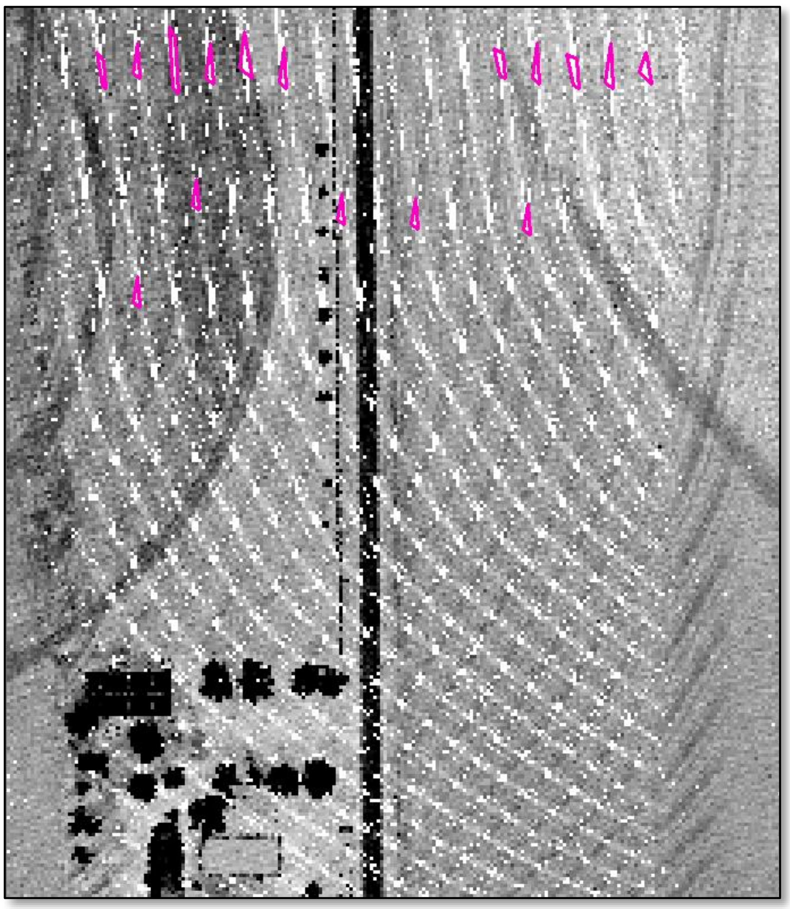
Date: 5/30/2018

Overview:

This document outlines background information regarding Riegl MTA zones artifacts and blind zone interpolation using synthetic points. A project example of the occurrence of this artifact is included. Additionally this document requests a call for action regarding guidance of the preferred processing treatment in regards to these artifacts.

Void Examples:

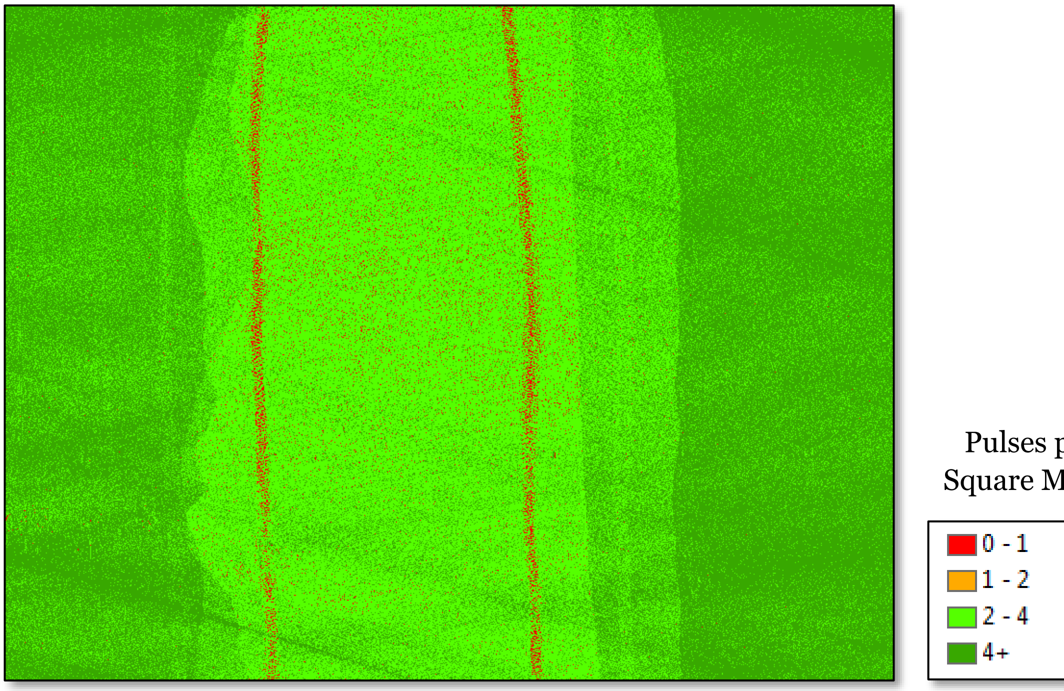
During Dewberry's evaluation of data acquisition for the Texas West Central project, it was observed that in one of the project blocks there were several localized areas with void artifacts. These identified voids are exceeding the USGS specification of $(4*NPS)^2$. Once these voids were further examined it was discerned that there exists a trend of localized density and spatial distribution artifacts throughout the acquisition block.



