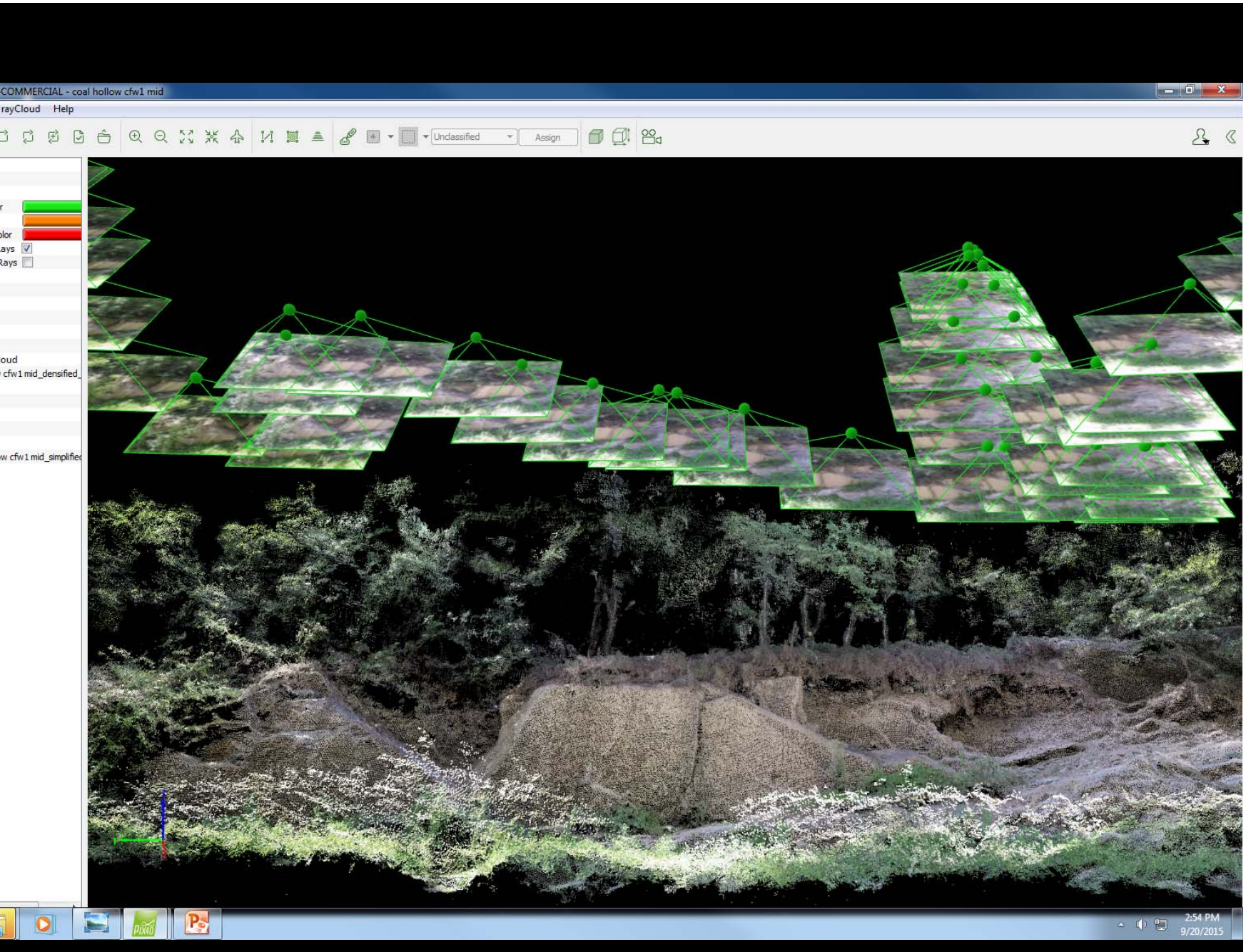
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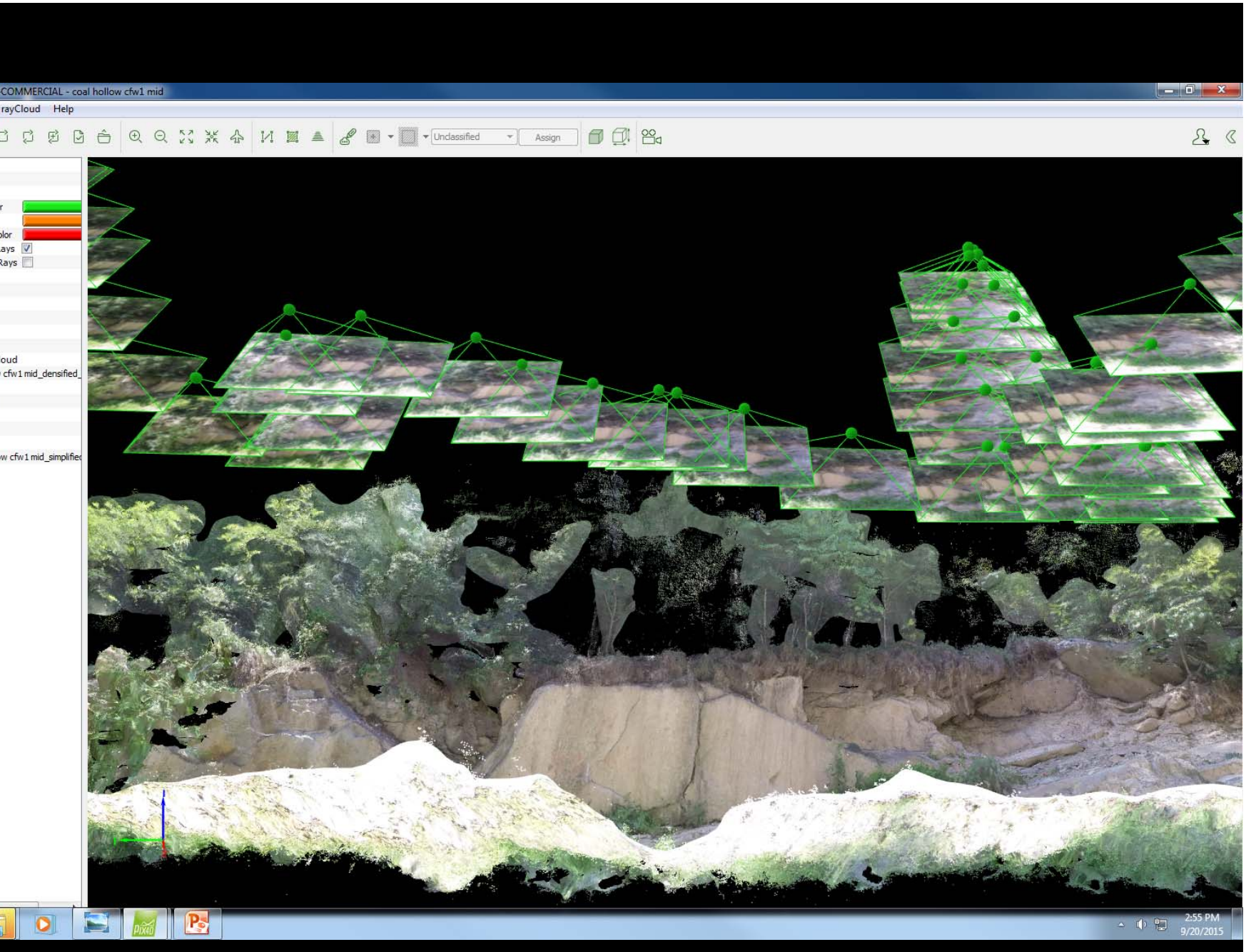
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