Tools, Tips and Workflows

Geiger-Mode LIDAR Workflow Review

GeoCue, TerraScan, versions 015.005 and above

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Geiger-mode lidar data is getting a lot of press lately as the "next big thing" in airborne data collection. Unlike traditional lidar sensors, which we will call "linear-mode lidar" for convenience, Geiger-mode sensors use a different detection method in the receiver – the "Geiger-Mode" part – to enable much higher data collection altitudes and higher resolutions than traditional sensors. Harris Corporation has been providing Geiger-mode lidar data to various US government agencies to validate the accuracy and cost-effectiveness of this technique for mapping applications. If you are interested in the technical aspects of what makes Geiger-mode different, there were several excellent papers on the technology at this year's ILMF conference.

With the growing availability of Geiger-mode data sets, we decided we wanted to look at the data in the context of software tools and workflows. We wanted to verify that data from a Geiger-mode system will work seamlessly with your current tools and techniques. To assist us in this review, Harris provided us with a copy of sample Geiger-mode lidar data and we ran it through a typical production and exploitation workflow. Our primary objective was to establish that Geiger-mode LIDAR data can be ingested into existing workflows and software tools by users without difficulty. A secondary objective was to compare the Geiger-mode data, in this example collected from 17,000 feet, to a traditional linear LIDAR data set collected at 1,700 feet.

The sample data provided by Harris consisted of two data sets; a linear-mode collection (LML) collected at 1,700' above ground level (AGL) and a Geiger-mode (GML) data set collected at 17,000' AGL. The data was delivered in LAS V1.2 PDRF 1 format. The linear data had previously been classified to extract a ground surface. The Geiger-mode data was unclassified. We used the following workflow as a general representation of the anticipated workflow for Geiger-mode LIDAR data in production:

1. The source data was imported into a single GeoCue project, but on to separate layers for each data type (GML, LML).
2. Each set of source data was segmented (tiled) into 1,000' x 1,000' production tiles. Larger or smaller tiles could be used at this point, but for comparison purposes they were kept the same for each data set.
3. The GML data was unclassified. To extract a ground surface a TerraScan ground classification macro was assigned to the working segments. A basic ground macro was used with no attempt to optimize the macro steps or classification algorithm parameters specifically for Geiger-mode data.

4. The TerraScan ground macro was run as an automated batch processing job via GeoCue's built-in distributed processing engine.
5. To allow for direct comparison purposes (see below), the ground class of the LML data was moved to Class 12 (Overlap). An above ground height segmentation was also done to the LML data since this had not been done in the previous classification. This was also accomplished via GeoCue distributed processing of a TerraScan macro.
6. A utility step was used in GeoCue to clean-up the LAS file headers and correctly assign the proper georeferencing information to the data.
7. To create a reference image, the point cloud data was rasterized as a LIDAR Ortho in GeoCue. This is a standard step in production even when supporting imagery is available. The raster was generated using the intensity data of the points to create a raster with a 1' pixel ground sample distance (GSD). A global intensity normalization was calculated and applied by GeoCue as part of the raster generation process. Separate LIDAR orthos were generated for each source data type. The LIDAR orthos were used to do a qualitative assessment of coverage and resolution of the data sets. A second set of LIDAR orthos was generated using a Class/Intensity rasterization as an additional comparison
8. The point cloud data was reviewed and analyzed in LP360. See below for a detailed discussion of the various analysis methods used in LP360. Typically for a production company using GeoCue, such interactive work is launched directly from GeoCue into LP360 via the production checklist. To more realistically represent the end user experience of a local, state or federal government user, a separate standalone LP360 project was built from the GeoCue working segments for this analysis. The two approaches are identical for the purposes of this comparison and further supports the claim that Geiger-mode LIDAR data will be easily integrated by end users into existing software environments.

