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TECHNOLOGIES

# How to Achieve Effective Terrain Visualization with TerraGo 3D GeoPDF

unleash your geo

## Executive Summary

The growth in the use of LiDAR as source data for terrain analysis has resulted in an explosion in the amount of this data available for consumption throughout the world. This availability has fueled a demand for access from customers who wish to leverage their investment in LiDAR collection to provide products for use by non-technical, non-GIS savvy users. These users typically do not have the training or software necessary to take advantage of this data in its native format. In addition, file sizes are large, making them difficult to disseminate to remote workers. Complex viewing software tools must also be downloaded.

To solve these problems, some of the leading geospatially savvy organizations are turning TerraGo Technologies and the popular industry format—GeoPDF—as a means of providing users an easy to use, easy to access method of delivering LiDAR-derived products as 3D models for display. This new solution not only addresses the ease of use and functionality requirements by leveraging the free Adobe Reader, but it also provides an infrastructure that supports the visualization and dissemination of the data by virtually anyone, anytime, anywhere.

The purpose of this white paper is to discuss the challenges many organizations face as they invest heavily in LiDAR data collection. While this data is extremely valuable to engineers and technical resources, the true value of it can be unlocked when it can be shared with the people who need it most—when they need it, where they need it. Equipped with the right information, these people—soldiers, intelligence officers, transportation and urban planning managers, disaster management officials, watershed management directors, and even taxpayers/constituents who are often funding the data collection efforts—are able to make better decisions, respond faster, and be more productive.

## Increasing Demand for 3D Display

LiDAR data collection and processing has been growing at a rate of 18 percent per year since 2005, even in the face of a declining economy. To date, the primary use of this data has been for analyses, cartographic production, terrain modeling and general GIS intelligence. However, the fundamental value of LIDAR data is in its use for terrain visualization.

Unfortunately, LIDAR visualization is currently limited to users having access to specialized software and with unique skills in manipulating LIDAR data sets. While the number of users with such access and skills might be numbered in the thousands, the number of users with a potential need for terrain visualization can certainly be numbered in the millions.
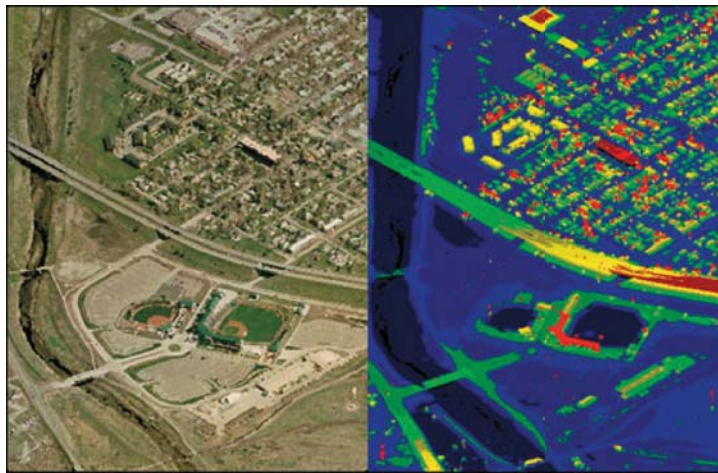
*Figure 1: A raw point cloud at right compared to the image at left demonstrates how challenging it can be for a non-GIS savvy user to understand what the LiDAR data shows.*

Perhaps the best example of this need is the U.S. Army, operating in the challenging terrain of Afghanistan and Pakistan. The Army has collected enormous amounts of LiDAR and imagery data in these areas via its BuckEye program but has found that it is unable to furnish this data to those in greatest need of terrain awareness. To address this problem, the Army Geospatial Center is pursuing the use of enhanced 3D PDF files to deliver 3D surface models and draped imagery as a terrain visualization tool.