The example above shows a 1 meter non-interpolated intensity image of an area exhibiting this artifact. The shapes outlined in pink are void polygons that exceed the void specification. These voids are considered a sensor artifact as they cannot be otherwise explained as water bodies or any other natural occurrence.

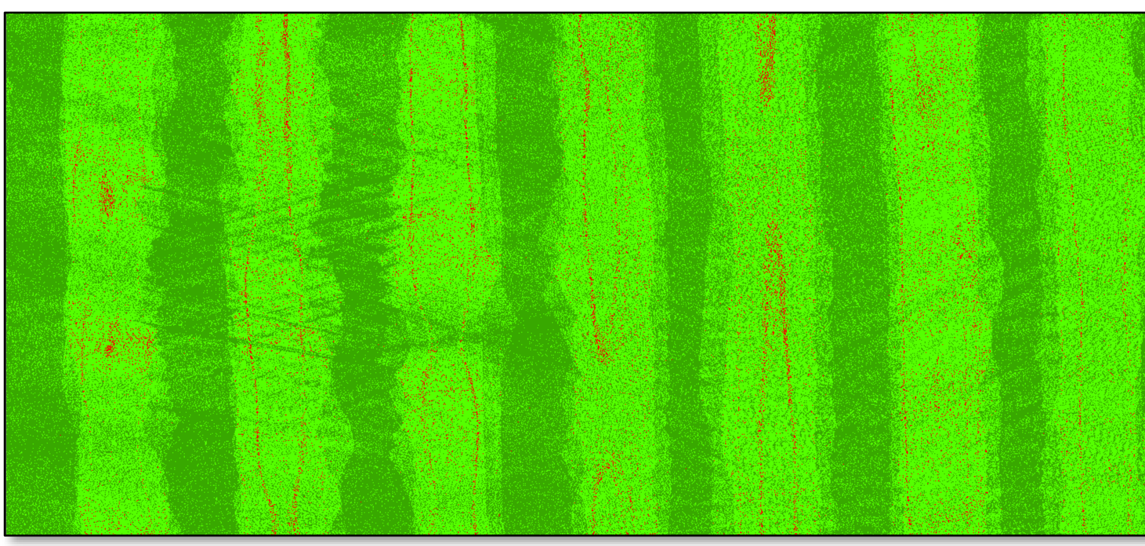
Density Artifacts:

In addition to this type of sensor artifact creating small voids, there also exists a density artifact in these regions. In the areas where this artifact occurs, there is a localized drop in pulse density that manifests itself as multiple “tracks”. These regions vary in width but tend to cover approximately 10-20 meters in width.



Above: Pulse density shown in the tenderloin region of a swath.

Below: Pulse density shown across several swaths. Note the darker green regions represent the overlap between swaths.



