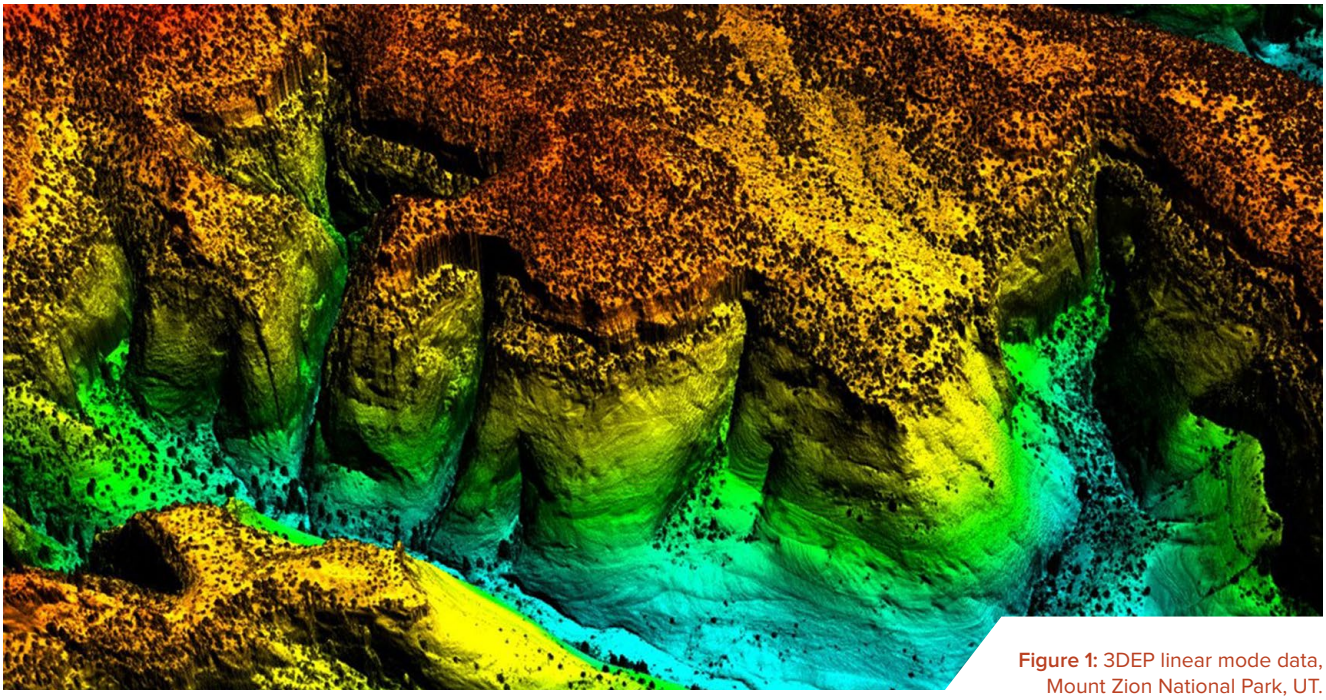
3D ELEVATION PROGRAM

Looking Back and Forward



Courtesy of Woolpert.

Figure 1: 3DEP linear mode data, Mount Zion National Park, UT.

In the early part of the decade, the idea to collect nationwide lidar sounded like an impossible dream to many, even within the U.S. Geological Survey (USGS). The cost of the data alone, estimated at $1B, seemed out of range for the USGS National Geospatial Program (NGP), which was operating at an annual budget of about $60M a year to produce national hydrography data and topographic maps as well as manage a national elevation program. Further, the sheer volume of data that would result from nationwide coverage posed an unprecedented management and delivery challenge. But, convinced by signs of the rapidly growing demand for lidar for a broad range of critical applications, and the advances being made in the industry to improve efficiency and drive down cost, USGS undertook the audacious goal of nationwide data coverage in 8 years. The team that has worked to make this dream a reality included: Larry Sugarbaker, NGP Senior Advisor (retired), whose vision and drive resulted in the National Enhanced Elevation Assessment (NEEA) and the design of the 3D Elevation Program (3DEP); Kevin Gallagher, Associate Director for Core Science Systems, who wore out his shoe leather in reaching out to Federal partners and bringing the dialog about the need for these important data to the executive level through the 3DEP Executive Forum; and the