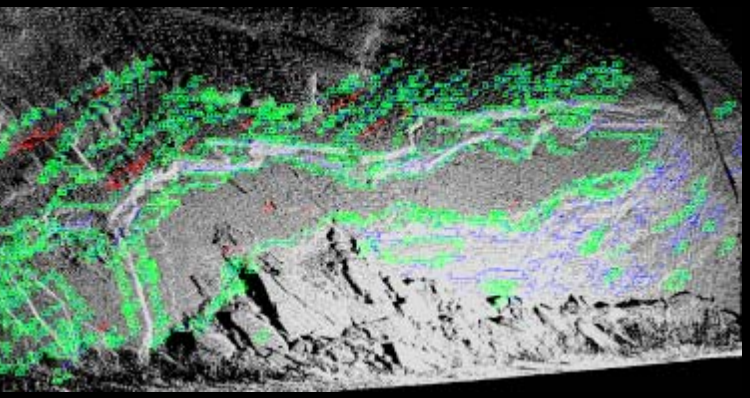
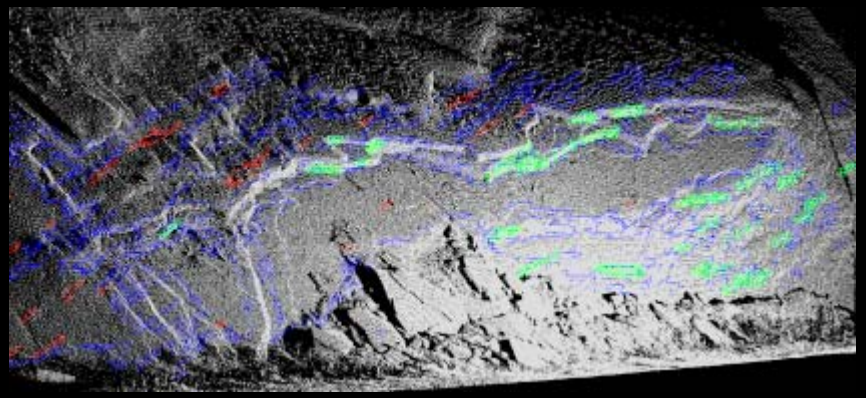
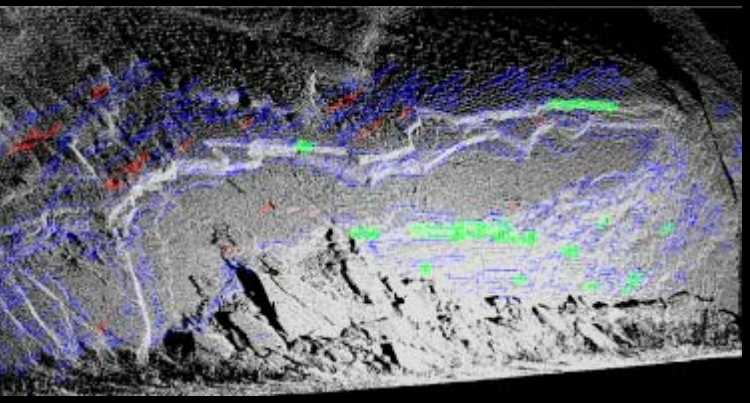
