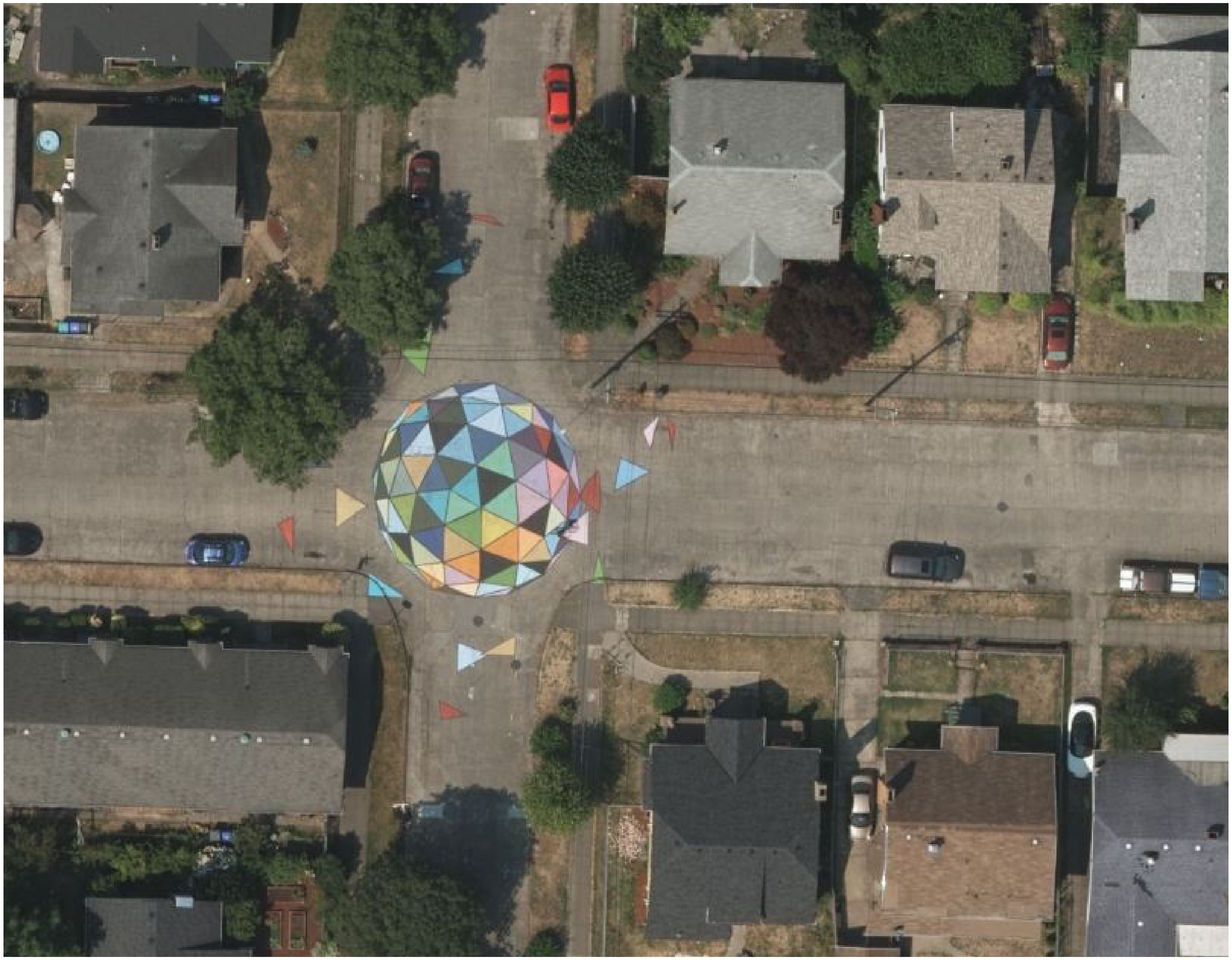
OLC Metro 2014: Final Delivery



Trimble R7 receiver and R8 antenna set up over GPS monument MET_06 (left) and MET_06 survey cap (right).

Data collected for:
Oregon Department of Geology and Mineral Industries

800 NE Oregon Street
Suite 965
Portland, OR 97232

Prepared by:
WSI, A Quantum Spatial Company

421 SW 6th Avenue
Suite 800
Portland, Oregon 97204
phone: (503) 505-5100
fax: (503) 546-6801

517 SW 2nd Street
Suite 400
Corvallis, OR 97333
phone: (541) 752-1204
fax: (541) 752-3770

Contents

WSI, A Quantum Spatial Company (QSI) has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data of the OLC Metro 2014 survey area, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The OLC's Metro 2014 project area of interest (AOI) encompasses 792,960 acres.

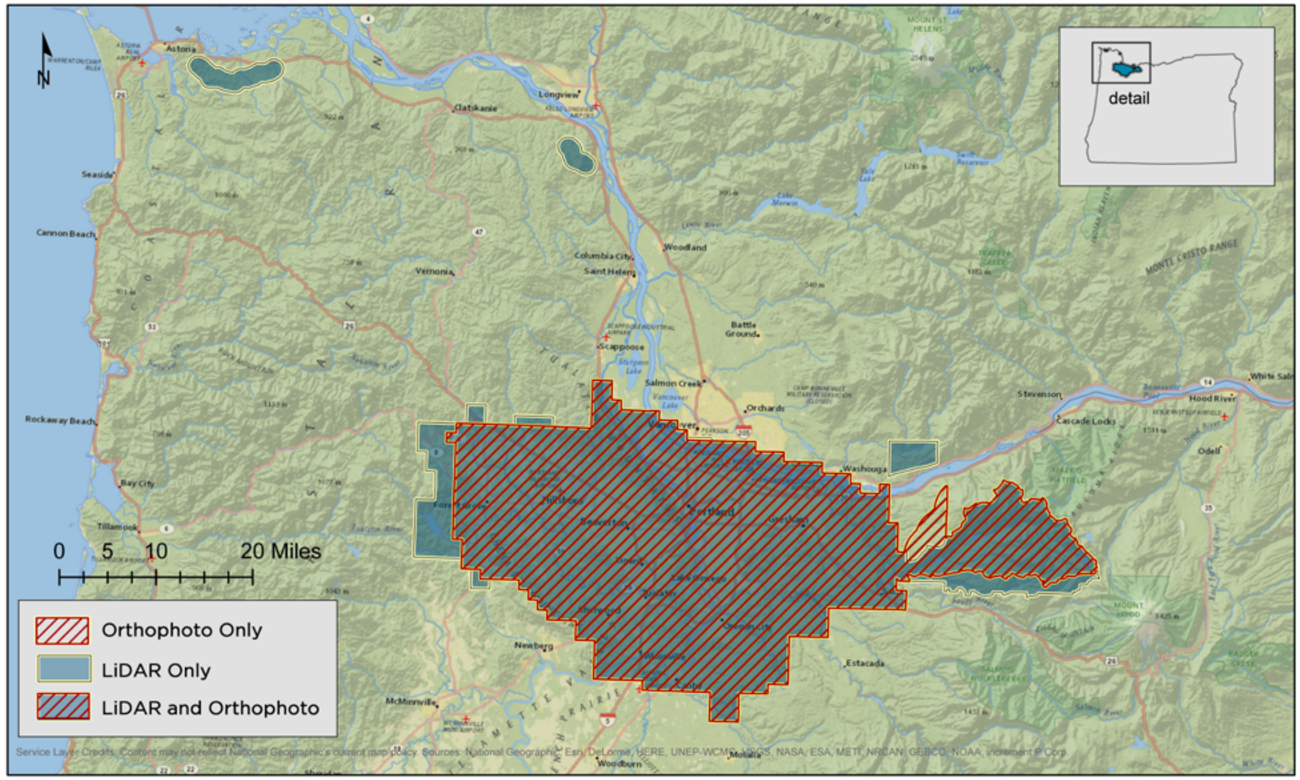
OLC Metro 2014 was broken up into multiple delivery areas which had different deliverable data products and resolutions, see delivery schedule map and table on page 3.

