DR. A. STEWART WALKER

Unexpected Nuggets

This month's editorial is a tad threadbare because I have been on a long vacation in Europe, but this was not without its lidar-related moments. For the first time since I was a child, I visited Culloden, the site of a battle in 1746 in which a dissenting minority of the Scots (mainly the Highland clans), who were supporting the (Catholic) Jacobite Stewarts, were routed by the English. As I was leaving the excellent visitor center to step out on to the battlefield itself, I noticed a display by Forestry Commission Scotland, the organization that manages public forests. A transportation network was built in Scotland, begun after the previous Jacobite rebellion of 1715, often called General Wade's Roads after their creator, to connect several fortified barracks and facilitate the movement of military personnel and materiel. After Culloden, these roads were used to advantage by General William Augustus "Butcher" Cumberland (1721-65), the victor at Culloden, who subjected the Scots to a repressive regime, including civil penalties, burning of crops and homes, looting and forced emigration, to weaken Gaelic culture and undermine the clan system that was prevalent in the Highlands of Scotland, to ensure that the dissent would not be repeated. The network was extended from 1740 to 1767 by Major William Caulfield and there are numerous bridges, some of which still exist. Those in Achlain Forest have been thoroughly investigated and surveyed prior to restoration. The display in the visitor center showed a lidar scan of one of them, so the enormous numbers of tourists to this critical historical site are seeing our technology's value in critical conservation work.

Before reaching Culloden, I attended a reunion of my undergraduate geography class at the University of Glasgow (45 years, so the male students were showing considerable hair loss) and visited my mentor, Professor Gordon Petrie. During our long conversation, I extracted an undertaking from him to write one or two articles for the magazine, so we look forward to that. We talked, of course, about how to spell the name of our technology—a debate I opened in my last editorial - and, as I expected, he is firmly in the "lidar" camp. He followed up with an e-mail and produced a complete lecture (see sidebar). I set things in motion in the March/April issue, but now the debate is far better informed. The "lidar people" remain in the ascendancy! Thank you, Gordon, for furthering the education of your student and his readers.

One of the pleasures of a vacation is returning home to a stack of unread copies of *The Economist* and yet again lidar hits the headlines. In the issue of 7 April 2018, a piece entitled "The art of reflection" examines the colors of cars, starting with Henry Ford's predilection for black. It transpires that dark colors not only absorb sunlight, but

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also much of the signal transmitted by radar and lidar sensors on other cars. The author must have read last month's article on Cepton, however, because he notes that "miniature versions are being developed" to supersede existing systems, because, "At present, lidar is big and bulky (the blob-shaped roof racks on self-driving cars are lidar sets)". Ideally, cars should all be painted in colors that strongly reflect the radar and lidar signals, but that is unlikely as owners have feelings about colors. PPG, a Pittsburgh supplier of paints and coatings, is researching paint modifications at the molecular level so that high reflectivity is maintained regardless of how the color appears to the human eye. Their techniques are based on how the aubergine (eggplant) works: infrared radiation passes through its black skin and is reflected by the white flesh inside, so the plant remains cool in the summer. PPG uses this approach to keep aircraft cool even if they are painted in dark colors and it is but a step to develop paints for cars that retain high reflectivity. Similarly, road signs can be painted so that they are bright and easily readable by humans yet do not blind lidars. In the issue of 22nd March, a report on the tragedy caused by an Uber autonomous vehicle (AV) noted that Arizona is attractive for testing AVs as it is warm and "snow can confuse the LIDAR sensors [that] AVs use to scan their surroundings". I wonder whether in fact the lidar measures the snow surface correctly but, of course, the result will not match the system's database of road topography and roadside features.

There is a new feature in this issue—a book review. The publishers contacted me and asked if we would be interested, so I said yes. I reviewed this one myself, but if any readers are interested in writing reviews of other books, please let me know. We will review only books with substantial lidar content: other periodicals, such as *PE&RS* and *The Photogrammetric Record*, include excellent reviews of a broader range of geomatics books, so we can afford to be choosy!

