Since 3D laser scanning technology first splashed onto the scene in 1998, professionals have had varying interpretations about what makes this technology different from others. Some have focused on its speed, “imagine capturing 1,000 points per second!” Others focused on its 3D aspects, heralding “the dawn of 3D surveying” (not!). Still others zeroed in on its remote measurement capabilities, labeling it for inaccessible or unsafe sites. And still others focused on its colorful, informative images.

The fact is that 3D laser scanning is about all of those things and more. Fundamentally, however, its single most important and differentiating technical aspect is its high point density. With high point density as “the primary driver,” its other key features are natural companions.

High Point Density
It’s not uncommon for a 3D laser scanner to capture a radial “grid” of points for a site in which the points are centimeters or inches apart (in some cases even millimeters apart). This orders-of-magnitude leap in “survey density capability” raises the question of why traditional topographic and planimetric surveys are typically done at a stationing or grid density of 50m, or 25m, or, if it’s really tight, 1m? For that matter, why do surveyors collect points at corners, intersections, edges, features, or in areas of sharp changes in geometry? Why not just blanket the site with points, so that you leave no doubt about the site’s geometry? Blanketing the site with points would also save a surveyor from having to return to the site for any of the following reasons:

- Re-checking points in question (reduce potential errors)
- Something was missed (reduce potential omissions)
- Project scope is changed
- Other clients want different data from the same site
Theoretically, someone could use conventional means for this sort of high-density or blanket topographic survey. However, surveying practices must be cost-effective for producing maps that meet the needs of the map users. The extra cost and time needed to do such a dense survey with traditional methods would not (normally) be cost-effective; the extra data and detail would be “nice to have” … but not worth the added cost and time.

**Laser Scanning Today: Cost-Effective High-Density Surveying?**

Typically today, if you compare laser scanning with traditional methods for the types of projects in which laser scanning is most often used, you will find the following:

- Scanning field time and labor scanning costs are less
- Scanning office time and labor costs are the same or higher
- Scanning equipment depreciation costs are higher
- Scanning ancillary costs (e.g., lane closure fees, lift rentals, downstream construction savings, facility down-time savings, per-diems, “go-backs,” etc.) are less
- Scanning requires a different approach to project control.

On a project cost basis, a project manager is often weighing laser scanning field and ancillary cost savings against its higher office and depreciation costs. Depending on the project, the net project cost today of using laser scanning for a detail, engineering, and as-built survey can be less than, the same as, or more expensive than traditional methods. What if it didn’t cost any more … or not much more … to blanket a site with points? Why wouldn’t professionals want to have this extra data and extra detail, the extra confidence from a high-density survey? These are the types of questions that laser scanning is prompting professionals to ask today. [Note: A detailed discussion of laser scanning project costs will be the subject of a future article. This article only addresses cost considerations at a very high level, such that discussions on technical and feature differentiation are balanced with economic considerations.] Similarly, we will visit the question of training costs and personnel qualifications in a future article.

**Remote Measurement: The Only Way to Cost-Effectively Achieve High-Density**

In order for a high-density survey to stand any chance of being cost-effective, it needs to rely on ultra-fast data gathering (hundreds or thousands of points/sec). This, in turn, means that it’s not feasible to use methods that rely on each point being visited by a person. Thus, to achieve an economical high-density survey, all laser scanners rely on remote measurement or reflectorless technology.

Many readers may not realize this, but a traditional total station or EDM actually “dwells” its beam on a single point,
averaging perhaps a thousand intermediate measurements over a short time span (e.g., one second) to generate a final, more accurate single point measurement. A laser scanner, on the other hand, records each of those one thousand or more “intermediate measurements” as unique points; rather than dwell its beam on a single point, a scanner sweeps its beam (using internal mirrors and motors) over the surrounding scene. Since remote measurement is inherent in every laser scanner, laser scanners offer all the generic advantages of remote measurement for mapping:

- Sites difficult to physically occupy (e.g., domed ceilings, industrial piping and equipment, vertical rock faces, etc.)
- Sites hazardous to occupy (e.g., hazardous materials pits, decayed building interiors, busy roadways, etc.)
- Objects or sites that are fragile or should not be touched or disturbed (e.g., heritage structures, crime scenes, etc.)