The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

WSI LiDAR data acquisition occurred from July 9 - September 7, 2014. Orthophotos were collected from July 30 - August 11, 2014.

Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

OLC METRO 2014: Overview



Final data products created include RGB extracted LiDAR point cloud data, 3-foot digital elevation models of bare earth ground models and highest-hit returns, 1.5-foot intensity rasters, 3-foot ground density rasters, 3-inch RGBN and 6-inch RGB orthophotos, study area vector shapes, acquisition shapes and corresponding statistical data.

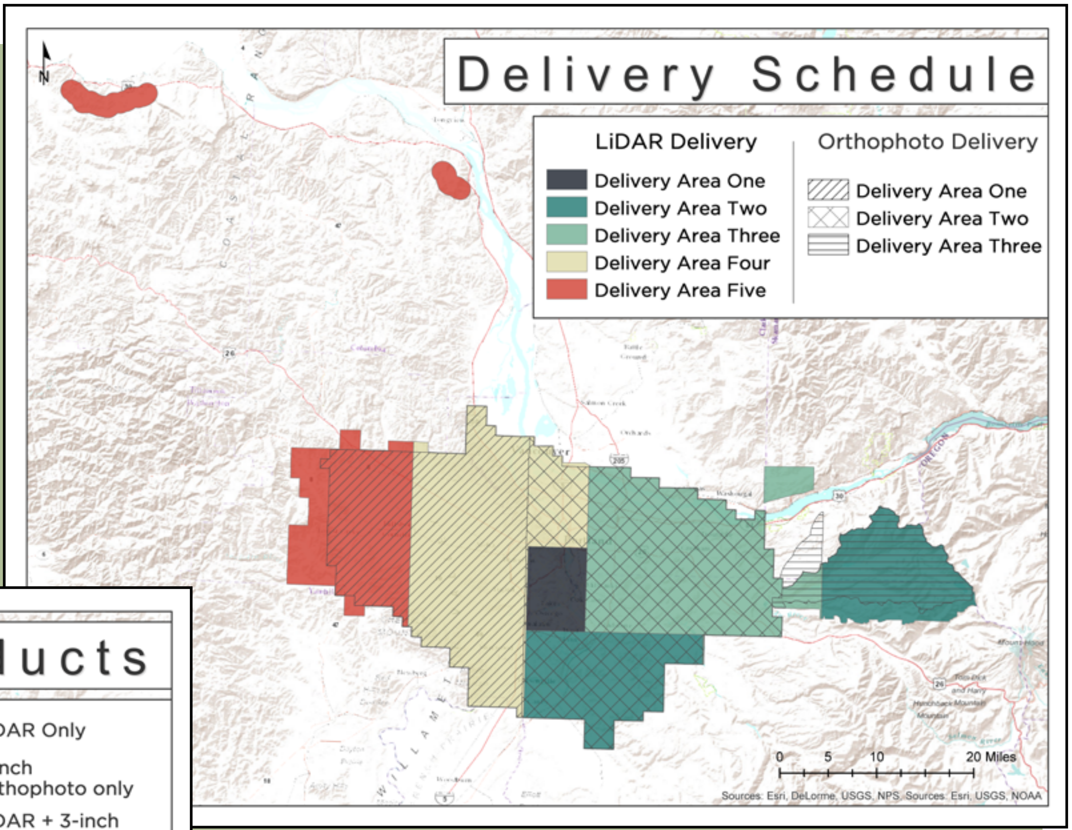
WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Metro 2014, all final deliverables are projected in Oregon Statewide Lambert, endorsed by the Oregon Geographic Information Council (OGIC),[1] using the NAD83(2011) horizontal datum and the NAVD88 (Geoid 12A) vertical datum, with units in international feet.

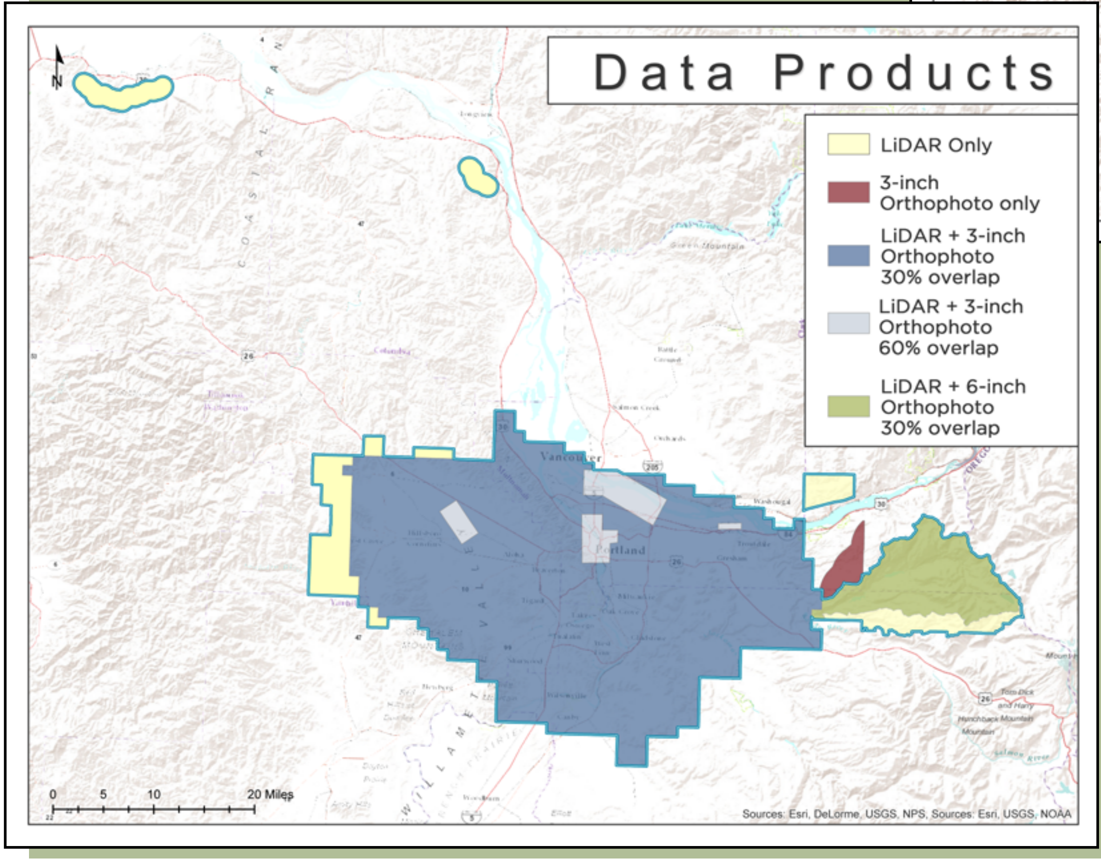
OLC Metro 2014 Data Delivered: May 8, 2014		
Acquisition Dates	LiDAR	July 9 - September 7, 2014
	Orthophotography	July 30 - August 11, 2014
Area of Interest	LiDAR	781,836 acres
	Orthophotography	705,861 acres
Projection	Oregon Statewide Lambert (OGIC)	
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)	
Units	International Feet	