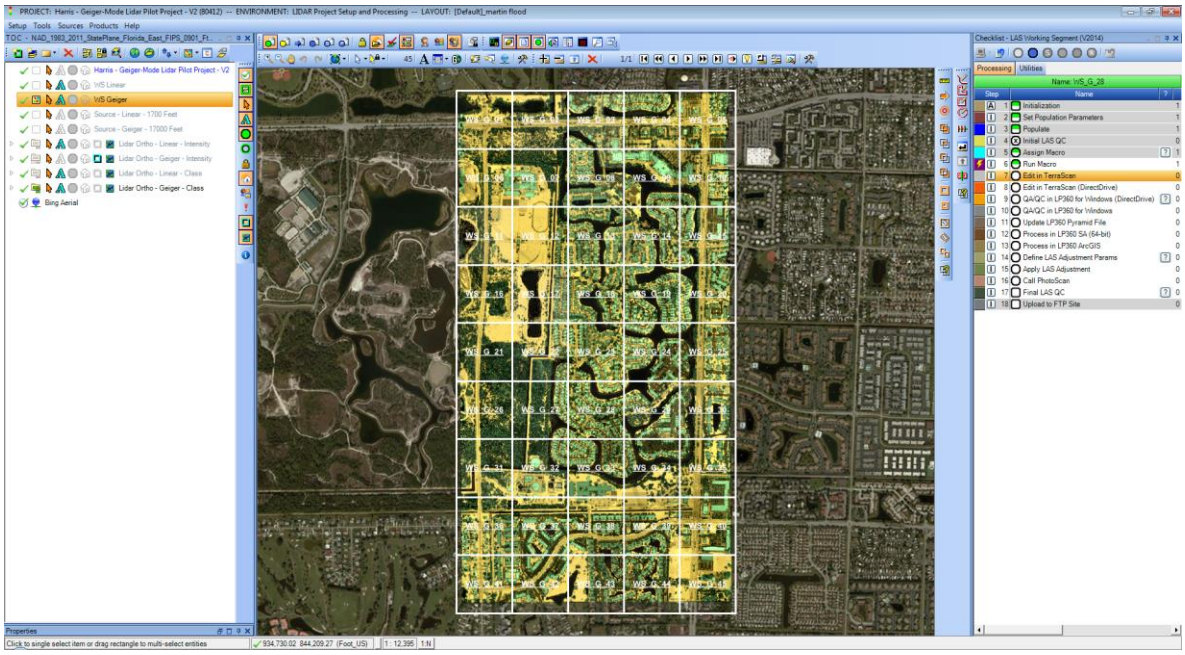


Figure 1 - Geiger-Mode LIDAR Data Project Set-Up in GeoCue

The initial assessment of the data was done by reviewing the LIDAR ortho rasters generated from the point cloud data by GeoCue. Comparing the GML orthos to the LML orthos provides a qualitative check on the similarities of the data sets. The orthos were generated using a 1' pixel (GSD) with global intensity balancing applied. These were viewed at 1:2000 and 1:500 map scale. Note in the screen captures the blue background color bleed thru indicates areas of voids > 1' with single pixel voids (< 1') being filled.

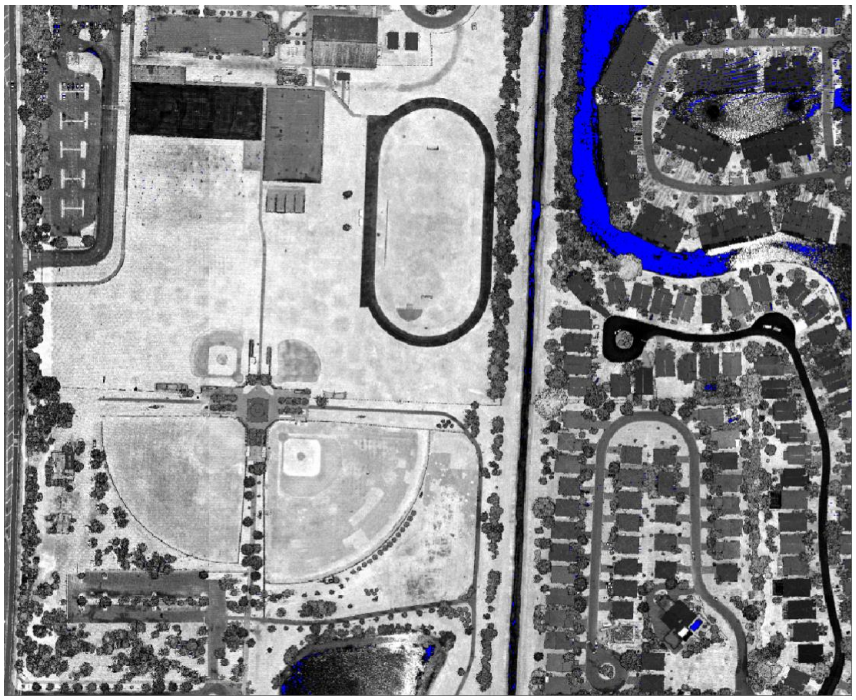


Figure 2 - LML Intensity Raster (1' Pixel, 1:2000 Map Scale)

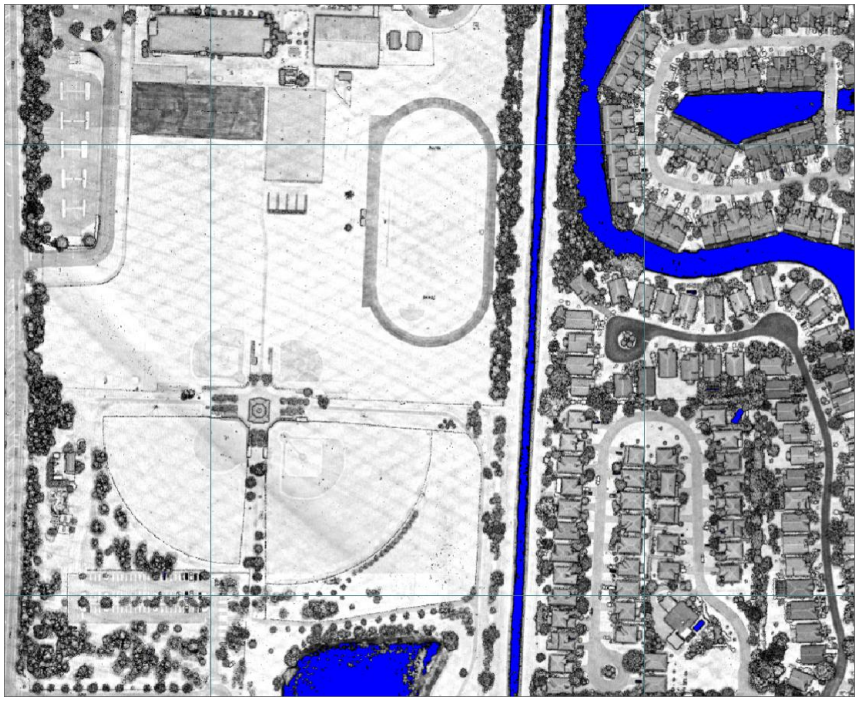


Figure 3 - GML Intensity Raster (1' Pixel, 1:2000 Map Scale)