The scale of the density examples shown on the previous page exhibit the artifact in a region approximately 10-20 meters wide, typically in 2 "tracks" within the swath. The explanation following in this document will detail why this artifact's width is dependent on topographic relief. The testing conducted by Dewberry reveal that these artifacts do not cause the failure to meet density or spatial distribution specifications as defined in the Lidar Base Specification.

Riegl MTA Zones:

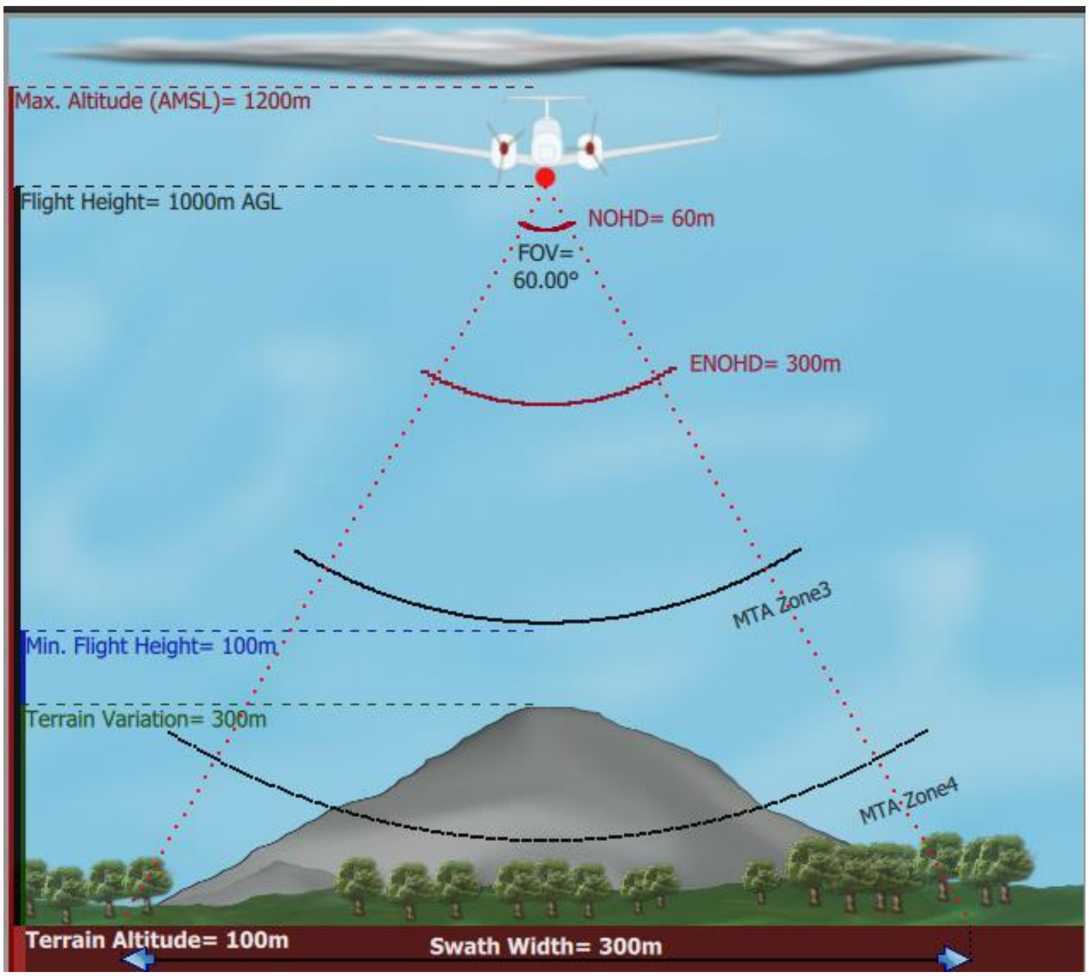


Image courtesy of Riegl RiParameter

Time of flight laser measurements have their maximum unambiguous range restricted by the maximum distance the laser can travel round trip before the next laser pulse is emitted. One strategy to solve them problem is to limit "valid" returns to a fixed range gate window. This processing strategy has the limitation of if the terrain exceeds or is less than the range window distance, returns are either not captured, or in some cases georeferenced as the wrong pulse. This effect becomes more pronounced as laser pulse rate frequencies increase, or larger terrain variation.