Furthermore, by combining high-density data with remote measurement, another unique advantage emerges: higher confidence for many remote measurements. When a small feature such as a corner or a particular point on a structure is captured with a laser scan, the user can enjoy higher confidence that the coordinates of the corner (once extracted from the scan) are, in fact, correct. Uncertainty is removed that a single-shot, reflectorless measurement may have captured some other point on the structure (e.g., not the exact corner, or perhaps captured something in between the instrument and the desired structure).

3D and Imagery are a “Bonus”

When a scanner’s X,Y,Z measurements (i.e., points) are displayed on a computer monitor, the point density is often so high that the resulting “point cloud” has a photographic-like quality to it. Images can be one-color, gray-scale, false-colored, or even true color. Since all of the laser scan points are 3D, the files can also be viewed and navigated just like a 3D computer model. This 3D visualization and the accompanying imagery can provide additional insights into the scene. A few years ago, a famous, old Buddha statue that had been carved into a Korean mountainside was laser scanned. Local residents had long been curious as to why the statue did not have a smiling face, as all other Buddhas are smiling. When researchers examined the laser scan of the Buddha’s face in 3D on a computer, lo and behold, the face did have a smile...even though people standing at the base of the statue couldn’t discern it.

High Point Density + 3D + Imagery = High Definition

3D visualization and informative imagery combine with high-density X, Y, Z data to provide a rich “high-definition” representation of the scene or structure. Laser scanning’s initial 3D and imagery-filled impressions can excite our senses. In reality, however, if you look at the commercial practice of laser scanning today, the primary value of laser scanning resides more in its project-related economics than in its 3D and imagery aspects. Whether the data are used to create 2D deliverables, spreadsheet tables of values, 3D line-work, full 3D models, or simply used as a backdrop for design or construction QA, it is the net project cost, the completeness of the data, and the added confidence in the data that are usually the primary sources of economic value for a given project.

Added Confidence in the Survey

A key potential advantage of a laser scan survey is that it can provide more confidence in the survey results than those of a traditional survey. This added confidence comes from several sources:
- A higher density topographic survey is essentially a more complete topographic survey. Details can be captured that might otherwise be overlooked.
- Extra data can be considered as “over-sampling” or added...
redundancy, akin to taking extra shots, double- and triple-checking data, etc. High point density often eliminates “guesstimates” or the need to make assumptions about the geometry and relative spatial positioning of objects or structures.

- All captured measurements are direct measurements of the surface in question. No offsets or poles are used, so concerns about poles not being vertical or offset estimates being incorrect are eliminated.
- Imagery and 3D visualization inherent in laser scan surveys can also provide added confidence that the mapping results correspond to what was really there at the site.

The potential for laser scanning to provide added confidence in a topographic survey’s results resonates to the very core of the survey and engineering professions. One of the main reasons why surveyors are contracted over non-surveyors is that clients want results they can trust from an expert. This is also often why a client may choose one survey or engineering company over another or use one sub-consultant exclusively: the client trusts their work more.

For engineers (i.e., a surveyor’s client), having more accurate and complete as-built information can deliver big, downstream economic and schedule benefits for revamp projects, construction QA, asset management, etc. For example, an engineering manager for a major brewing company recently cited >$700,000 in estimated downstream construction re-work savings for a plant revamp project thanks to the accuracy and completeness of a $35,000 laser scan as-built survey of his plant. It is no surprise, therefore, that laser scanning technology has attracted—and continues to attract—so much interest within the surveying and engineering professions.

**Summary**

In summary, the high-density feature of laser scanning is its most fundamental, driving technical differentiators compared to other survey methods. In addition to high-density data, a laser scan survey also features ultra-fast data capture, remote measurement, 3D visualization, and informative imagery. Altogether, a laser scan survey could be called an “ultra-fast, high-definition, reflectorless topographic survey.” This unique combination of features leads to several key potential advantages over other survey methods for detail, engineering, and as-built surveys, including the fundamental potential advantage for the surveyor and engineer to enjoy more confidence in the survey results.

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