1 http://www.oregon.gov/DAS/EISPD/GEO/pages/coordination/projections/projections.aspx

› LiDAR data were divided into five delivery areas. Orthophotos were divided into three delivery areas, beginning in the western portion of the study area and moving east, as depicted in the map to the right. The table at the bottom right details the delivery of each data product.

ˇ The OLC Metro 2014 survey area was comprised of 8 ppsm LiDAR, with areas of 3-inch and 6-inch pixel resolution orthophotos, having either 30% overlap or 60% overlap.





OLC Metro 2014 Data Products	
Product	Orthophoto Delivery
Orthophoto only	3
3-inch Orthophoto with 30% Overlap	1,2,3
3-inch Orthophoto with 60% overlap	1,2
6-inch Orthophoto	3
LiDAR Only Area	Delivered with LiDAR Delivery Area 2, 3, and 5

Aerial Acquisition

Cessna Caravan

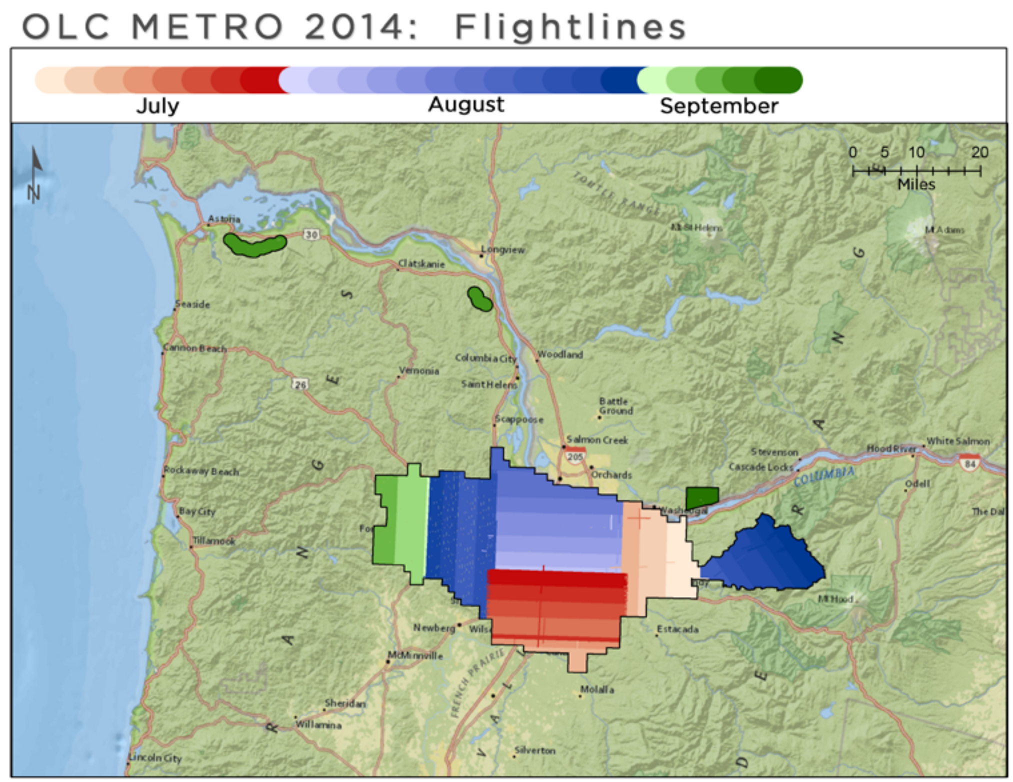
LiDAR Survey

The LiDAR survey used a Leica ALS70 sensor and an Optech Orion H sensor mounted in a Cessna Caravan 208B, Cessna U206G or Piper PA-31. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz, and flown at 1,400 meters or 900 meters above ground level (AGL), capturing a scan angle of +/-15 degrees from nadir (field of view equal to 30 degrees). These settings are developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

The native pulse density is the number of pulses emitted by the LiDAR system. Some types of surfaces such as dense vegetation or water may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and lightly vary according to distributions of terrain, land cover, and water bodies. The study area was surveyed with opposing flight line side-lap of greater than 60 percent with at least 100 percent overlap to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernible laser returns were processed for the output dataset.

OLC Metro LiDAR Acquisition Specifications	
Sensors Deployed	Leica ALS 70 and Orion H
Aircraft	Cessna Caravan 208B, Cessna U206G, Piper-PA
Survey Altitude (AGL)	1400 m / 900 m
Pulse Rate	190-198 kHz
Pulse Mode	Single (SPiA)
Field of View (FOV)	30°
Roll Compensated	Yes
Overlap	100% overlap with 60% sidelap
Pulse Emission Density	≥ 8 pulses per square meter

To solve for laser point position, it is vital to have an accurate description of aircraft position and attitude. Aircraft position is described as x, y, and z and measured twice per second (two hertz) by an onboard differential GPS unit. Aircraft attitude is measured 200 times per second (200 hertz) as pitch, roll, and yaw (heading) from an onboard inertial measurement unit (IMU). As illustrated in the accompanying map, 1,767 flightlines provide coverage of the study area.