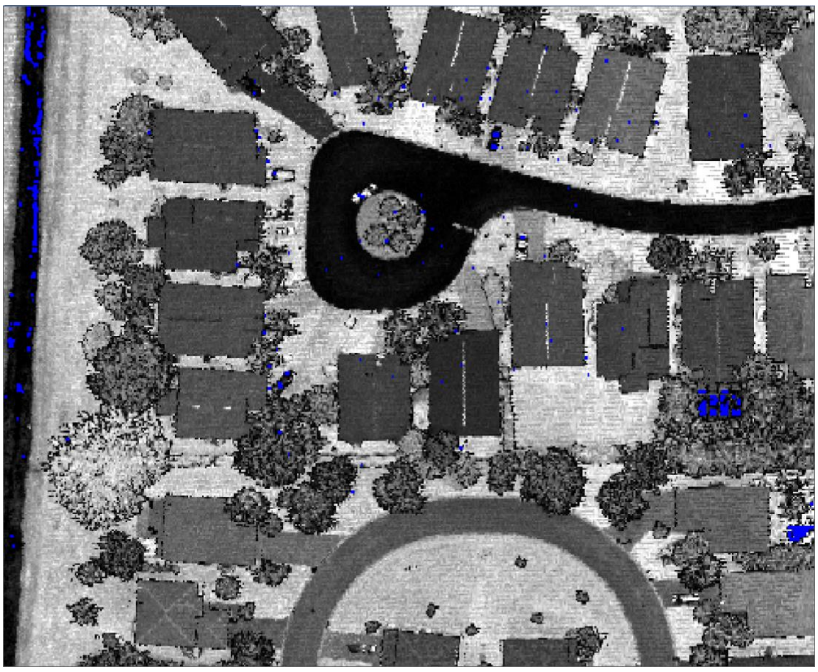


Figure 4 - LML Intensity Raster (1' Pixel, 1:500 Map Scale)

Figure 5 - GML Intensity Raster (1' Pixel, 1:500 Map Scale)

Qualitatively these are very similar results. The GML raster appears slightly sharper with a brighter and more uniform intensity scale, although it does appear to have some cross-hatching in the open areas. The LML raster appears to have slightly more bleed thru in non-water body areas. It also contains noise in the water bodies, but this is probably attributable to less manual clean-up of the point cloud after classification.

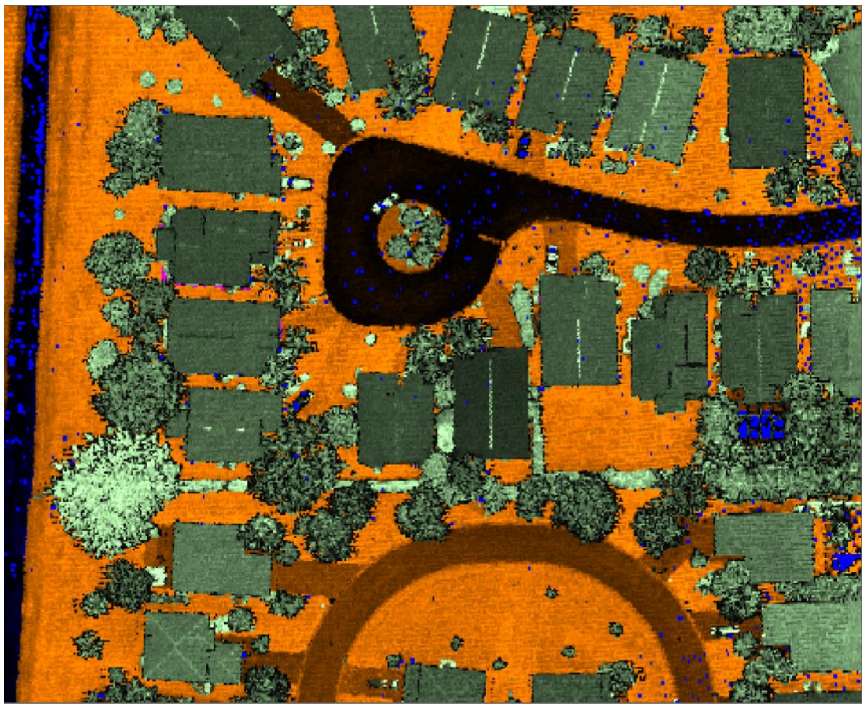


Figure 6 - LML Class/Intensity Raster (1' Pixel, 1:500 Map Scale)