A similar need has been revealed within the Red River Basin of the upper Midwest, which is undergoing a 40,000 sq. mile LiDAR collection effort. This project currently has no method for providing the data to its non-professional constituents and is also considering a PDF-based solution.
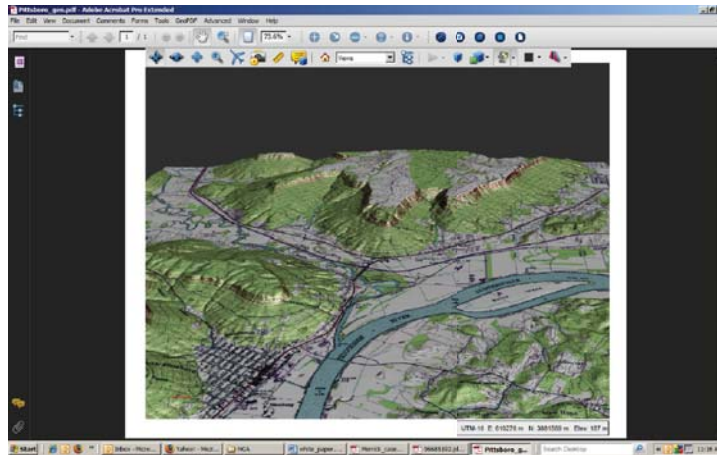
*Figure 2. Here, a digital elevation model is draped over a USGS quad sheet to enhance terrain visualization via 3D GeoPDF.*

## The Challenges of 3D Terrain Visualization

Clearly there is a need for simple, freely available 3D terrain visualization software as well as commercially available tools for converting LiDAR data sets to standard formats, which can be consumed by those viewers. There are, however, a number of challenges facing any organization attempting to deliver this capability.

In order to be useful, a 3D terrain visualization tool must meet a minimum set of requirements, some of which are unique to the geospatial domain. While there are many 3D viewing applications available for gaming, manufacturing and AEC, terrain visualization has additional requirements for measurement and coordinate display. The software must allow surface points to be located and coordinates and measurements displayed in a variety of standard geodetic projection systems and datums. In addition map users have now come to expect features such as layers, interaction with other geospatial applications like Google Earth, and the ability to make mark-ups and share these with other users.

Beyond these technical issues of data display, there are other expectations related to usability that must be met. Discussions with potential users in the U.S. military and intelligence agencies, as well as several civilian organizations, suggest that these issues may be as important for success as the technical ones. The most often mentioned of these is simplicity of use, followed by the need for small file size, fast display speed, minimal training, and software installation. Lastly, any viewing software must be supported by tools and technology for converting standard LiDAR and DEM formats to the geospatial viewer format.

## 3D GeoPDF – The Solution

What is needed for exploitation of the vast amount of available LiDAR data is a simple, freely available 3D viewer which meets the specific viewing requirements of terrain visualization. The basis for such a viewer is currently available in the Adobe Reader product, which is currently installed on more than 900 million systems. Many people may not be aware that Reader has a full complement of 3D model viewing tools. While there are many other freely available 3D viewers, the world-wide availability and acceptance of Adobe Reader argues for its use in this role. Because it is already part of most baseline software installations, there is no need for users to locate and install an additional viewing program. Training, support and maintenance have generally already been expended, so there is no additional burden on the organizations charged with those tasks. If the Adobe Reader software could be enhanced to meet the specific needs of terrain visualization, the existence of the Adobe infrastructure will aid in the rapid adoption of this approach.

While the need for 3D terrain visualization is a recent phenomenon, the same earlier need existed for distribution and display of 2D map and GIS products. This need was successfully resolved in 2004 with the introduction of TerraGo GeoPDF and the free TerraGo Toolbar, an extension of the Adobe Reader format to support geospatial functionality. This approach has now been widely adopted and most major GIS software systems can now export GeoPDF files, while more than 500,000 copies of the Toolbar have been installed. For example, the U.S. Army has equipped every computer in its organization with both Adobe Reader and the TerraGo Toolbar. As further evidence of the acceptance of GeoPDF, the USGS has converted all 60,000 of its US quad sheets to GeoPDF and has made them freely available through its web site.