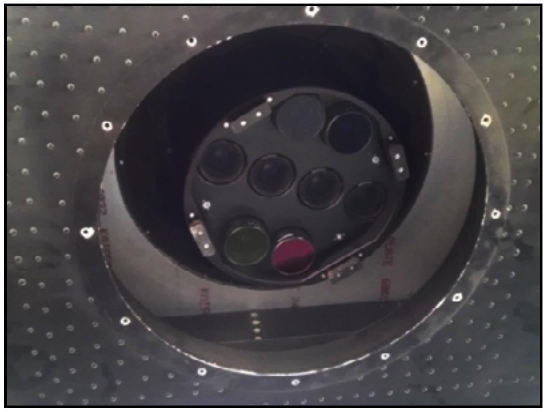


Photography

The photography or Four-Band Radiometric Image Enhanced Survey (FRIES) utilized an UltraCam Eagle 260 megapixel camera mounted in a Cessna 208B Caravan. The UltraCam Eagle is an 80 mm, 260 megapixel large format digital aerial camera manufactured by the Microsoft Corporation. The system is gyro-stabilized and contains a fully integrated UltraNav flight management system with a POS-AV 510 IMU embedded within the body of the camera unit.

The Eagle was designed with high efficiency, high resolution, and high accuracy in mind. With a physical pixel size of 5.2 microns, the Eagle captures a 6.5 cm ground sample distance (GSD) at a flying height of 1,000 meters AGL. This sensor size of the camera is 20,010 x 13,080 pixels in size, which allows for total ground coverage of 1300 x 850 meters within a single captured image frame at 1,000 meters AGL. This large footprint coupled with a fast frame rate (1.8 seconds per frame) allows for highly efficient acquisition. The precise integrated UltraNav system is accurate enough for direct georeferencing in many applications.

The UltraCam Eagle simultaneously collects panchromatic and multispectral (RGB, NIR) imagery in 14 bit format. The spectral sensitivity of the panchromatic charged coupled device (CCD) array ranges from 400-720 nm, with 16,000 grey values per pixel. Four separate 27 mm lenses collect red (590-720 nm), green (490-660 nm), blue (410-590 nm) and near infrared (690-990 nm) light. Panchromatic lenses collect high resolution imagery by illuminating nine CCD arrays, writing nine raw image files. RGB and NIR lenses collect lower resolution imagery, written as four individual raw image files. Level 2 images are created by stitching together raw image data from the nine panchromatic CCDs, and ultimately combined with the multispectral image data to yield Level 3 pan-sharpened TIFFs in either 8 bit format.



Above: UltraCam Eagle lens configuration as viewed from the Cessna Caravan.

Above: A Cessna Grand Caravan 208B was employed in the collection of all orthoimagery.

Below: UltraCam Eagle installed in the aircraft.

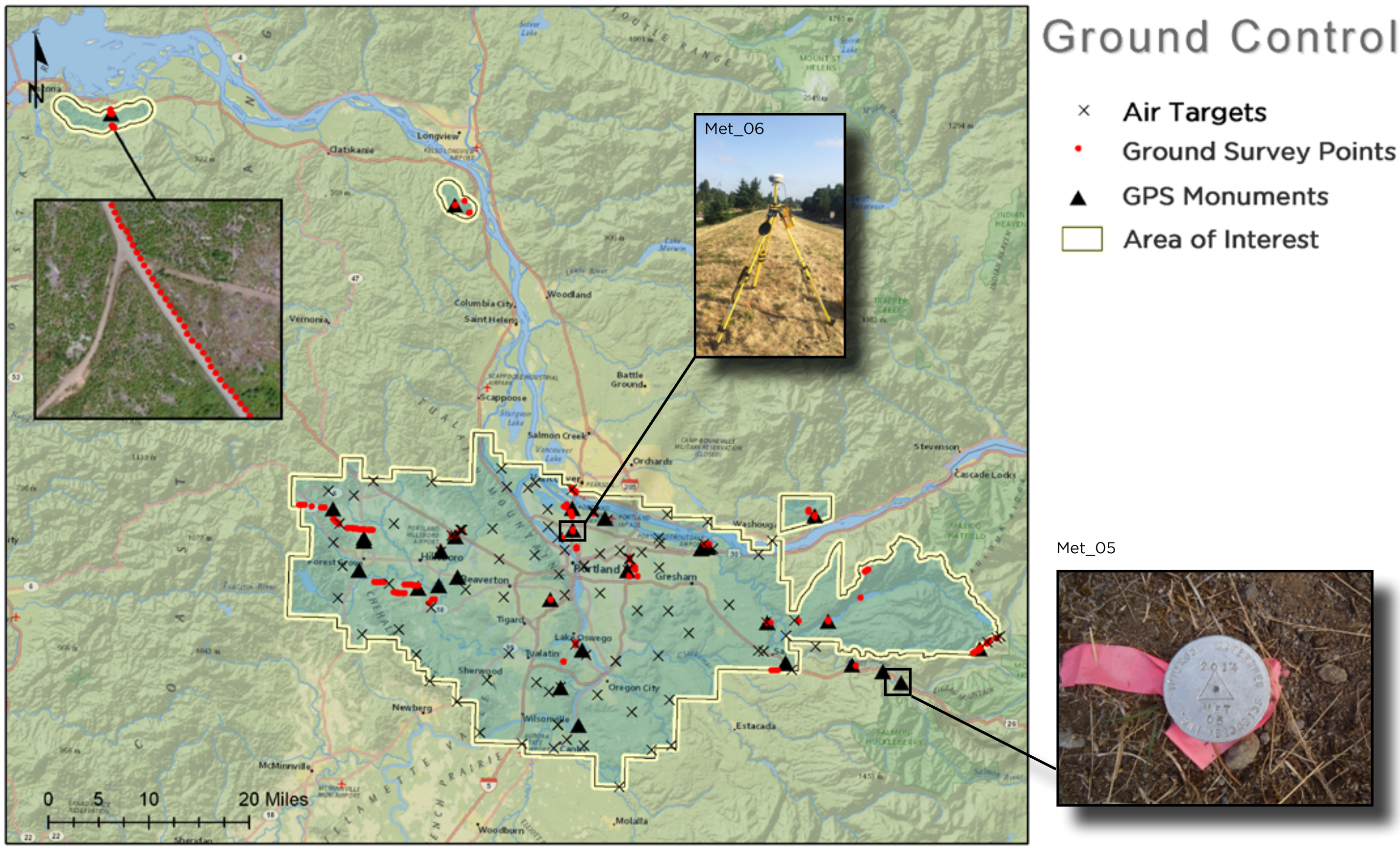
Ground Survey

Ground control surveys, including monumentation, aerial targets and ground survey points (GSPs), were conducted to support the airborne acquisition. Ground control data are used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data and orthoimagery products. See the table below for specifications of equipment used.

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R8	Integrated Antenna R8 Model 2	TRM_R8_GNSS	Static, Rover
Trimble R10	Integrated Antenna R10	TRMR10	Rover

Instrumentation

All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas and Trimble R8 GNSS receivers with internal antennas. Rover surveys for GSP collection were conducted with Trimble R8 and Trimble R10 GNSS receivers.