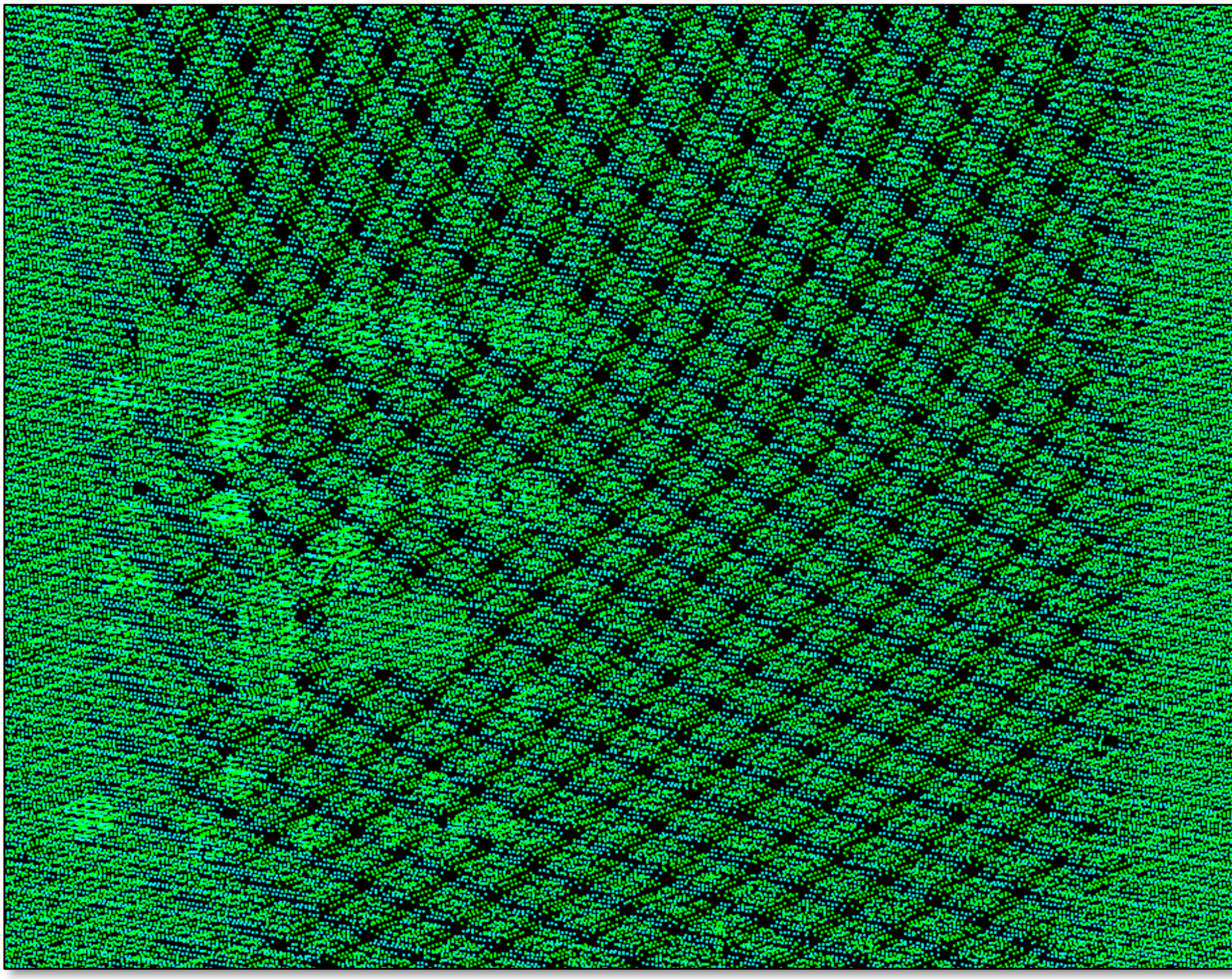
Riegl's Multiple Time Around (MTA) processing is a method that allows for the recording of returns any distance from the laser (within detection capabilities) without forcing range gate restrictions. This not only allows for objects to be mapped within each range "zone", but seamless transitions between range zones.