On 20 April 2018, I attended an ASPRS Pacific Southwest Region Technical Meeting, held at San Diego State University. Four presenters offered a variety of fare to an audience consisting of SDSU faculty and graduate students plus a handful of local ASPRS members. One described combining lidar and imagery to monitor ecosystem changes resulting from drought, shorter inter-fire intervals and human intervention. Another talked about a traditional aerial photography business, with a long history of film sensors, using digital sensors and lidar for the first time. I met a local drone start-up. This was a worthwhile afternoon and I'm pursuing some of the *dramatis personae* for articles—local meetings often yield unexpected nuggets!

Stewart Walker

A. Stewart Walker // Managing Editor

The spelling and useage of "lidar" BY GORDON PETRIE

I would like to respond and give my thoughts on the matter of "lidar" and its usage, besides the matter of its spelling. I am completely in agreement with your correspondent, Dr. Stoker. As far as I am concerned, "lidar" should be treated just like "radar" and "sonar". Furthermore, I feel that attempts to keep up a fancy spelling such as "LiDAR" are, quite simply, doomed to failure. Down the line, popular usage will cause "lidar" to become standard, just like "radar"—at least in my opinion! However, I would like to point out the use of the term by NASA, which, after all, is the organization that is responsible for so much of the development of the laser-based ranging technology that is used for mapping.

I. NASA describes all the devices that carry out laser profiling and scanning for topographic mapping applications from space as "laser altimeters", not "lidars":

i. "Shuttle Laser Altimeter" (SLA) mounted on two Shuttle flights during the 1990s
ii. "Geoscience Laser Altimeter System" (GLAS) mounted on the Earth-orbiting ICESat
iii. "Mars Orbiter Laser Altimeter" (MOLA) mounted on both the Mars Observer and the Mars Global Surveyor missions
iv. "Mercury Laser Altimeter" (MLA) on the Mercury Messenger mission
v. "Lunar Orbiter Laser Altimeter" (LOLA) on the Lunar Reconnaissance mission.

They all use the term "laser altimeter" and the letters "LA" in their acronyms. "Lidar" is never mentioned anywhere.

II. On the other hand, the laser ranging devices that are used by NASA for research into the tropospheric, mesospheric, and stratospheric layers of the atmosphere that exist around the Earth, i.e. to research into objects such as clouds, winds and aerosols, are invariably called "lidars":

i. "Tropospheric Ozone Differential Absorption Lidar" (TROPOZ DIAL) from Goddard Space Flight Center (GSFC)
ii. "Langley Mobile Ozone Lidar" (LMOL) from Langley Research Center (LRC)
iii. "Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation" (CALIPSO), also from LRC
iv. "Cloud Physics Lidar" (CPL), being flown on the high-flying NASA ER-2 (U-2) aircraft
v. "Tropospheric Wind Lidar Technology Experiment" (TWiLiTE), which is an airborne Doppler 'lidar' designed to measure wind profiles in clear air from 18 km to the Earth's surface. It is operated by GSFC from high-flying aircraft such as NASA's DC-8, ER-2 and Global Hawk.
vi. "Goddard Lidar Observatory for Wind" (GLOW), also employed by GSFC
vii. "Micro-Pulse Lidar Network" (MPLNET), which is a ground-based network of Micro-Pulse Lidar (MPL) systems run by GSFC. It is designed to measure aerosol and cloud vertical structures and boundary layer heights. The data are collected continuously, day and night, over long time periods from various ground sites around the World.
viii. "Lidar In-Space Technology Experiment" (LITE) that was mounted on the Shuttle Discovery, again operated by LRC
ix. "Differential Absorption Lidar" (DIAL). These are ground-based systems that have been measuring stratospheric ozone and middle atmospheric temperature from the JPL-Table Mountain Facility since 1988. Another DIAL system has been operating at the Mauna Loa Observatory, Hawaii since 1993.