Monumentation

Existing and newly established survey benchmarks serve as control points during LiDAR acquisition. Monument locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. NGS benchmarks are preferred for control points; however, in the absence of NGS benchmarks, WSI produces our own monuments, and every effort is made to keep them within the public right of way or on public lands. If monuments are necessary on private property, consent from the owner is required. All monumentation is done with 5/8" x 30" rebar topped with a two-inch diameter aluminum cap stamped "Watershed Sciences, Inc. Control." See Appendix B for a complete list of monuments placed within the OLC Metro 2014 Study Area.

Methodology

To correct the continuously recorded aircraft position, WSI concurrently conducts multiple static GNSS ground surveys over each monument. All control monuments are observed for a minimum of two survey sessions, each lasting no fewer than two hours. Data are collected at a rate of one hertz, using a 10 degree mask on the antenna. The static GPS data are then triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS) for precise positioning.

Ground Survey Points (GSPs) are collected using Real Time Kinematic (RTK), Post-Processed Kinematic (PPK), and Fast-Static (FS) survey techniques. For RTK surveys, a base receiver is positioned at a nearby monument to broadcast a kinematic correction to a roving receiver; for PPK and FS surveys, however, these corrections are post-processed. All GSP measurements are made during periods with a Position Dilution of Precision (PDOP) no greater than 3.0 and in view of at least six satellites for both receivers. Relative errors for the position must be less than 1.5 centimeters horizontal and 2.0 centimeters vertical in order to be accepted.

In order to facilitate comparisons with high quality LiDAR data, GSP measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. GSPs are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. GSPs were collected within as many flight lines as possible; however, the distribution depended on ground access constraints and may not be equitably distributed throughout the study area.

Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	0.05 m
St Dev z	0.05 m


Ground professional collecting RTK

Aerial Targets

Prior to photo acquisition, permanent and temporary aerial photo targets were located and installed throughout the study area. The air targets were set within two miles of a GPS base location and target control points (TCPs) were collected at each corner of the target, as well as the center point, for utilization in the processing and quality control of the orthophoto deliverables.

Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include existing aerial targets, turn-arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. Additional permanent air targets were identified in the field and used for processing orthophotos.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

Examples of temporary (left) and permanent (below) air targets.

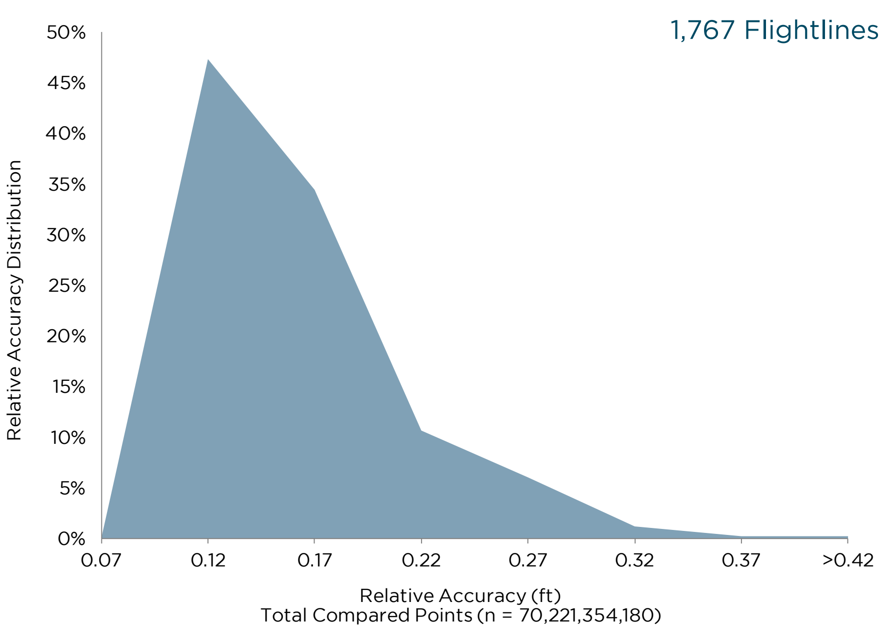
LiDAR Accuracy

Relative Accuracy

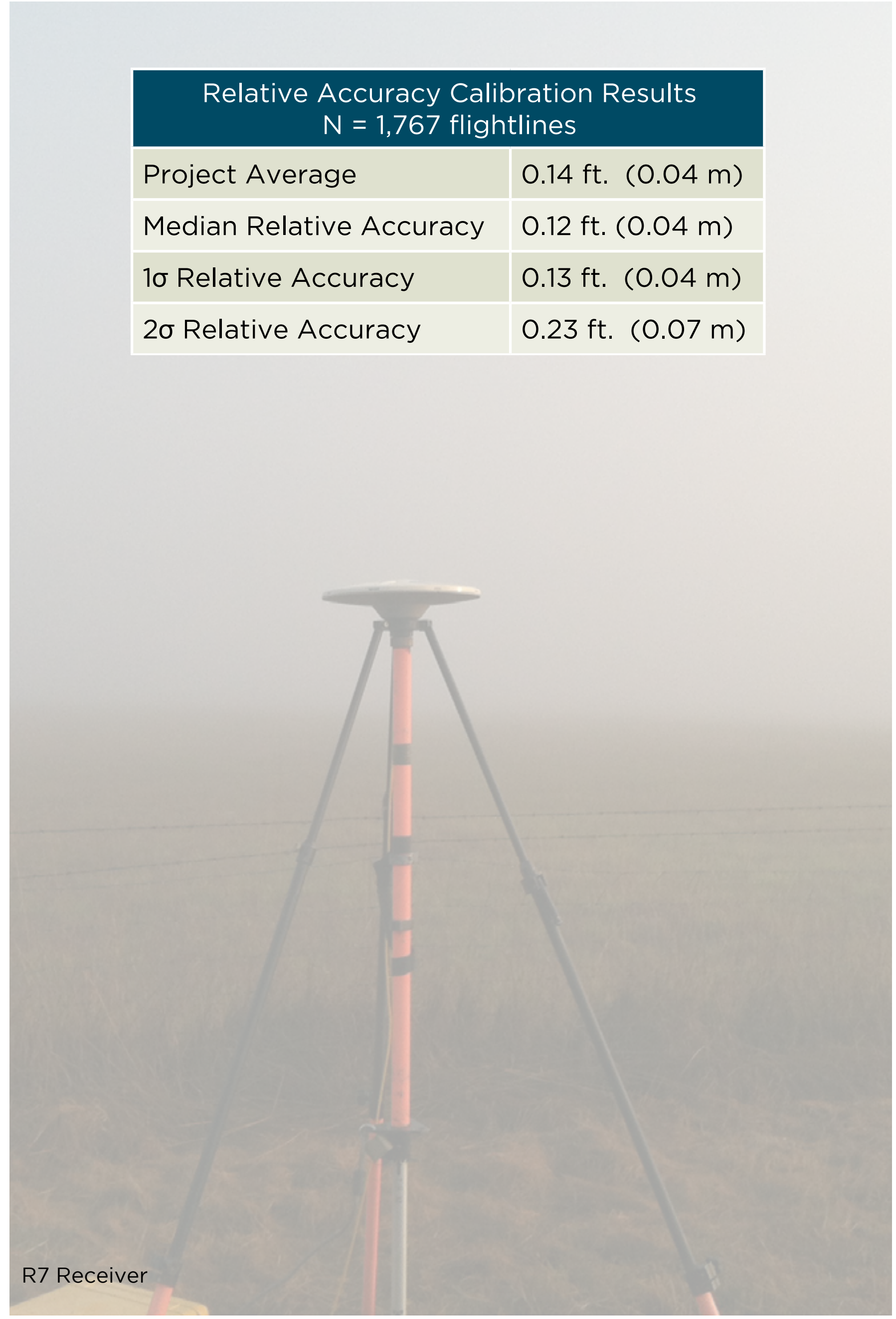
Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping area. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence is low (<10 centimeters). Internal consistency is affected by system attitude offsets (pitch, roll, and heading), mirror flex (scale), and GPS/IMU drift.