However due to the nature of lidar system design, there exists a physical limitation on detections occurring at the edge of these range zones. Since the zone edge is defined by the maximum round trip distance of a laser pulse between laser firings, the edge corresponds to a location where the timing events of a laser pulse returning and laser emission occur simultaneously. Due to the backscatter energy from the laser optics and the atmosphere directly below the aircraft, there can exist a narrow window of time where the ability to discern information about the laser return is blinded by this backscatter energy.

This narrow blind zone exists as a range window along the MTA zone edge (typically less than a meter) where point returns can be omitted. This can either be observed as localized area of voids or changes in point density. Since the effect is strictly range based, its horizontal extent is entirely variable on the topography of the objects being ranged at that zone edge. Because of this, the effect is more pronounced in flat terrain.

Blind Zone Example:

Shown below is an example of an MTA blind zone void occurring. Bottom image is a plan view of the lidar point cloud colored by intensity. The upper image is imagery of the same area for scale.



Plan view of point cloud, colored by VQ-1560i Channel (blue channel 1, green channel 2).

The above image is the same void area shown on the previous page. These regions can vary in width and severity depending on environmental and topographical conditions, but this is an example of a more extreme severity case. In most cases the artifact may only manifest as a few pulses missed or a slight change in localized point density. This particular screenshot example however does not exceed the USGS void specification of $(4*NPS)^2$. It has however been observed that in extreme cases this artifact may cause voids that exceed specification.

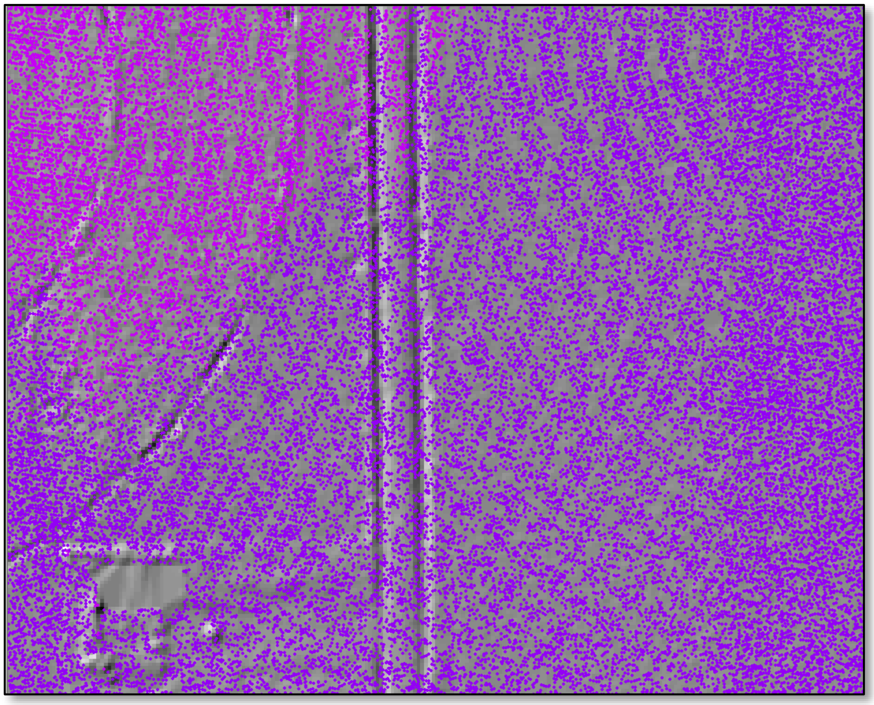
Synthetic point Solution:

Riegl offers a processing solution for filling these MTA void areas. This feature is known as a “blind zone interpolation”. This option is described in their documentation as:

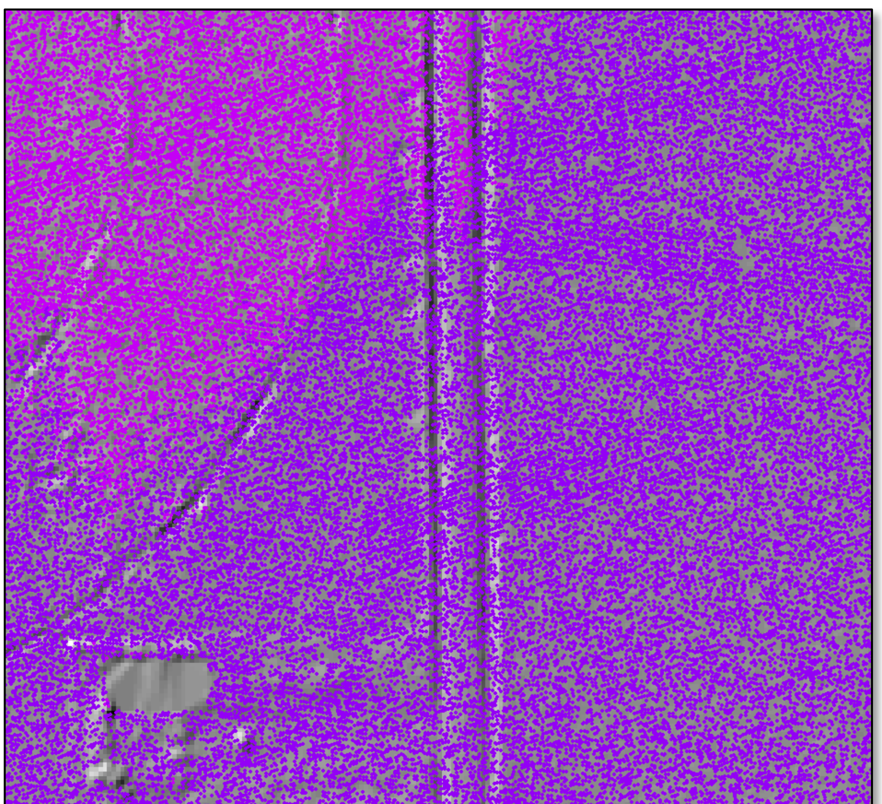
> "*Interpolate blind ranges in MTA zone transition*
> *: Enable this option to receive calculated targets in MTA zone transition.*
>
> *Depending on the type of laser scanner short blind ranges may exist. These are caused by the fact that the range finder cannot emit a laser pulse and receive an echo at the same time. Therefore, blind ranges appear in the transitions of consecutive MTA zones which leave small gaps in the point cloud. These gaps have a typical pattern which again is dependent on the type of PRR modulation.*
>
> *For post processing purposes SDCImport is able to interpolate coordinates within these blind ranges. The interpolation is done scan line by scan line, and considers valid (last) targets on both sides of each gap. Interpolated coordinates in LAS-files are of class "Ground" (classification value 2, if an appropriate classification method is enabled) and flagged as “synthetic” in the classification bit field, according to the LAS standard. In SDC- and SDW-files interpolated coordinates are of class "Ground" (classification value 2, if an appropriate classification method is enabled), according to the LAS standard 1.1, and flagged as "synthetic" in the channel descriptor field according to RIEGL's SDC file standard.*
>
> *The original raw scan data files (i.e. rxp or sdf-files) remain unchanged. Interpolated points are assigned a valid time stamp, which is essential for geo-referencing purposes, but do not carry any full waveform data, as well as no pulse width or pulse deviation values. Amplitude and reflectance values (if available) are calculated/averaged from surrounding points.*
>
> *The intention of providing interpolated points is to alleviate tasks in point cloud post processing (e.g., terrain modeling)."*

