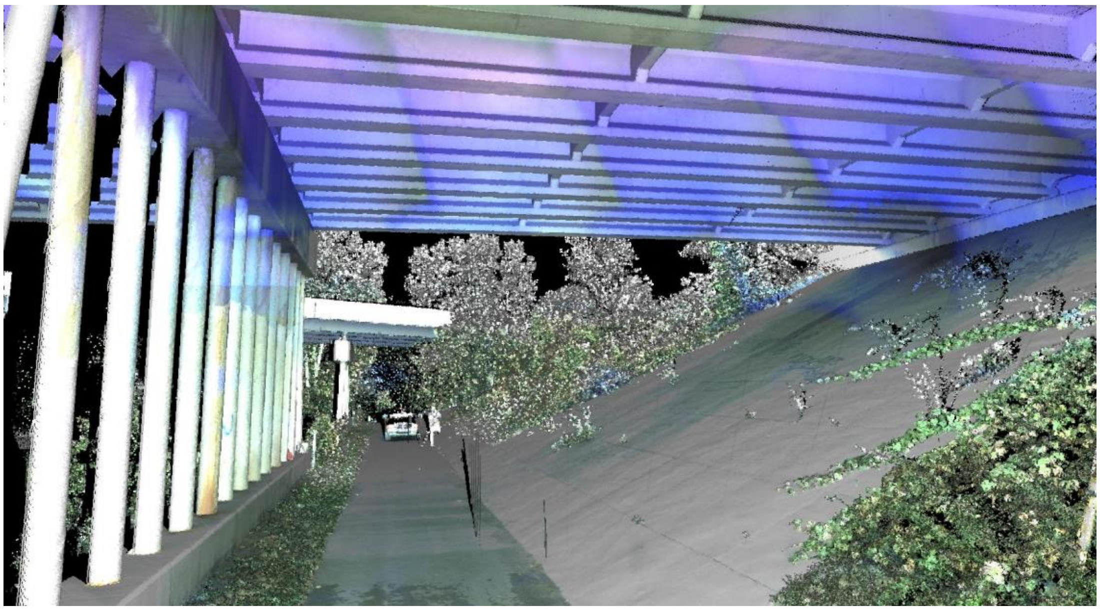
LIDAR Scanning: Definitely Worth the Trouble

How Standards & Specifications Can Help Organizations Use 3D Laser Scanning More Efficiently & Profitably



Point cloud rendering courtesy of Great Lake Geomatics. NB lanes of I-275, Lower Branch River Rouge, Canton Township, Michigan.

Light Detection and Ranging (LIDAR), or 3D laser scanning, is an increasingly mature technology with many obvious applications in traditional survey, design, and engineering practices. It is the premise of this paper that the creation of detailed standards and specifications for laser scanning work helps to realize the full potential of a laser scanning investment.

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Definitely Worth the Trouble

Laser scanning remains a complex and sometimes bewildering technology due to the sheer breadth of its applications and the many different fields it affects; when one basic solution is having a major (sometimes revolutionary) impact in arenas as diverse as medicine, cinema, design, and manufacturing, it's natural to feel some reluctance about jumping in.

On the other hand, as with any new technology, there is also the promise of new efficiencies and capacities.

In fact, LIDAR's potential return on investment (ROI) is high, for several reasons:

LIDAR Is Fast

Most laser scanning equipment intended for survey use is capable of gathering millions of points in a typical survey session. This means that complex topographic surveys and surveys of intricate structures, like bridges and wastewater treatment plants, can be completed many times faster with terrestrial scanners—work that might have taken days or weeks with total stations can often be completed in a single scanning session. Mobile (vehicle-mounted) terrestrial scanning and airborne LIDAR can realize even greater gains when compared to traditional methods.

LIDAR Is Accurate and Comprehensive

For many applications, laser scanning can produce deliverables better than any traditional method, regardless of the time allotted to the survey. For example, deliverables based on bridge scans (point clouds, models, and so on) enable deskbound designers to perform virtual on-site measurements without ordering new fieldwork. Scan-based design can also facilitate more offsite fabrication, creating a higher-value product for consumers of survey data. Similarly, mobile scanning units routinely produce highly accurate route surveys in high-traffic areas without lane closures—this capacity alone compels many government transportation agencies to evaluate scanning equipment.

Other Advantages

Additional advantages of LIDAR survey techniques continue to emerge as more laser scanning work is performed. Laser scanning is safer, as it can keep field crews away from dangerous areas like freeways, rock faces, and material piles. LIDAR data is so comprehensive it can be revisited as needed for additional survey information—"remining data"—after the initial project has been completed. To facilitate the use of data using Autodesk® Infrastructure Design Suite, LIDAR data can be used to extract linear survey features such as curb lines and edge of pavement, and to create or enhance ground surface models that are the basis for proposed infrastructure design. In addition, the Autodesk® Infrastructure Design Suite can display LIDAR data in different ways in order to help visualize and validate existing conditions—useful for conveying information in design and public presentations. The data sets produced by laser scanners are so large that additional uses will, no doubt, continue to be discovered.