BY VICKI LUKAS

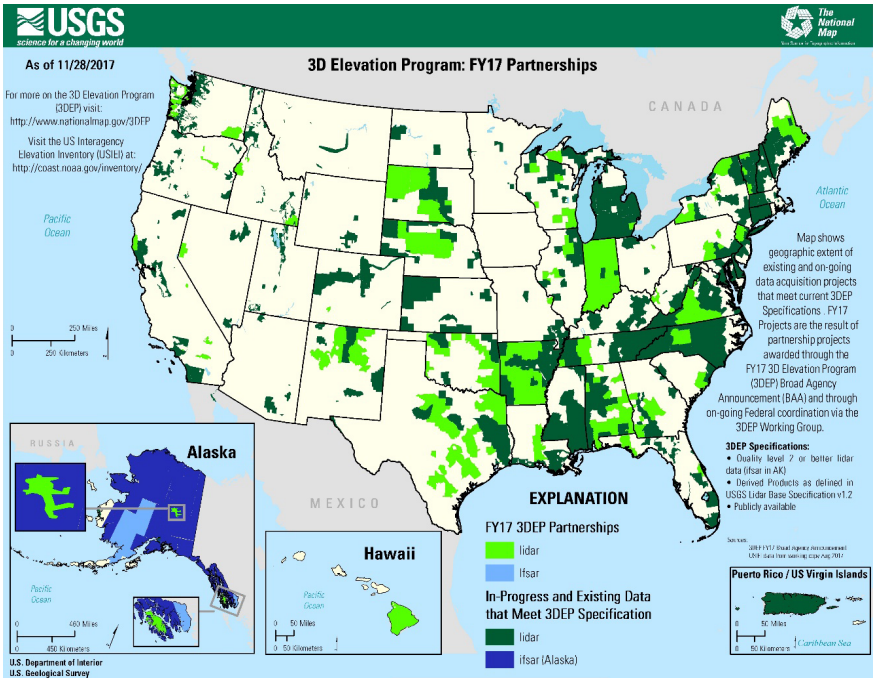


Figure 2: Status map of 3DEP coverage at the end of Fiscal Year 2017.

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

many USGS employees whose dedication and excellence on a daily basis result in program development and guidance, communication, data acquisition, contracting, quality assurance and control, production, data delivery, and research. These varied roles are unified in their goal to make nationwide 3DEP data publicly available.

3DEP was born from the NEEA that documented the elevation data needs of 34 Federal agencies, 50 states, and a sampling of local, Tribal, and private organizations. 3DEP is designed based on the NEEA benefit-cost analysis to conservatively provide new benefits of $690M/year with the potential to generate $13B/year in new benefits through applications that span the breadth of the U.S. economy. The 2012 study not only underpins the goals of 3DEP, it also continues to build a strong case for lidar among decision makers, for USGS and the whole community who collectively produce and use lidar.

The 3DEP design called for quality level 2 (QL2) lidar data nationwide, with QL5 interferometric synthetic aperture radar (IfSAR) data for Alaska, where clouds and remoteness prevent statewide lidar coverage. At the time, most large area acquisitions were being collected at QL3 (see tables 1 and 2). From 2012 to 2015 both USGS and its partners worked to complete ongoing QL3 acquisitions and processing while also transitioning to QL2 in new projects. In 2015, the first new 3DEP products and services were made available, and 2016 marked the first full year of 3DEP processing at USGS. This made 2016 the first year of the 3DEP eight-year goal to complete data acquisition by 2023. An example of QL2 data is shown in **Figure 1**.

With the program design and goal established, USGS has worked to build lidar acquisition partnerships among Federal, state, local, Tribal, and other entities. USGS and NOAA are co-leads of the OMB A-16 Elevation Theme under the Federal Geographic Data Committee, and jointly lead the 3D Nation Elevation Subcommittee to coordinate topographic and bathymetric elevation data. Under the auspices of this leadership role, the 3DEP Executive

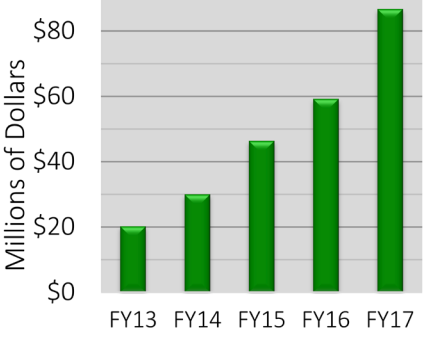


Figure 3: USGS and partner investments in 3DEP data acquisition by Fiscal Year (FY).

Figure 4: Lidar point cloud data fused with color imagery of Desecheo National Wildlife Refuge, Puerto Rico. Lidar was collected for all of Puerto Rico in 2016, before Hurricane Maria. These data provide a critical baseline for comparison with post-event data soon to be collected to aid in the recovery.
Created by Dr. Jason Stoker, USGS.