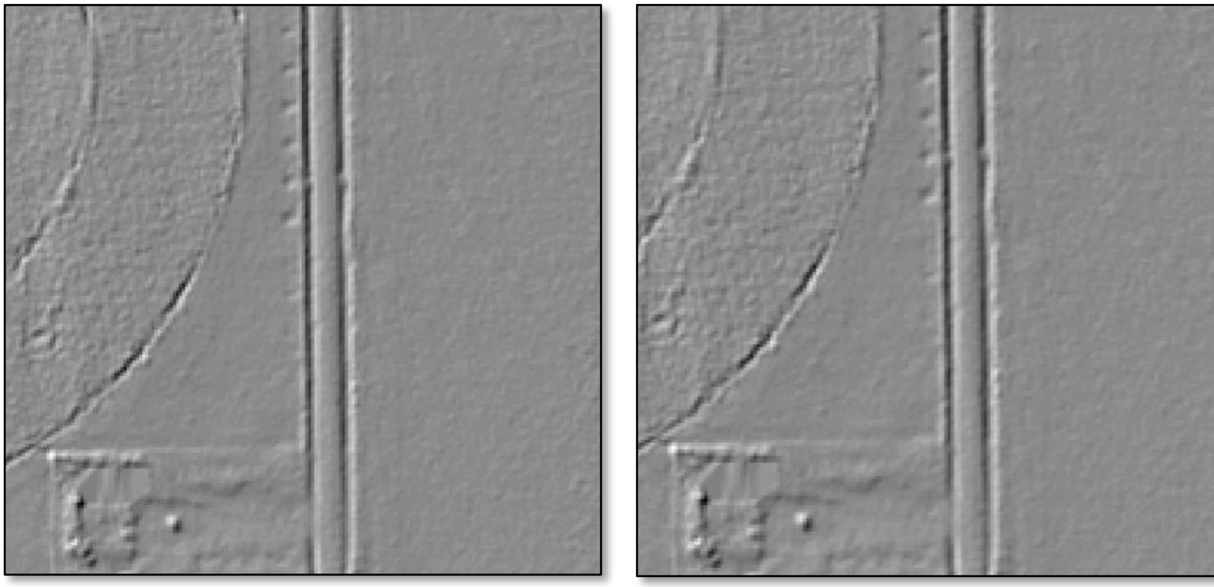
Synthetic Points Result:

The below results show test data that contains these Riegl MTA synthetic points. The observations of the results have shown that as described by Riegl, synthetic points are created in areas along the scan line where the processing software would otherwise expect a last return point.



Above: Ground classified points without synthetic points.
Below: Ground classified points with synthetic points. This is overlaid on a DEM of the sample area.





1m DEM hillshade of the sample area. Left: non-synthetic point DEM, Right: Synthetic point DEM. The DEM created from the synthetic points is virtually identical due to the linear interpolation of the DEM creation.

The resultant DEM from either of the point clouds does not contain any patterning resulting from either the blind zone interpolation or the existence of small voids. It is important to note that the synthetic points have virtually no effect on DEM creation as typical DEM generation utilizes linear interpolation, and the synthetic points themselves are linearly interpolated.

Examining the attributes of one of the synthetic points compared to the point collected before and after it reflect the properties as described by Riegl. This synthetic point (shown below) is a linear interpolation of elevation and intensity values, and placed in the X/Y position where the sensor would have expected the laser pulse to be at that missing return time.

Classification	Easting	Northing	Elevation	Intensity
0	410129.05	3558325.76	+633.11	490
0	410129.04	3558325.08	+633.09	468
0	410129.02	3558324.41	+633.10	474
S0	410129.00	3558323.76	+633.08	494
0	410128.98	3558323.07	+633.06	515
0	410128.97	3558322.39	+633.05	558

Conclusion:

The Riegl Multiple Time Around (MTA) blind zones are a physical phenomenon that exists in any time of flight lidar system that has multiple pulses in the air, and wishes to record all of them seamlessly without range gate limitations. These artifacts exist only in narrow bands of ranges and typically are dependent on flight planning parameters and project area topography.

Riegl offers a synthetic point solution that fills these voids with interpolated points using information from neighboring returns. Due to the typical linear interpolation of DEM processing, the use of these points have little to no effect on DEM generation or visualization.

Call for Action:

Dewberry requests guidance from the USGS in regards to the preference of data processing in situations similar to the examples previously shown. If the option of utilizing the synthetic interpolated point is selected, Dewberry will maintain the synthetic point flag for these points and document their method of creation and purpose in the report and metadata.