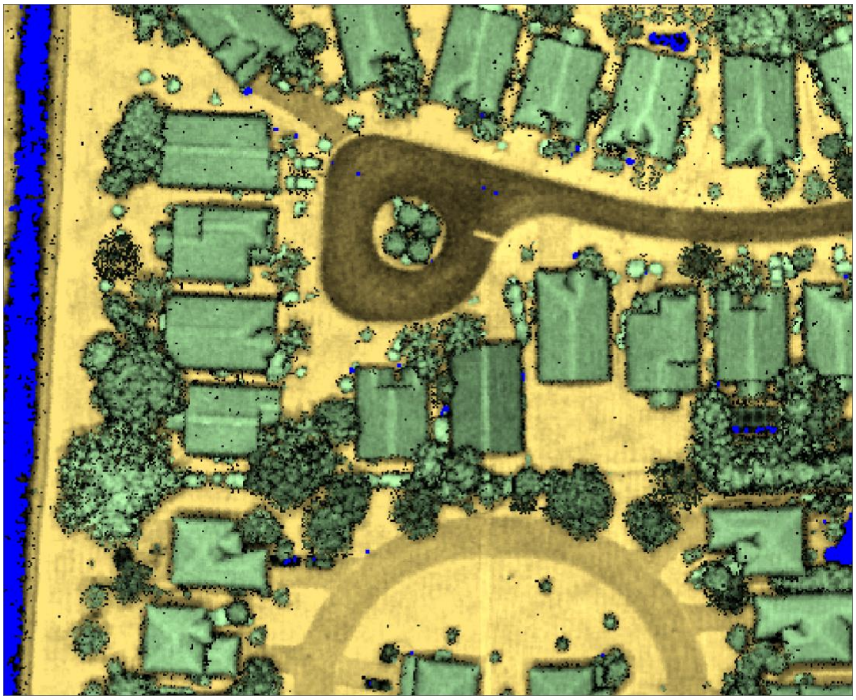


Figure 7 - GML Class/Intensity Raster (1' Pixel, 1:500 Map Scale)

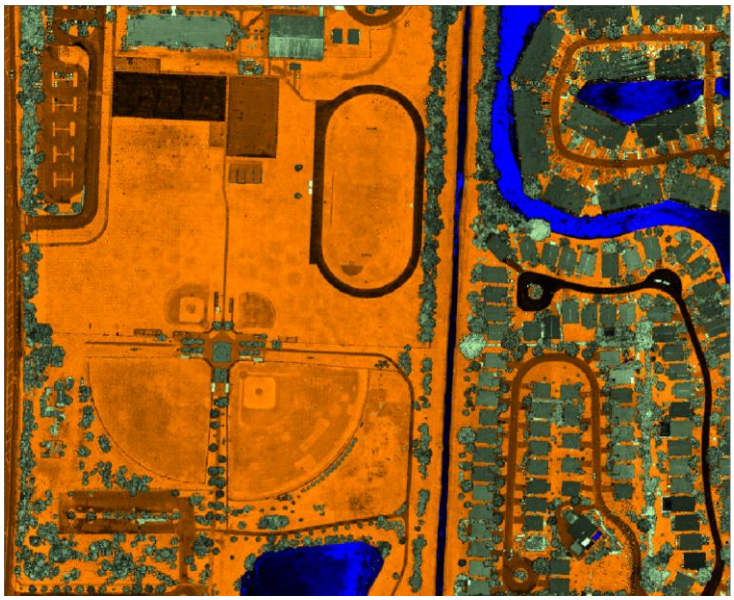


Figure 8 - LML Class/Intensity Raster (1' Pixel, 1:2000 Map Scale)

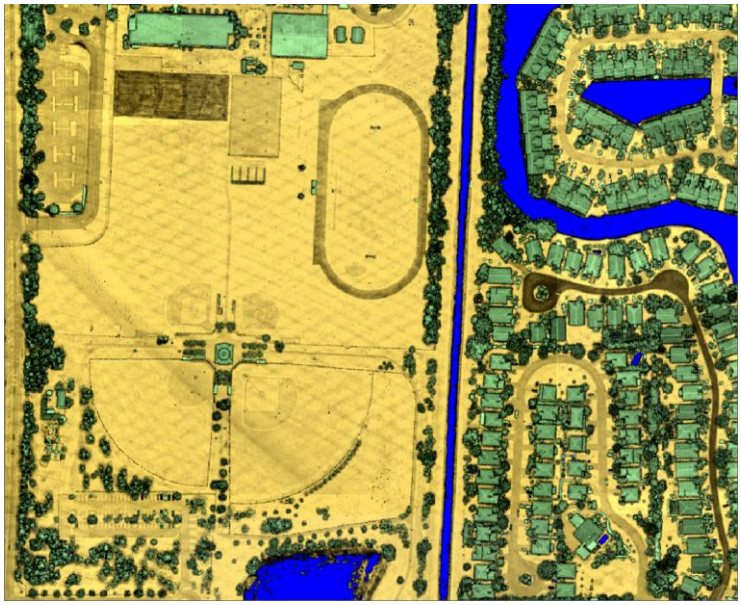


Figure 9 - GML Class/Intensity Raster (1' Pixel, 1:2000 Map Scale)

The class-based rasters also appear very similar, both giving very good visual differentiation between the various class. The greater sharpness of the GML image is particularly evident on the buildings to the east of the scene.