Relative accuracy statistics are based on the comparison of 1,767 flightlines. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Distribution



Relative Accuracy Calibration Results N = 1,767 flightlines	
Project Average	0.14 ft. (0.04 m)
Median Relative Accuracy	0.12 ft. (0.04 m)
1σ Relative Accuracy	0.13 ft. (0.04 m)
2σ Relative Accuracy	0.23 ft. (0.07 m)



R7 Receiver

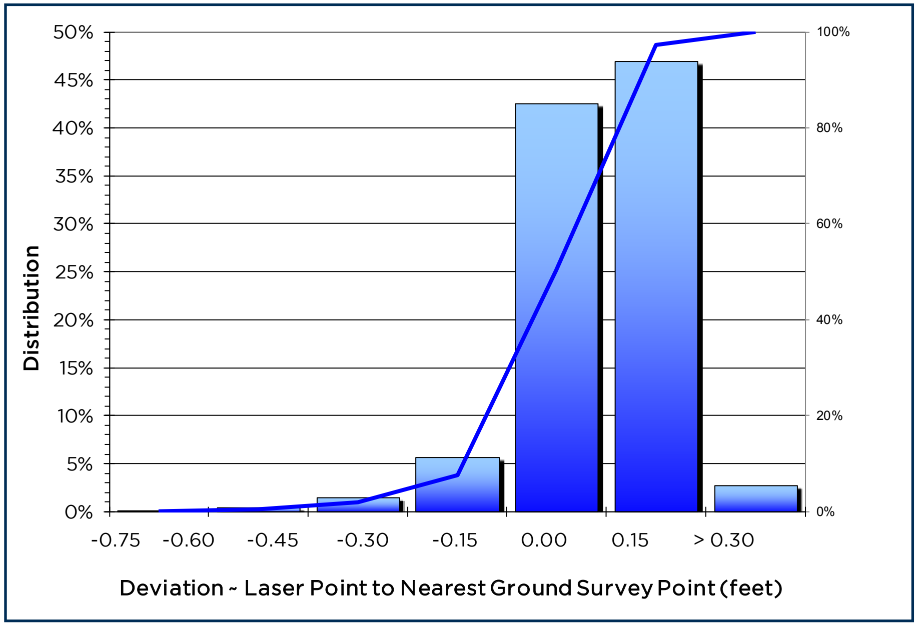
Vertical Accuracy

Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). The statistical model compares known ground check points to the triangulated LiDAR surface. Vertical accuracy statistical analysis uses ground check points in open areas where the LiDAR system has a "very high probability" that the sensor will measure the ground surface and is evaluated at the 95th percentile. For the OLC Metro 2014 survey, 3,606 GSPs were collected.

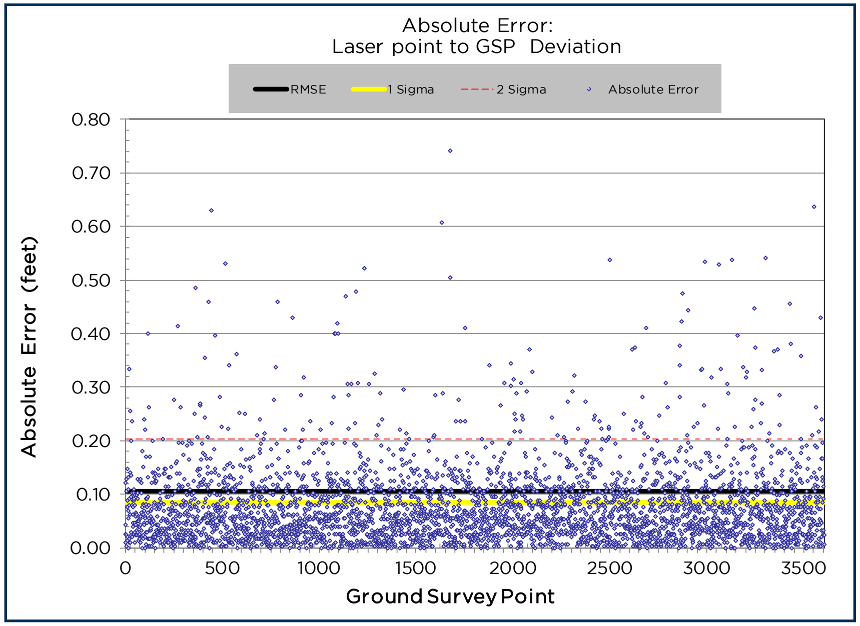
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

Vertical Accuracy Results	
	Cumulative
Sample Size (n)	3,606 Ground Survey Points
Root Mean Square Error	0.11 ft. (0.03 m)
1 Standard Deviation	0.09 ft. (0.03 m)
2 Standard Deviation	0.20 ft. (0.06 m)
Average Deviation	-0.01 ft. (0.00 m)
Minimum Deviation	-0.74 ft. (-0.23 m)
Maximum Deviation	0.31 ft. (0.09 m)