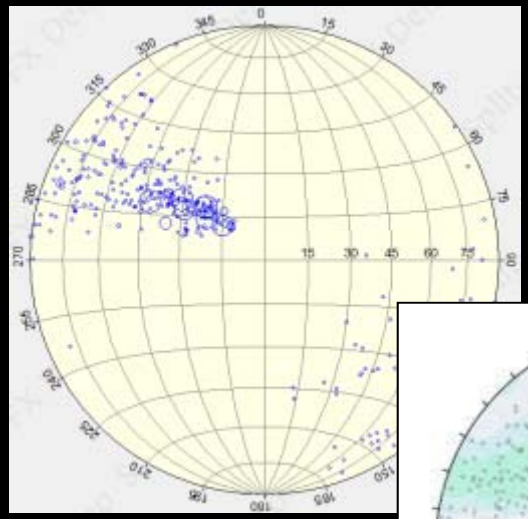
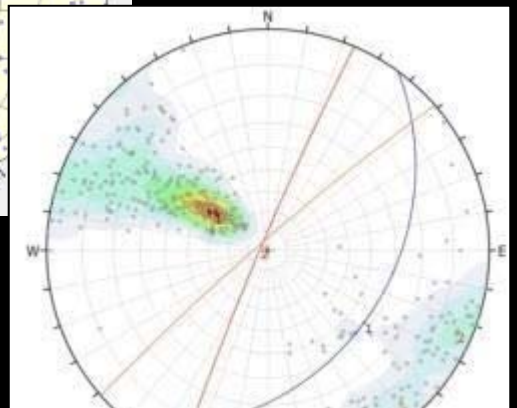
ction of discontinuity orientation data using Split-FX software…



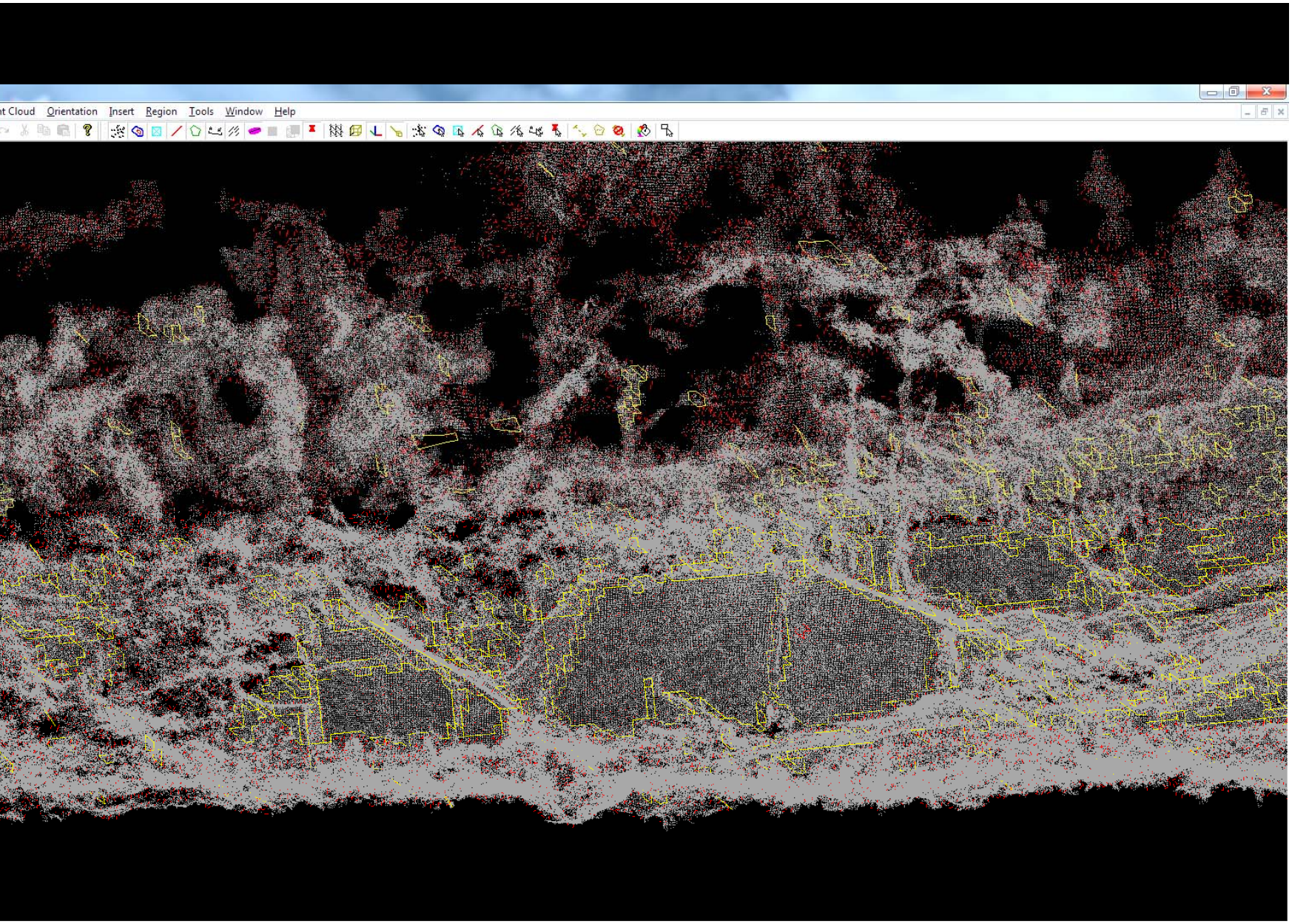