The next assessment of the point cloud data was to visually compare the two ground surfaces in LP360. Viewing the data in the profile provides an effective way to qualitatively compare the point clouds directly, as well as the two resulting ground surfaces. It also allows for the identification of the capture (or lack thereof) of specific features in the point cloud such as

power lines. The screen captures below show the full GML point cloud using the standard color-coding (ground= orange/brown, vegetation=green) and the LML ground points color-coded as purple. No offset was applied to the LML ground surface so in many case the two surfaces directly overlap (and appear orange/brown); in other areas there are clear deviations between the two surfaces.

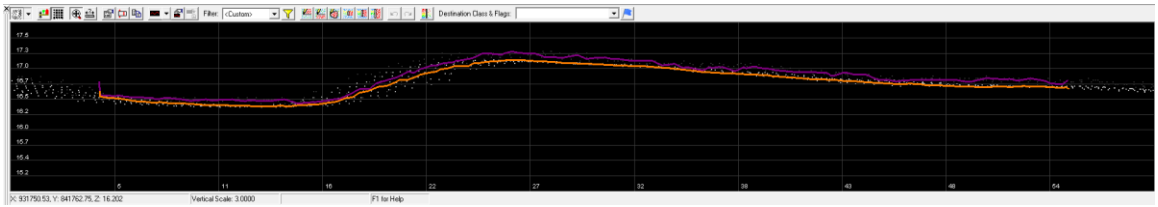


Figure 10 - LP360 Cross Section in Open Terrain (x3 Vertical Exaggeration)

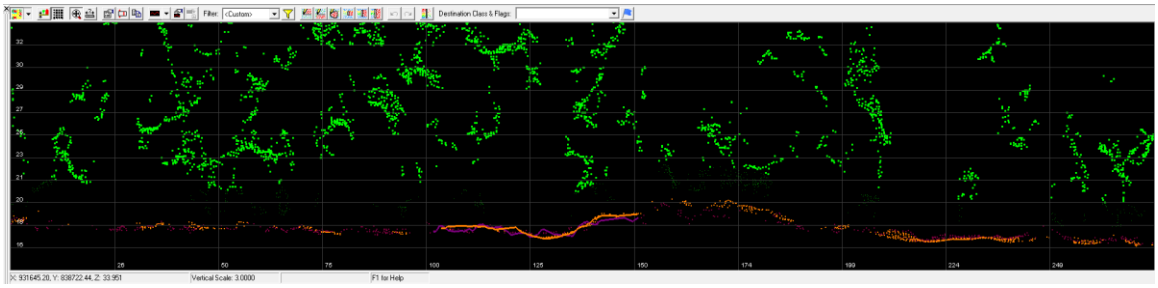


Figure 11 - LP360 Cross Section under Canopy (x3 Vertical Exaggeration)

Qualitatively these again look very similar. The LML surface appears slightly nosier than the GML surface, however it also clearly shows greater density under canopy. The difference in density does not, however, appear to visually affect the fidelity of the surface model.

Both data sets demonstrated the ability to capture thin linear features such as power lines in the point cloud as demonstrated in the profiles below.