Forum and Working Group lead Federal coordination and the processes to engage non-Federal partners in 3DEP data acquisition and other program matters. In partnership with NOAA, the USGS 3DEP team maintains and updates the U.S. Interagency Elevation Inventory (USIEI, coast.noaa.gov/inventory) annually to document all publicly available lidar acquisition which is complete, in progress, or planned, so that all users across the community can discover these data and plan projects to avoid duplication. The 3DEP Working Group supports and populates Federal data requirements in the NOAA Seasketch tool (fedmap.seasketch.org) to stimulate and broadly promote leveraging of partnerships. The Federal requirements compiled in Seasketch are published in the annual Broad Agency Announcement (see FedBizOps at www.fbo.gov/index?s=opportunity&mode=form&id=ad1b567dec828feb3b05651fe29db766&tab=core&_cview=0 and grants.gov at www.grants.gov/web/grants/search-grants.html?keywords=G17AS00116), to solicit partnerships from all sources. Additional enhancements on which the 3DEP team is working are to establish a national multi-year plan for acquisition made up of state acquisition plans, and a national tiling scheme for planning and data delivery. These efforts will result in an orderly, systematic plan for completing 3DEP data coverage for the nation.

The success of 3DEP relies on USGS's many partners. When partnerships

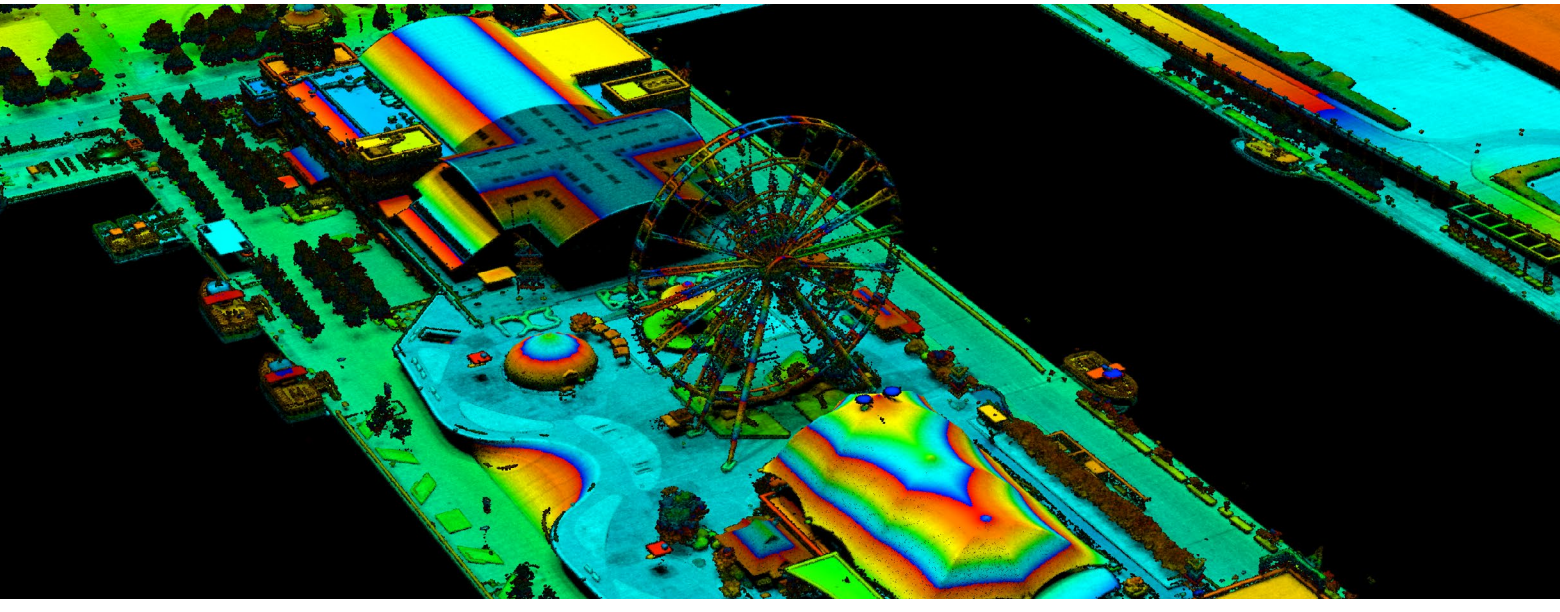


Figure 5: Sample data collected at 17,000' AGL at >20ppsm over Chicago, IL being used to assess Geiger-mode data for use in 3DEP.
Courtesy of Harris Corporation.