TerraGo has now met these terrain visualization challenges within the 3D GeoPDF environment. TerraGo has developed a service for converting LiDAR and DEM data to 3D GeoPDF, providing multi-coordinate display with elevation, measurement, layering, transparency and side-by-side display of 2D map and 3D model views, using the free Adobe Reader and TerraGo Toolbar.
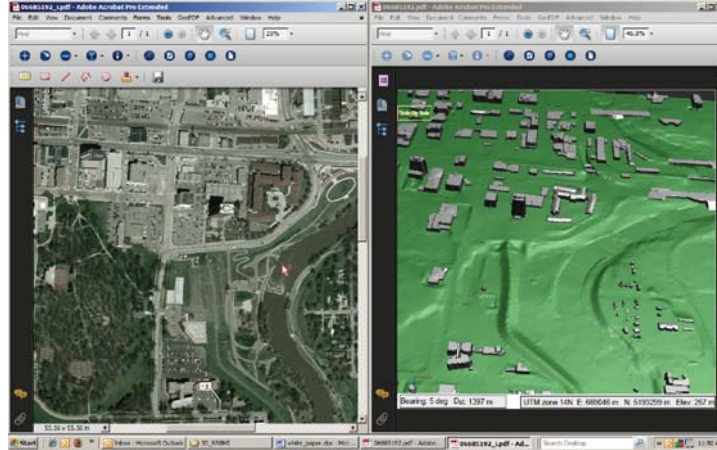
## Rendering LiDAR to 3D GeoPDF: How it Works

Most LiDAR data exists in the form of either LAS files or gridded GeoTiff files. These formats are intended to store detail data about either individual points or pixels and are poorly suited for display. For visualization, the points must be processed to create surfaces, a processor-intensive activity that requires both CPU power and time. By storing the surfaces, rather than the points, 3D viewers can provide very rapid translation, zooming and rotation, as well as location of points on the surfaces for measurement functions. The challenge is in generating these layers and in applying geospatial coordinates to the model.

Most LiDAR processing software provides the ability to render point data to surfaces in the form of VRML, which is one of the import formats supported by Adobe's 3D translator. Once the 3D model is available as PDF, TerraGo applies a projected coordinate system and utilizes the GeoJavaScript functions within the TerraGo Toolbar to transform the projected coordinates of the original model to any other available projection and datum for display.

The workflow for this process is:
- Create a surface model using any of the available LiDAR processing products.
- Export the surface model to VRML.
- Convert VRML to 3D PDF using Adobe Acrobat.
- Apply geo-registration with TerraGo 3D Composer.
- Display the result with the free Adobe Reader and the TerraGo Toolbar.

Since 3D PDF supports layers, colors, textures and transparencies, it is also possible to create very rich models by overlaying bare earth, buildings, contours and vegetation, using multiple LiDAR returns.

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For large volume conversion projects, Adobe LiveCycle and TerraGo 3D Composer for Server can be used for batch processing, controllable through various scripting languages. A future application will provide dynamic model building, allowing users to select an area and stitch several LAS files into a single 3D GeoPDF.

## Use Cases for Implementing 3D GeoPDF

One of the most common uses of LiDAR is the creation of digital terrain models (DTM) and digital elevation models (DEM) for use in planning and design. The difference being that DEMs show bare earth only, while DTMs may include vegetation and man-made structures. While this data often covers areas inhabited by hundreds of thousands, if not millions of people, very few of these will have access to these models for their own use in viewing their environment or planning events in their lives. The success of Google Maps, Virtual Earth and other publicly available imagery applications has demonstrated the public thirst for data about their own world and access to 3D models are likely to be similarly desirable.

Just as the results of aerial imagery surveys have been made available for download via the web, the public has a reasonable expectation that the results of LiDAR collections will also be made available. Of course, providing LAS data will defeat that purpose, but 3D GeoPDF can be consumed by almost anyone who can connect, and the small additional cost of the conversion can be included in the project budget.

Or consider a more specific use case for leveraging LiDAR to enhance the value of the collection effort: that of levee maintenance and inspection. Most major river systems subject to flooding have authorities for insuring the effectiveness of the protective levee systems. These organizations are responsible for the safety of millions of people and billions of dollars of property. Many of them are now employing LiDAR to create a more accurate model of the levees and surrounding terrain.