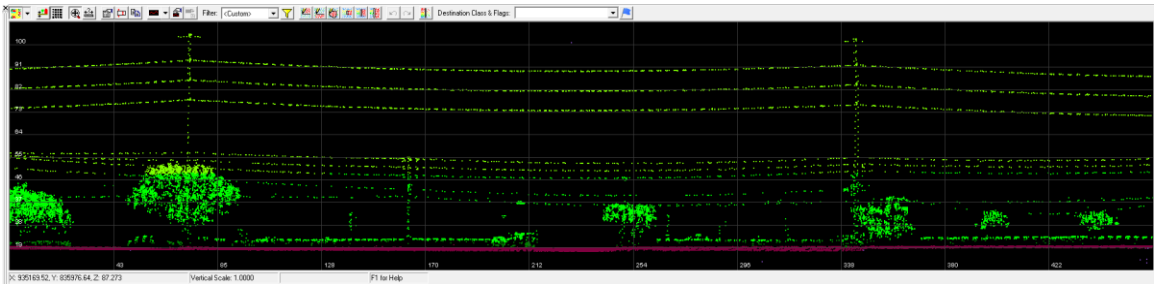


Figure 12 - Residential Utility and Phone Lines Captured in LML Data

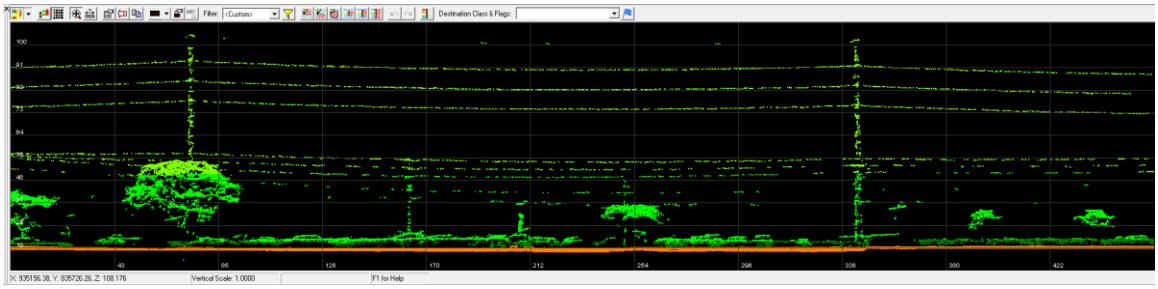


Figure 13 - Residential Utility and Phone Lines Captured in GML Data

Although not tested in this review, the ability of GML to capture small linear features in the point cloud with at least an equal visual resolution to LML means it can assumed that most software tools developed for feature extraction from LML, for example power lines or building footprints, will likely work just as well with GML.

The next assessment of the data involved quantifying the vertical differences between the ground surfaces from the two data sets. To quantify the difference, a set of control points was created from the LML surface and compared to the GML surface, essentially taking the LML surface as “truth”. This technique is a standard method in LP360 and takes advantage of the ability to quickly conflate test points to a surface and then run a control report. Two sets of control points were created, 30 points were collected in open terrain, typically road surfaces or parking lots, and 30 from forested areas under canopy. The results are summarized below.

Table 1 - Relative Vertical Accuracy Analysis (GML to LML)(US Survey Feet)

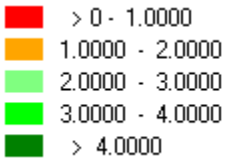
Category	Mean Error	Min	Max	RMSE (All)	RMSE (27 of 30)	VAC	CI
Open	0.027	-0.103	0.180	0.076	0.059	0.08	0.24
Canopy	-0.289	-2.443	0.410	0.665	0.386	0.67	2.01
Combined	-0.131	-2.443	0.410	0.473	0.186	0.48	1.44

The two surfaces obviously diverge under canopy, however some of this error can be attributed to interpolation error introduced by the measurement approach. The check points created from the LML surface were not verified to be over areas where there was corresponding GML data (remember the GML data is less dense than the LML under canopy), consequently some of these points are over void areas. The resulting analysis uses the interpolated GML surface in these areas.

It should be noted that even with this basic approach to generating the GML ground surface, the resulting surface would support generating 2’ contours under canopy from the collection height of 17,000 feet. The two surfaces are essentially interchangeable in the open, showing a fit less than 0.10 feet in all open areas.

Figure 14 - Distribution of Check Points Collected in LP360 (Yellow=Open, Pink=Under Canopy)

Both the GML and the LML data sets were collected with a nominal point density specification of 30 points per square meter. This is approximately 2.8 points per square foot. To assess the density of the data, LP360's display by point density view was used with the following points per square foot settings and a 5' analysis grid:



Looking at the entire point cloud (all classes), the GML shows a fairly uniform point density in the 2-3 points per square foot range across open areas with the density increasing > 4 points per square foot in areas of canopy. There are random areas where the density drops to 1-2 points per square foot. Applying intensity shading to the density display adds visual context for clarity.

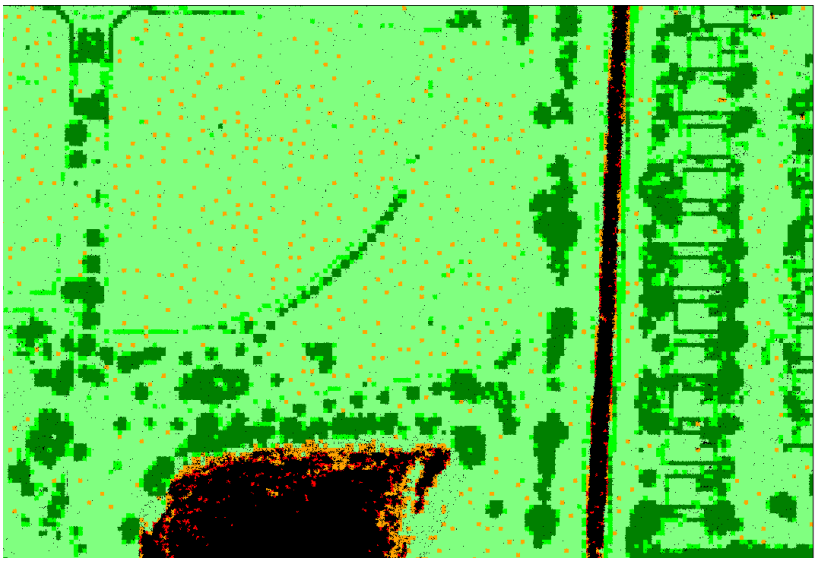


Figure 15 - GML Point Density (All Points)(Light Green is 2-3 pts/sq. ft.)