From the above, it appears that NASA makes a clear distinction between its laser ranging devices mounted on spacecraft and aircraft and on the ground on the basis of their applications - "laser altimeter" if used for the measurement of topography and "lidar" if used for atmospheric research.

III. However, there are two or three older laser ranging devices and systems that have been designed and operated by NASA on aircraft that don't adhere to this policy:

i. "Experimental Advanced Airborne Research Lidar" (EAARL), which is a bathymetric laser scanner used for shallow-water coastal surveys
ii. "Airborne Oceanographic Lidar" (AOL), an early bathymetric profiler and scanner used from the 1980s onwards
iii. "Scanning Lidar Imager of Canopies by Echo Recovery" (SLICER), which is based on the older "Airborne Topographic Laser Altimeter System" (ATLAS) [Note again the use of "LA" in the acronym!].

As far as I am aware, the first two of these older devices were designed and operated by the Wallops Flight Facility in Virginia, rather than one of the mainstream NASA research centers such as GSFC, LRC or JPL. I am fairly sure that GSFC developed the SLICER, but I am not sure whether Wallops was involved with the original ATLAS on which it was based.

IV. This leads me to the titles of the more recent NASA airborne instruments and systems featuring a pushbroom (i.e. non-scanning) type of swath mapping of the Earth's topography, instead of the conventional cross-track laser scanning:

i. "Slope Imaging Multi-Polarization Photon-counting Lidar" (SIMPL)
ii. Multiple Altimeter Beam Experimental Lidar" (MABEL)
iii. "Airborne LIST Simulator" (ALISTS), which is oriented specifically towards satisfying the requirements of the proposed LIST (Lidar Surface Topography) mission, which would utilize a wide-swath non-scanning multi-beam lidar mounted on a satellite to map the Earth's solid (land and ice) topography and vegetation on a global scale from space.

Partly as a result of all of these considerations, I have tried to avoid using the word "lidar" in my chapters of the *Topographic Laser Ranging and Scanning* book[1]. Wherever possible, I use "laser ranging", "laser profiling" and "laser scanning", depending on what is being discussed. It was quite impossible, however, to avoid using "lidar" altogether. As Dr. Stoker has also pointed out, "lidar" is used (i) as part of the name of several commercial instruments and systems; and (ii) in the titles of a number of the papers that have been quoted in the text and therefore appear in the list of references at the end of each of the chapters.

So, before you embark on your editorial that is designed to stimulate a discussion about the 'Spelling of LiDAR', you may also want to consider the various closely related matters about the usage of "lidar" that I have raised above.

Gordon Petrie is emeritus professor of topographic science at the University of Glasgow in Scotland. He joined the University in 1958 after a short career as a professional land surveyor with the U.K. Directorate of Overseas Surveys, working mainly in Yemen. He taught and researched in photogrammetry, remote sensing and surveying in Glasgow until his retirement, but continues to write and research extensively, for example on the history of mapping and on photogrammetric and laser instrumentation. Gordon has had strong connections with the U.S.A. through his frequent participation in academic and professional meetings and his spells as visiting professor at the University of Georgia (twice) and Miami University of Ohio. He received the Fairchild Photogrammetric Award from ASPRS in 2008 and has also been the recipient of the President's Medal by the U.K. Photogrammetric Society and the Bartholomew Globe by the Royal Scottish Geographical Society. Together with his co-author, Professor Charles Toth of Ohio State University, he has contributed the first three chapters on laser instrumentation to the book on *Topographic Laser Ranging and Scanning* (see above).

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1 Shan, J. and C.K. Toth (eds.), 2018. *Topographic Laser Ranging and Scanning: Principles and Processing*, Second Edition, CRC Press, Boca Raton, FL, 654 pp.