Return on Investment

The California Department of Transportation (Caltrans) published a cost-benefit analysis in connection with the department's first major use of mobile terrestrial scanning, the Doyle Drive Project in San Francisco; this was a high-accuracy survey of about 20 miles of high-traffic, four-lane freeway. Even when accounting for mobilization costs of the mobile scanning equipment (the work was subcontracted to an out-of-state provider) the department realized a direct savings of $65,800. When costs of freeway shutdown (to the public) are factored in, the report estimates a total savings of $167,800. Neither of these figures accounts for additional savings due to remining of the scanned data, additional utility due to data use in visualizations, or increased crew safety due to minimization of traffic exposure.

Premise

Progressive firms and agencies have many reasons to seriously consider major investments in LIDAR data collection and workflows, but must also acknowledge the risks associated with new technology and techniques. One way to optimize laser scanning ROI is to create enterprise-level standards and specifications for laser scanning deliverables, data collection, project selection, field routines, and associated laser scanning tasks.

Benefits of Laser Scanning Standards Creation

Laser scanning data can be used to accurately depict existing locations of utility poles, fences and signs, to evaluate encroachment issues

Creating standards and specifications for laser scanning has the potential to facilitate widespread implementation of this new technology and give new users, of the equipment and the data, a comfort zone, which can lead to more consistent collection and use of the data. It also provides a way to capture institutional knowledge as more is learned about the technology, and helps to specify and evaluate the work of subcontractors.

Benefits of standards creation include:

- Increased institutional acceptance of a new technology (internal marketing)
- Enforcement of standards for deliverables across multiple departments
- Reduction of project planning time due to checklists and increased understanding of technology
- Minimization of rework and errors
- Wider adoption of standards throughout an organization
- Improved results when using subcontractors for scanning

Many of these benefits are intuitively obvious. Few would dispute the utility of writing down procedures, creating manuals and checklists, defining standards, and so on. Other benefits emerge during the standards creations process; that is, the very act of defining standards and specifications helps an organization to identify useful aspects of laser scanning workflows and deliverables.

So, what might a formal set of standards and specifications for laser scanning look like? What makes it useful? What are possible creation processes?

Terrestrial Laser Scanning Specifications

At the basic organizational level, laser scanning standards should contain sections that discuss, for example, equipment setup and calibration procedures, considerations for project assignment and crew preparation, minimum criteria for deliverables and documentation, and project selection criteria for the different types of scanning methods that are acceptable, including stationary (tripod-mounted) terrestrial laser scanning (STLS) and vehicle-mounted mobile terrestrial scanning (MTLS). Best practice dictates that checklists of items and information needed before and after scanning, and before and after registration and/or vectoring, should also be included.

Standards should move easily between "entry-level" scanning information—for example, the glossary and overview sections defining stationary and mobile scanning—and considerably more detailed and referenced information. As an example of the latter, consider this passage from standards created by the California Department of Transportation, which are published in Caltrans Survey Manual, Chapter 15:

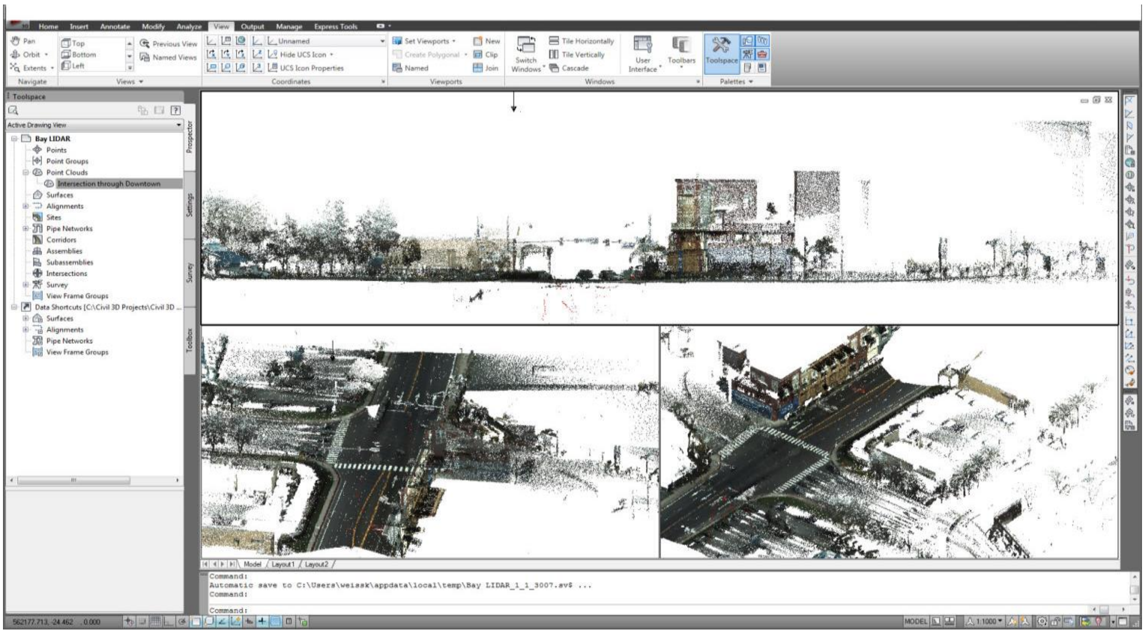
"Just as with reflectorless total stations, laser scan measurements that are perpendicular to a surface will produce better accuracies than those with a large angle of incidence to the surface. The larger the angle, the more the beam can elongate, producing errors in the distance returned. Waveform system elongation errors have been documented and can be corrected. (See: "Improving quality of laser scanning data acquisition through calibrated amplitude and pulse deviation measurement" by Martin Pfennigbauer and Andreas Ullrich, Proc. SPIE 7684, 76841F (2010), DOI:10.1117/12.849641 http://www.SPIEDigitalLibrary.org)"