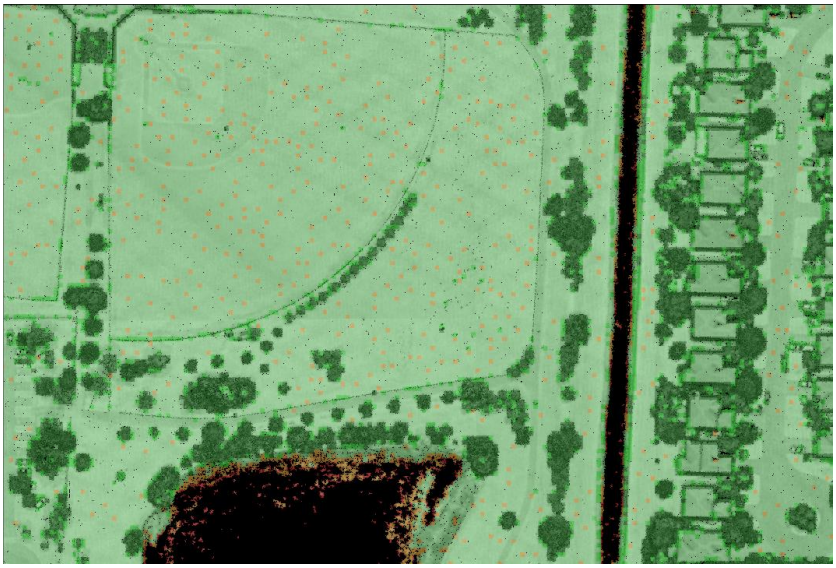


Figure 16 - GML Point Density with Intensity Shading (All Points)

Conversely, the LML data in the same area shows a larger variance of density. This appears to be due to overlap areas between flight lines. There is also more structure within the density distribution within the individual flight lines themselves. The average point density over the entire scene is similar, but the GML shows more uniform point density over local areas.

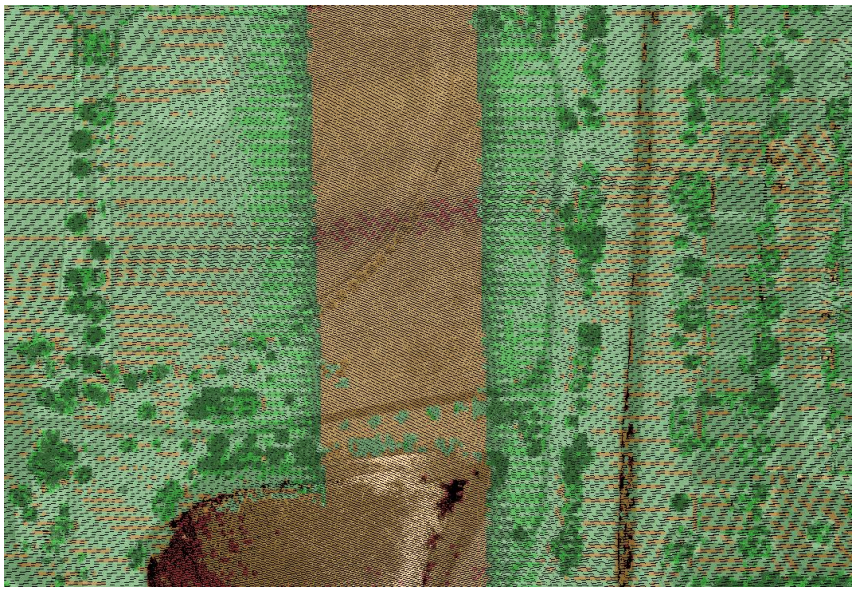


Figure 17 - LML Point Density with Intensity Shading (All Points)

Reviewing the point density achieved under canopy (density of the ground surface under canopy), both data sets drop-off significantly, as expected, to less than 1 point per square foot, however they appear very similar qualitatively when viewed in LP360 as 1’ contours (yellow contours below). Visually the GML data does exhibit large voids in local areas (blue arrows) compared to the LML data.

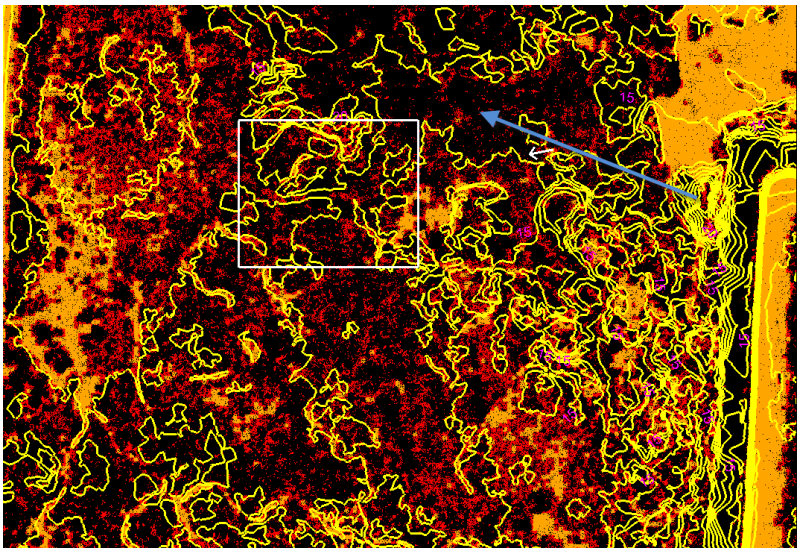


Figure 18 - GML Density Under Canopy (1' Contours)

