## **High-resolution Imaging Tools for Understanding Geologic Processes**

By Greg Stock, Ph.D.

Yosemite Valley's impressive granite cliffs, while stunningly beautiful, also present potentially serious hazards to park visitors, employees, and residents. Since 1857, over 700 rock fall events have been documented in Yosemite Valley, with fifteen associated fatalities and numerous injuries. Park planning efforts require information on geologic hazards, but until recently, monitoring rock-fall activity was very difficult due to the sheer scale of Yosemite Valley. Geologists typically would gather geologic data of rock faces by climbing them or by viewing them with a spotting scope or from a helicopter. These techniques posed obvious dangers but also provided only limited data. However, thanks to super-high resolution gigapixel images and digital maps produced by laser scanning, we now have unprecedented access to the geological features of one of the world's most famous parks on a laptop computer.

The new imagery was produced using a combination of laser scanning and digital photography. LiDAR (Light Detection and Ranging) is a relatively new mapping technique that utilizes laser scanning of the land surface to produce very high-resolution digital topographic maps. The laser scanner can be placed either in an airplane, yielding a bird's-eye view of the landscape, or mounted on a tripod on the ground surface and aimed up at the cliffs (Figure 1). We have utilized both techniques in Yosemite, and integrated the results to provide full threedimensional representation of Yosemite Valley's complex morphology. The resulting images are useful for mapping previous rock falls and simulating potential future rock falls, but the real value of the technique comes from repeating scans through time. By comparing scans of cliff faces before and after rock falls, we can precisely determine the rock fall location, volume, and pre-failure geometery. We can also analyze the geologic structure assess the hazard of large rock falls in 2010.



that contributed to Figure 1. Ground-based laser scanner the failure, and use collecting digital topographic data for the this information to southeast face of El Capitan, site of several

similar areas. With baseline LiDAR data for most of Yosemite Valley already in place, it is possible to quickly rescan a cliff after a rock fall to analyze that event in high resolution.

In collaboration with scientists from the U.S. Geological Survey, we have now documented many rock falls in Yosemite Valley using repeat LiDAR, including the October 2008 Glacier Point rock fall (Figure 2) and more recent rock falls near Half Dome and the Royal Arches.

In addition to laser scanning, new advancements in high-resolution digital photography allow for photo-documenting the walls of Yosemite Valley in unprecedented detail. As part of The Yosemite Extreme Panoramic Imaging Project, a collaborative project between the National Park Service and Los Angeles-based photographers from xRez Studio, gigapixel panoramic photographs were captured for all of the major cliff faces in Yosemite Valley. A primary goal of this project was to produce high-

resolution baseline imagery of Yosemite Valley's cliffs to aid geologists in documenting and understanding the frequent rock falls in Yosemite Valley.

On a single day in May 2008, photographic teams positioned themselves on the landscape to shoot images simultaneously to ensure uni-



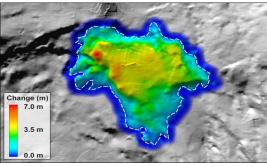
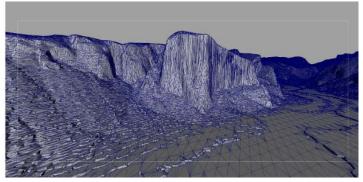


Figure 2. Photograph showing the source area for the October 2008 Glacier Point rock fall (left) and repeat LiDAR analysis showing amount of change between pre- and post-rock fall scans (right). The total volume of this rock fall is calculated to be 5663 ± 36 cubic meters.

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**Figure 3.** High-resolution gigapixel photograph of the southwest face of El Capitan (left), and the corresponding LiDAR-based digital topographic map of the area (right). Projecting the photography onto the LiDAR data yields a full three-dimensional rendering of this predominantly vertical terrain.



**Figure 4.** Orthorectified panoramic image of the north wall of Yosemite Valley, produced by merging several individual panoramic images and projecting them onto LiDAR-based digital topography.

form lighting. Each team produced 500 overlapping shots from a single vantage point, and these images were assembled into 20 high-resolution panoramas. These panoramas were then projected onto a onemeter resolution digital terrain model produced from airborne LiDAR data in 3-D rendering software (Figure 3). This graphic process unified Yosemite Valley's walls into an orthorectified view, yielding perspectives of large areas of Yosemite Valley (Figure 4). Printed out at magazine-quality 300 dpi resolution, the merged photos

api resolution, the merged photos stretch uninterrupted for 40 feet.

As with the LiDAR data, the gigapixel photographs have proven very useful for documenting rock fall events. Numerous rock falls have been bracketed by before and after photographs, revealing important details about the nature of these failures. In addition, repeat high-resolution photography has documented rock falls that had previously been unrecognized (Figure 5).

While rock falls have been documented in Yosemite for over 150 years, these new high-resolution imaging tools provide opportunities for documentation and analysis never before possible. It is now possible to immediately repeat imaging after a rock fall to quantify that event precisely and make effective science-based management decisions. The techniques being pioneered in Yosemite are already proving valuable for park planning efforts that require information on the stability of cliffs and the extent of future rock-fall runout zones. In conjunction with

other rock fall investigation methods, such as field mapping and instrumentation, park staff are developing a comprehensive set of tools for furthering our understanding of this complex and potentially dangerous process. In the long-term, it's possible that these imaging tools could help geologists forecast when rock falls are likely to occur. Although predicting rock falls is not yet possible, documenting and understanding the events that happen is an important step toward this goal. •







**Figure 5.** Gigapixel panoramic photograph of the northwest face of Half Dome from the Diving Board (top), white rectangle shows location of lower views of the face prior to (left) and after (right) rock falls occurring between 2005 and 2006.

Volume 1 Number 1 Winter 2011 5