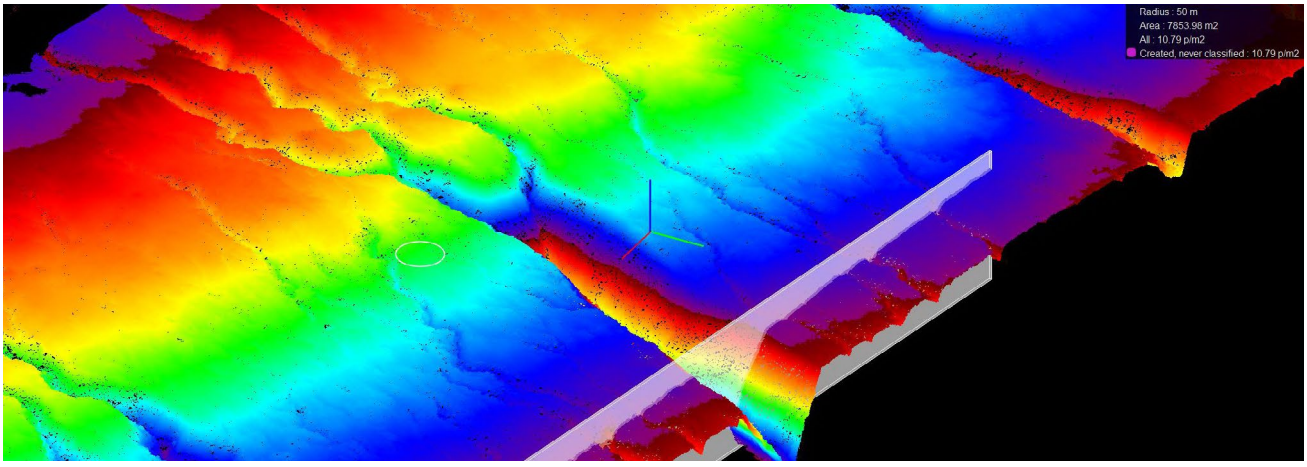


Figure 5: Sample lidar profile collected at 12,300' AGL at quality level 1 (QL1) density over a ravine on the big island of Hawaii being used to assess single-photon lidar (SPL) technology for use in 3DEP.
Courtesy of Woolpert.

have been formed and codified through agreements, data are acquired through the Geospatial Products and Services Contracts (GPSC) or cooperative agreements. USGS has processed growing data acquisition investments, for example in fiscal year 2017 nearly $87M of data acquisition was processed for a large range of Federal, state, local, Tribal, and other partners.

When the data are delivered from the private sector contractors and cooperative agreement partners, USGS performs quality control, using the USGS Lidar Base Specification (doi.org/10.3133/tm11B4) to ensure data quality and consistency. The specification is maintained by the 3DEP team and used as a standard across the industry. Version 1.3 of the specification was recently published in early March 2018.

After the data pass inspection, the 3DEP team processes and publishes the data in *The National Map (*nationalmap.gov*),* which is publicly accessible. The data that 3DEP provides support a broad range of nationally significant applications including flood risk management, infrastructure construction and management, energy development, geologic resource assessment and mapping, natural hazards assessments and mitigation, natural resource management, precision agriculture, and more.

In 2017, USGS and its partners contracted for about 12 percent of the Nation, bringing the total 3DEP-quality data available or in work to 37 percent (**Figure 2**) and investments in 3DEP have been growing each year (**Figure 3**). Prospects are strong for the upward trend to continue in FY18, though Federal budgets were not yet finalized at the time of writing. At the FY19 President's Budget level, nationwide 3DEP acquisition would be completed in 2033.

The 3DEP team continues to look forward and is moving to the cloud, assessing emerging technologies for use in the program (figs. 4, 5 and 6), and testing inland bathymetric data acquisition with a goal to extend the elevation surface under water bodies in the future. USGS is working with NOAA to develop the successor to NEEA, the 3D Nation Requirements and Benefits Study. The new study will use a technology-agnostic approach, add rivers, lakes, coasts and oceans to the equation, and once again rely on user requirements and benefits to inform program design as we begin to look at repeat coverage, when nationwide coverage is completed.

What once seemed an impossible dream to provide consistent nationwide lidar coverage is becoming more of a reality every day, thanks to a vibrant industry, ongoing advances and improvements in the technology and processes, and a growing and innovative user base. 3DEP is truly a community achievement, from the partners that fund acquisition to the private sector mapping firms that collect the data. The USGS 3D Elevation Program is honored to serve the community with USGS's elevation co-lead NOAA, to advance high quality, publicly available elevation data from the depths of the oceans to the peaks of the mountains.

Vicki Lukas is the Chief of Topographic Data Services in the National Geospatial Program of the USGS, where she oversee the 3D Elevation Program and the National Hydrography Datasets of The National Map.