Information contained in the standards should serve several different audiences: those seeking to learn more about a newly available solution (thus facilitating internal marketing); actual users of scanning equipment and data; and project managers creating RFPs for scanning work.

Standards documents may contain theoretical, largely educational information intended for those who want to learn more about a complex technology, as well as practical, nuts and bolts information for those who actually need to get work done.

Consider the standards development from the viewpoint of a crew chief newly assigned to laser scanning work. After first reviewing theoretical sections to get up to speed on the basics of scanning technology (for example, the differing strengths of time-of-flight and phase-based scanners), he can consult sections on applications and project selection to make sure he is using his assigned equipment appropriately—much of this information is in list or table form, enabling quick decisions. He can then refer to detailed guides that help him plan and execute survey projects, evaluate results, and prepare deliverables.

Likewise, office consumers of laser scanning data—from internal or external providers—should be able to consult the developed standards to determine whether scanning is the most cost-effective means of obtaining data for a particular project, as well as to specify quality and form of deliverables once that determination has been made. There may also be detailed routines, updated as needed, for processing laser scanning raw data and importing point clouds into design software, such as Autodesk InfraWorks 360®, AutoCAD® Civil 3D® and AutoCAD® Map 3D software.



Point Cloud of intersection examined in AutoCAD Civil 3D.

Since LIDAR is an emerging technology, standards and specifications should be considered a living document—one that is revised as better procedures and equipment comes online. As an example, after completing an initial mobile scanning project covering several miles of freeway, one agency learned the hard way (after fieldwork and post-processing) that point data was highly consistent within "passes" (discrete segments of scan data gathering) but that positional consistency between passes was unacceptably loose. This data was used to establish minimum overlap standards and guidelines for separately surveyed reference points appearing in multiple passes, and these procedures are now being incorporated into the agency's standards. Thus, lessons learned on one project are captured and published for the benefit of subsequent projects.

Can standards be developed by adapting standards originally developed for traditional survey equipment, such as total stations? Most experts believe that this is an ineffective approach, because laser scanning data is fundamentally different from traditional survey data. For example, while it's true that individual points may not be as accurate as points gathered with total stations, the gathering of millions of points make a model more accurate in a way that goes well beyond what can be done with total stations. As technologies like 3D machine guidance become more common, this will have to be acknowledged. In some ways, the work of establishing standards for laser scanning is just beginning.

As the laser scanning knowledge base increases, it will likely become a recommended method for capturing existing conditions. But it is unlikely to completely replace current methods. Rather, laser scanning should be seen as another tool in the toolbox; it will quickly become routine to evaluate a project to determine if scanning is the appropriate "tool."

Creating Standards & Specifications that Work

There will no doubt be one or more laser scanning evangelists at any given organization, and it makes sense for them to be involved in standards creation. But where possible, it also makes sense to call on any available external resources, such as consultants or academics.

When creating the earlier referenced Chapter 15, Caltrans gathered together research consultants at the University of California, Davis, as well as experts from several Caltrans districts and from vendors and scanning subcontractors. An approach where one invested individual spearheads a group effort could also work at most agencies. Other approaches are possible of course; but as the first successful codification of laser scanning standards and specifications, the Caltrans methodology merits consideration by other agencies taking on this task. The results are publicly available and are already influencing other agencies.

The use of laser scanning is just getting started but will probably expand quickly. At some government agencies, it has already expanded into accident reconstruction and asset management, and geotechnical teams are using laser scanning to keep crews off of unstable rock faces. Having good standards provides a base for that expansion.

So, is it prudent to prepare standards and specifications for laser scanning at large firms and agencies that are beginning to use this exciting new solution? Experience has shown that it is, indeed, *definitely* worth the trouble.

[1] Mobile Scanning - Cost and Benefit Analysis Caltrans District 4 Doyle Drive Project San Francisco, CA - December 2009

[2] http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/15_Surveys.pdf

[3] http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/Fig_5_1A_Ratio-2006.pdf