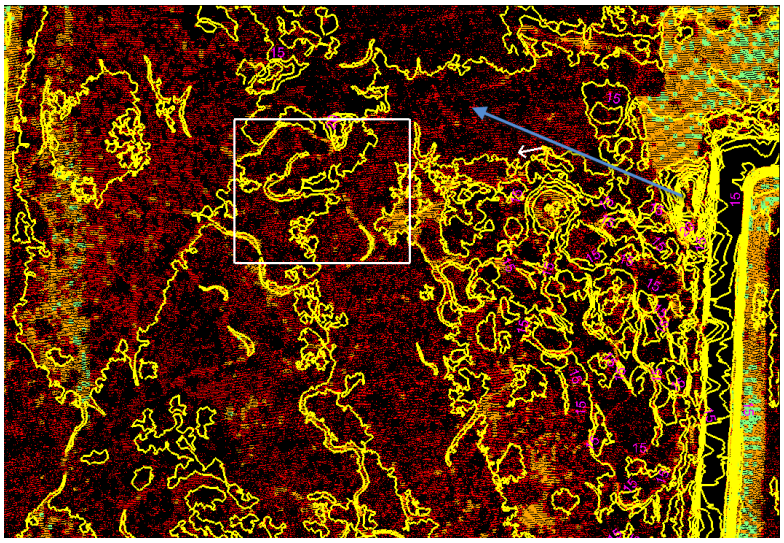


Figure 19 - LML Density Under Canopy (1' Contours)

Viewing the same local area but resetting the LP360 density view baseline to 1 point per square foot shows the LML does consistently out-perform the GML in achieving this target density under canopy, but the GML does achieve 1 point per square foot in the same local areas (see for example the white rectangle), just not as widely across the local surface.

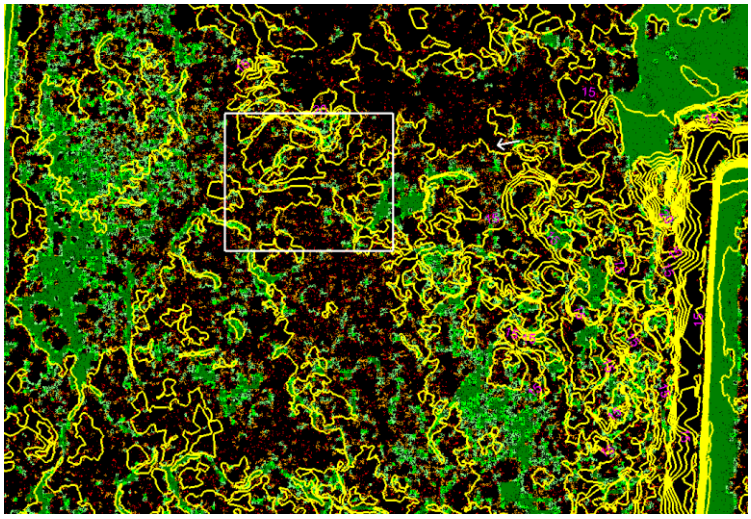


Figure 20 - GML Density Rescaled to 1 pt./sq. ft. Max

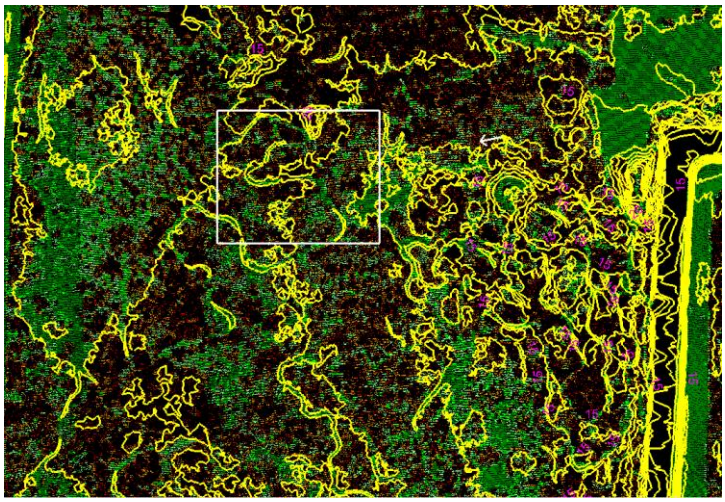


Figure 21 - - LML Density Rescaled to 1 pt./sq. ft. Max

To summarize our findings. Our review of the standard production workflow in GeoCue and Terrasolid software, followed by qualitative and quantitative analysis of the data in LP360, indicated that Geiger-mode LIDAR data sets can be ingested and used in established LIDAR workflows and software tools with no changes. The usability of the Geiger-mode data should be identical to linear-mode lidar for production shops and end users. An extensive technical comparison of the two data sets was not part of the scope of this review, but it was demonstrated that that the GML collected at 17,000 feet provided a very similar end product to the LML collected at 1,700 feet. In open terrain the two resulting ground surfaces where within 0.1' of each other. Under canopy the LML exhibits higher density and there is greater variance between the two surfaces, but both were able to support 2' contour generation, at a minimum. Further refining the ground extraction macro specifically for GML data should improve this fit in the future. The GML data also exhibits a more uniform density distribution when compared to the LML data.