Vertical Accuracy Distribution



GSP Absolute Error



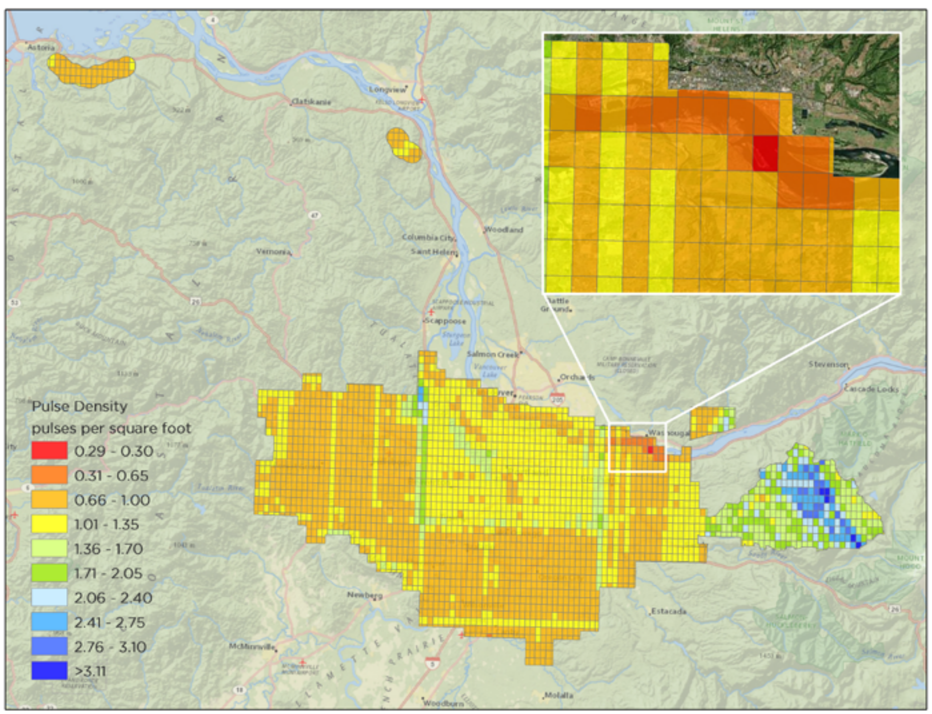
Density

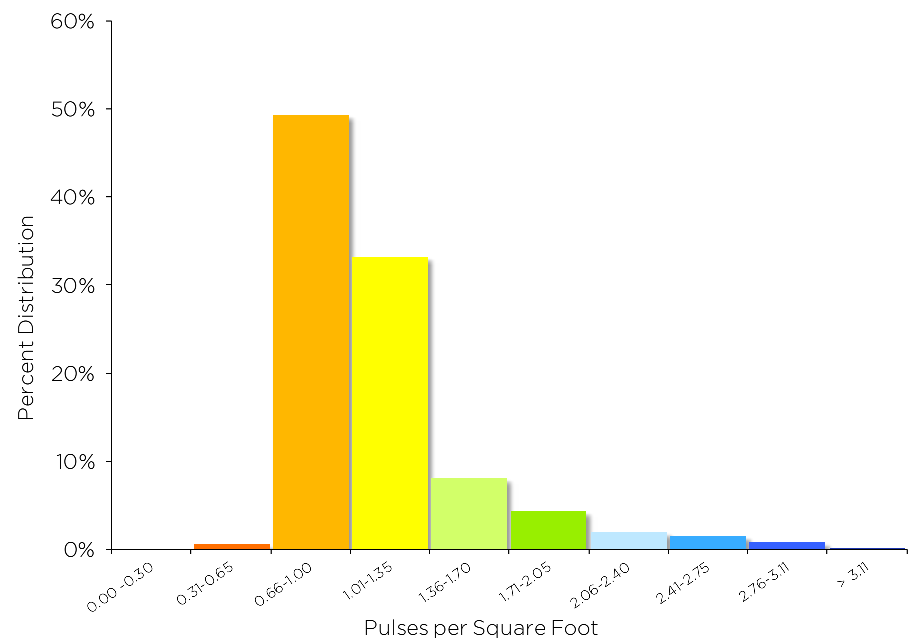
Pulse Density

Final pulse density is calculated after processing and is a measure of first returns per sampled area. Some types of surfaces (e.g., dense vegetation, water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover, and water bodies. Density histograms and maps have been calculated based on first return laser pulse density and ground-classified laser point density. Densities are reported for the survey area.

Average Pulse Density	pulses per square meter	pulses per square foot
	12.24	1.14

Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart), note area of low pulse density of Columbia River.