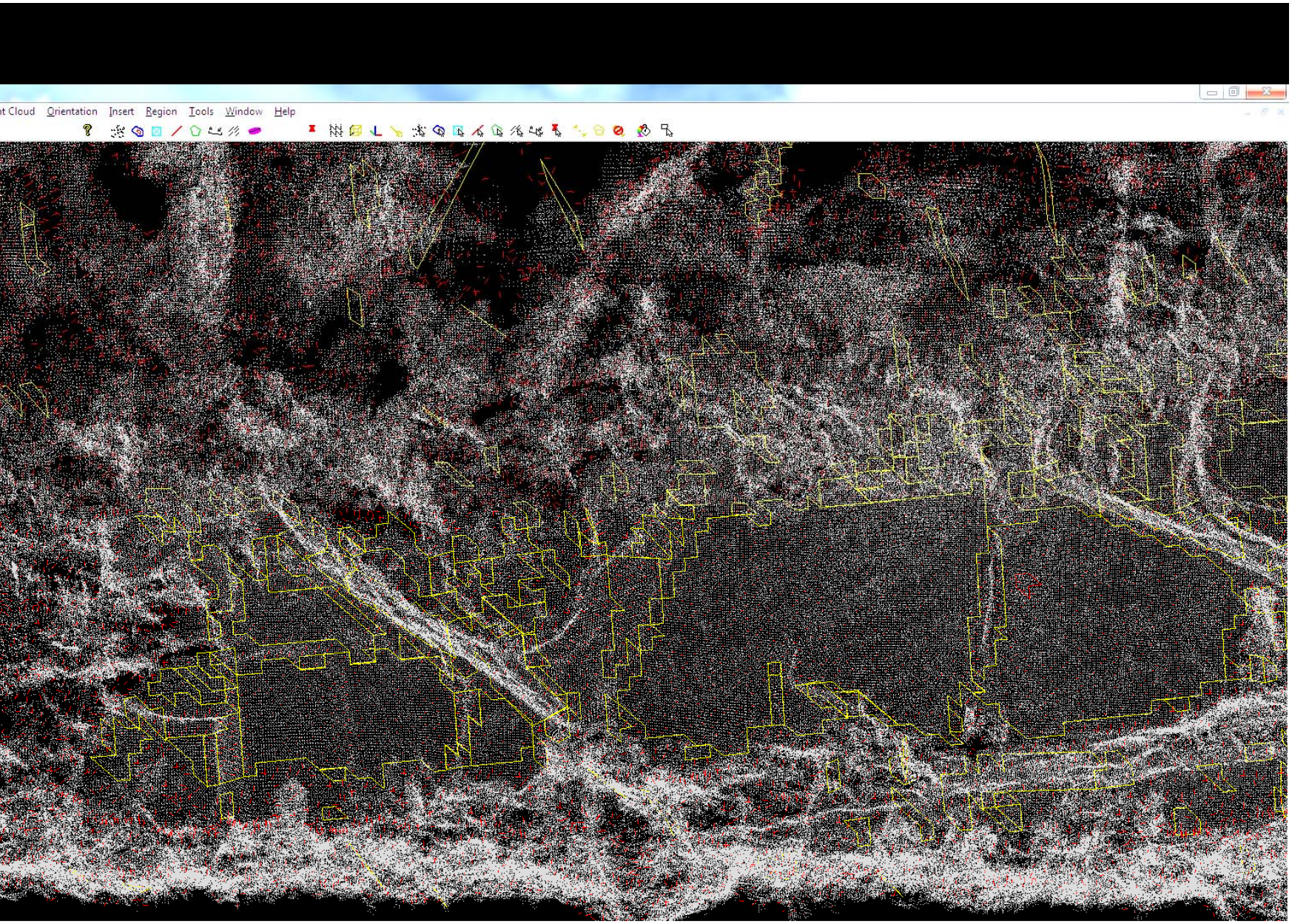






Various steps in processing point
loud data to obtain structure data
for stereonets using Split-FX


t Cloud Orientation Insert Region Tools Window Help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oint Cloud - Stereonet stability analyses

629 Deerfield, VA