While the LiDAR model is invaluable to engineers in creating design models, very few of the people needing to visualize the levee system will be able to view it unless the data is provided to them in some simpler format. Levee board members, county and municipality executives, business leaders and voters will be completely dependent on the expressions of specialists for making critical and expensive decisions regarding flood protection unless they also have access to the models.
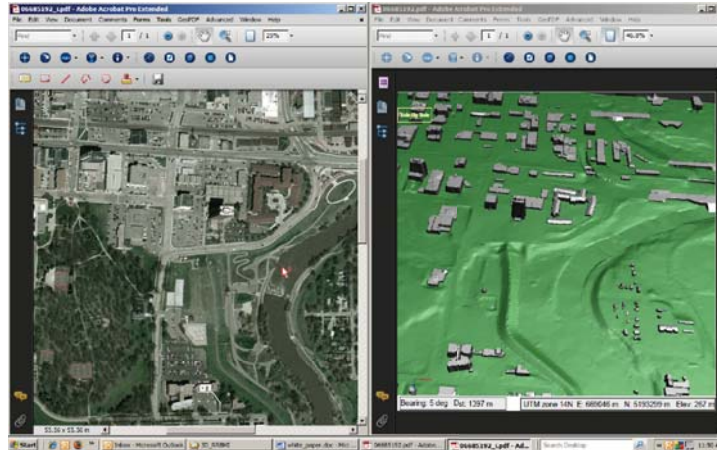
*Figure 4: LiDAR derived DEM of a levee system by Fugro Horizons.*

Publishing the LiDAR data to GeoPDF will allow anyone with the free Adobe Reader and TerraGo Toolbar to view the levee system from any perspective and see the effects of various design and flood scenarios. Even technical experts will benefit from the ability to mark up and comment on the models, allowing public collaboration on a critical subject.

## Considerations in 3D Visualization Project Design

Organizations considering the implementation of 3D GeoPDF will need to plan carefully before undertaking the project. There are a number of issues which must be dealt with to insure that end users receive the full potential of the data and can confirm the value of the effort to project sponsors. Among these considerations are resolution, file size, tile dimensions, color selection, data access, software installation, and documentation. There will of course be others, depending on the size and complexity of the project.

Perhaps the key determining factor in the success of 3D GeoPDF utilization is file size. For projects utilizing web-based distribution, the limiting size for downloading of files is generally considered to be 10 MB. Users will hesitate to download larger files, regardless of their potential value. For users obtaining files through a network or via DVD, larger file sizes are practical, although performance problems may discourage use of files above 20 MB. The controlling factors for file size are LiDAR resolution, tile dimensions and the use of aggressive data thinning techniques that TerraGo can employ. Since resolution is probably set by other considerations, tile sizing and thinning must be used for file size control.

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Providing access to the data and software is an important element of project success. For projects involving many contiguous tiles, use of an index map will allow users to easily locate their area of interest and download only tiles in that area is recommended. This can be done with the TerraGo Composer solution.

Documentation of the features of the data is essential to insuring wide spread adoption by users. This documentation must be simple and effective, using straightforward language to describe the value of the data and the tools for displaying it. For complex, multilayered models, the use of a simple tutorial can also help users leverage the data.

## Summary

That there is a general need for access to LiDAR-derived 3D imagery is without dispute. The challenge has been to provide this data in a format that can be readily consumed by non-technical users without access to specialized software and skills. A sophisticated 3D viewer is now installed on virtually every PC in existence in the form of Adobe Reader. Rendering LiDAR to 3D GeoPDF can provide access to this data to almost anyone anywhere and leverage the investment in data collection and processing by several orders of magnitude.

The tools for converting LiDAR to 3D GeoPDF are now available. Distribution of the results can be accomplished through the web or via physical media. Once obtained, viewing, coordinate display, measurement, markup and collaboration are available using the free TerraGo Toolbar.

**About TerraGo Technologies**

TerraGo Technologies delivers software applications that extend the access and application of maps and images for non-GIS users and customers. More than 700 organizations, including many defense and intelligence agencies, utility companies, public safety departments, and environmental engineering teams, depend on TerraGo software. The TerraGo Publisher Suite® allows organizations to consume and optimize data from any source and create a geo-enabled PDF, also known as a GeoPDF®. The TerraGo Collaboration Suite® offers desktop, web-based and mobile software applications that automate geospatial collaboration and information gathering. When used in conjunction with TerraGo Composer®, customers are able to configure easy-to-use maps and images while embedding relevant business context, forms and workflows. With a strong ecosystem of partners, including Adobe, ESRI, ERDAS, Intergraph, BAE Systems and Trimble, millions of professionals use geospatial data that has been enabled by TerraGo in order to be more productive, improve quality and make better decisions. **For more information, visit www.terragotech.com.**

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