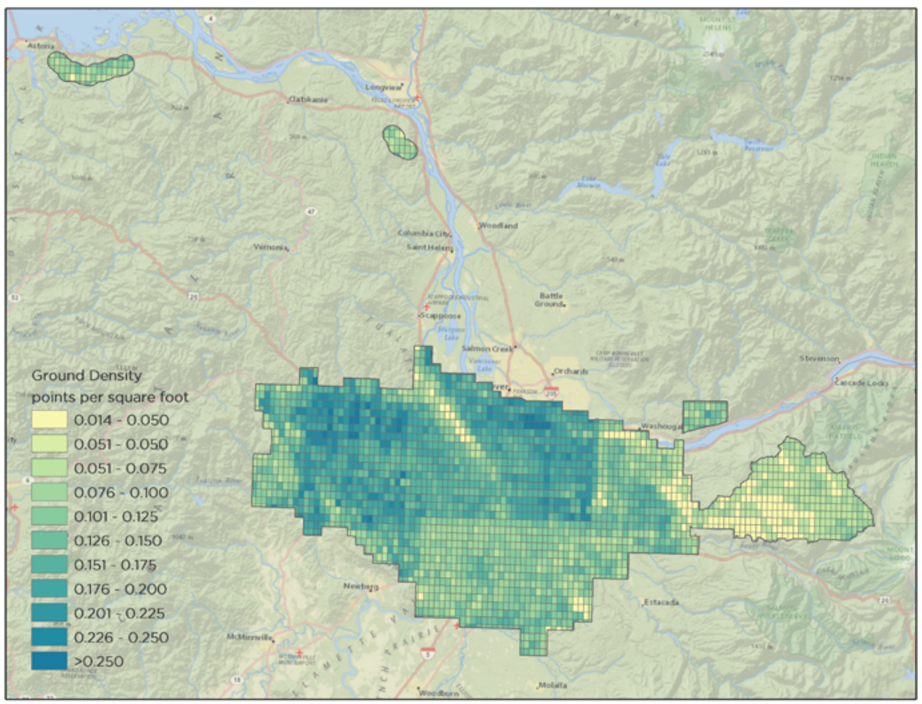


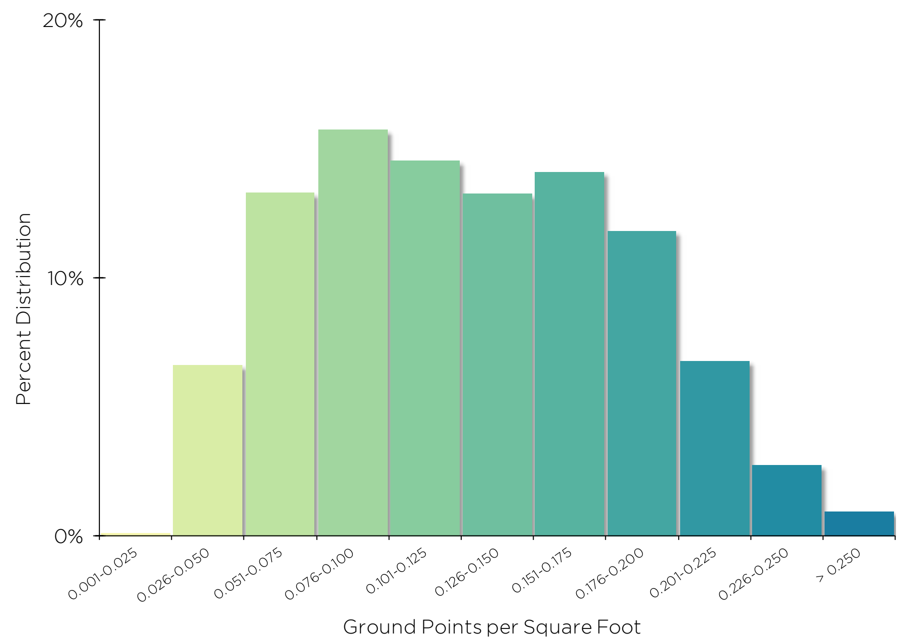
Ground Density

Ground classifications were derived from ground surface modeling. Further classifications were performed by reseeding of the ground model where it was determined that the ground model failed, usually under dense vegetation and/or at breaks in terrain, steep slopes, and at tile boundaries. The classifications are influenced by terrain and grounding parameters that are adjusted for the dataset. The reported ground density is a measure of ground-classified point data for the survey area.

Ground Density	points per square meter	points per square foot
	1.40	0.13

Average Ground Density per 0.75' USGS Quad (color scheme aligns with density chart).





Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Fifty-two target control points, distributed evenly across the total acquired area, were generated on permanent air target surface features, such as painted road lines and fixed high-contrast objects or on temporary air targets. They were then compared against check points identified from the LiDAR intensity images. The accuracy of the final mosaic was calculated in relation to the LiDAR-derived check points and is listed below. Accuracy statistics are reported for the entire OLC Metro 2014 Orthophoto AOI.

Orthophoto horizontal accuracy results.

Orthophoto Horizontal Accuracy (n=52)	WSI Achieved International feet
RMSE	1.02
1 Sigma	0.86
2 Sigma	1.95

Above: Example of co-registration of color images with LiDAR intensity images. **Below:** Examples of permanent air targets located within the Lane County project area.

Appendix A : PLS Certification

WSI provided LiDAR Services for OLC Metro 2014 project as described in this report.

I, John English, have reviewed the attached report for completeness and herby state that it is a complete and accurate report of this project.

5/7/2015

John English
Project Manager
WSI, a Quantum Spatial Company

I, Christopher Glantz, being duly registered as a Professional Land Surveyor in the state of Oregon, say that I hereby certify the methodologies and results of the attached LiDAR project, and that Static GNSS occupations on the Base Stations during airborne flights and RTK survey on hard-surface and GSP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between July 9, 2014 and September 7, 2014. Accuracy statistics shown in the Accuracy Section of this Report have been review by me and found to meet the "National Standard for Spatial Data Accuracy".

5/7/2015

Christopher Glantz, PLS
Land Surveyor
WSI, a Quantum Spatial Company

REGISTERED
PROFESSIONAL
LAND SURVEYOR
OREGON
JUNE 2, 2010
CHRISTOPHER A. GLANTZ
83648
RENEWS 6/30/2015

Appendix B : GPS Monument Table

List of GPS monuments used in OLC Metro 2014 Survey Area. Coordinates are on the NAD83(2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid 12A.

OLC Metro 2014 County GPS Monuments

PID	Latitude	Longitude	Ellipsoid Height (meters)	NAVD88 Height (meters)
AD9178	45° 32' 04.20113"	-122° 56' 49.56788"	38.359	61.23
AD9185	45° 35' 18.86472"	-122° 36' 43.25399"	-16.379	6.360
AD9186	45° 32' 59.91962"	-122° 23' 54.10651"	-12.867	9.760
AI2002	45° 28' 09.59881"	-122° 43' 12.11367"	102.440	125.275
AJ8185	45° 24' 42.18046"	-121 50' 13.43977"	808.560	829.742
AJ8198	45° 23' 50.72678"	-122° 39' 08.16405"	36.546	59.333
BULLRUN_A_PPK	45° 26' 51.13818"	-122° 08' 55.58413"	245.062	267.306
MET_01	45° 26' 36.07450"	-122° 16' 25.38323"	213.176	235.707
MET_02	45° 17' 18.93784"	-122° 39' 19.97581"	38.521	61.424
MET_03	45° 32' 52.93364"	-122° 24' 43.87569"	-12.972	9.685
MET_04	45° 20' 33.94108"	-122° 41' 37.97491"	226.458	249.294
MET_05	45° 21' 39.65931"	-121° 59' 50.09800"	343.773	365.518
MET_06	45° 34' 13.54283"	-122° 40' 40.74508"	33.302	56.137
MET_09	45° 30' 50.14085"	-122° 33' 46.23603"	56.128	78.900
MET_11	45° 29' 53.78724"	-122° 54' 40.70147"	41.320	64.265
MET_12	45° 29' 05.32586"	-122° 56' 59.01722"	21.851	44.7445
MET_13	45° 23' 05.84707"	-122° 05' 54.74845"	280.227	302.358
MET_14	45° 30' 12.15237"	-123° 06' 50.91944"	29.554	51.8805
MET_15	46° 02' 02.91263"	-122° 56' 22.74535"	201.183	222.872
MET_16	46° 08' 55.65660"	-123° 39' 31.46790"	38.181	60.599
MET_17	45° 35' 57.50867"	-122° 10' 53.16682"	210.681	232.869
MET_18	45° 33' 50.43308"	-122° 13' 20.02080"	159.866	267.306
MET_19	45° 35' 27.60711"	-123° 10' 18.54771"	30.773	52.7605

OLC Metro 2014 County GPS Monuments

PID	Latitude	Longitude	Ellipsoid Height (meters)	NAVD88 Height (meters)
ODOT_52	45° 32’ 59.75442”	-123° 06’ 22.07491”	30.826	53.2295
ODOT50	45° 32’ 44.43869”	-123° 06’ 22.60391”	31.080	53.483
ODOTRP	45° 28’ 49.55438”	-122° 59’ 30.68308”	33.683	56.489
RD4213	45° 22’ 34.20936”	-122° 02’ 05.43942”	302.065	323.952
SANDY_03	45° 23’ 11.51935”	-122° 14’ 05.13635”	338.497	361.010
WMET_04	45° 33’ 21.75869”	-122° 55’ 07.19972”	41.842	64.722
WMET_10	45° 36’ 06.07310”	-122° 40’ 45.93967”	-17.711	5.119