Appendix 3. Nongovernmental Requirements and Benefits Data

The information in this appendix was generated from interviews with representatives from The Nature Conservancy and a sampling of private sector businesses. Representatives of these organizations were asked to detail their requirements for elevation data and to estimate the expected benefits that would result if their requirements were met. Only a selected number of key organizations were interviewed to illustrate important nongovernmental uses of elevation. There are many other nongovernmental organizations and industries where lidar could play a significant role.

Agren

Points of Contact: Stan and Tom Buman, (712) 792-6248

A small-business, agricultural and natural resources consulting firm based in Iowa, Agren responds to agricultural and environmental challenges by providing comprehensive, integrated services to groups and individuals to positively affect our natural resources.

Agren's business model supports the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Performance Results System (PRS) to include numerous conservation practices, conservation systems, and conservation programs for which Agren has developed geographic information system (GIS)-based tools.

Agren's points of contact identified the following major functional activity with mission-critical requirements for enhanced elevation data.

- Agricultural and Environmental Services, under BU#1, Natural Resources Conservation, BU#2, Water Supply and Quality, and BU#8, Agriculture and Precision Farming.

Agricultural and Environmental Services

Mission-Critical Requirements:

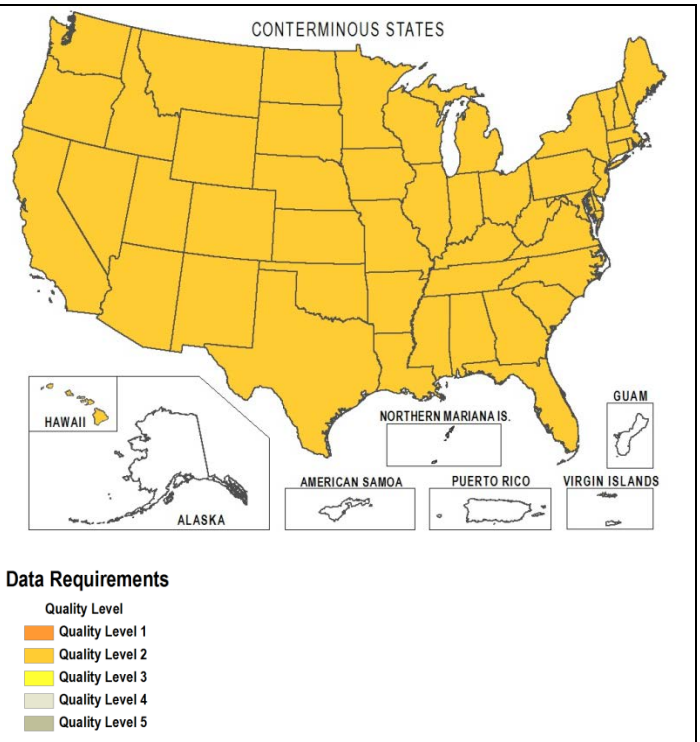
Quality level (QL) 2 light detection and ranging (lidar) is required of 49 States for an array of GIS-based agriculture and environmental services pertaining to croplands, grasslands, rangelands, and forests, including development of wetlands, ponds, basins, and waterways.

Update Frequency: 6–10 years; more recent if major erosion event

Business Use: Natural Resources Conservation, BU#1, Water Supply and Quality, BU#2, and Agriculture and Precision Farming, BU#8.

Estimated Program Budget: Not available

Quantifiable Benefits of Enhanced Elevation Data: With GIS-based tools such as RUSLE2, PondBuilder, WetlandBuilder, BasinBuilder, and WaterwayBuilder, lidar data enables conservation planning and implementation tasks to be performed in 30-60 minutes that would typically require 10-20 hours without lidar, and avoids the need for on-site field surveys; cost benefits to landowners nationwide are major, but cannot be estimated.



Agren relies on lidar data, where available, for GIS-based tools (WetlandBuilder, PondBuilder, BasinBuilder, and WaterwayBuilder) used for the development of conservation practice plans to NRCS standards. In addition to the online GIS-based Revised Universal Soil Loss Equation (RUSLE2) calculator, Agren has 4 to 5 additional tools under development where lidar would help landowners to be better stewards of their croplands, grasslands, rangelands, and forests.

- Lidar data would enable conservation planning tools to assist the large percentage of absentee landowners to see what is happening to their land (by webinars) and make decisions on, for example, how to reduce soil erosion, loss of soil health, or degradation of rangelands
- Lidar data would enable effective smoke and fire modeling
- Lidar data would improve plans for prescribed fires, intentionally set for ecological reasons

- Lidar data would enable watershed assessments
- Lidar data would enable the efficient analysis of biofuels to determine if removal of residue off the ground would create more erosion and where harvesting can take place

QL3 lidar (2-foot (ft) contour accuracy and DEM point spacing of 1 to 2 meters (m)) is minimally acceptable for some of Agren's tools, but QL2 lidar (1-ft contour accuracy and less-than-1-m point spacing) is required for best results.

Lidar has made it possible for Agren to develop new technology that is rapidly increasing the ability of agencies and organizations to provide conservation alternatives to landowners. For example, with Agren's WetlandBuilder, a soil and water conservation district can provide an accurate wetland estimate to a landowner in 30 minutes (fig 3–1) instead of 10 hours with current methods. If lidar were available nationwide, it would allow conservation planning tools to be deployed to a much larger audience. In addition, it would allow Agren to develop considerably more applications for other conservation practices, such as irrigation and range management. The savings to conservation planning agencies and organizations are major. For example, increasing the development of wetlands has benefits that include improving water quality, controlling floods, and providingwildlife habitats.

Using lidar data, Agren's tools can be used to produce a variety of accurate estimates in less than 1 hour, saving extensive time and costs for private consultants or government entities, such as the NRCS or State and local agencies, by not having to travel to distant locations for onsite assessments and field surveys. The user can provide a multitude of realistic visualizations of a given practice and the resulting footprint on the land, providing more options to landowners and giving them the information they need to make better decisions. By webinars, these users can even communicate effectively with absentee landowners throughout the Nation. Subsequently, lidar data enable conservation planning and implementation tasks to be performed in 30 to 60 minutes that would typically require 10 to 20 hours without lidar. Lidar also allows for the timely development of conservation practice plans and estimates instead of waiting until field conditions are suitable for field survey. Some examples of unsuitable field conditions include leaves on trees, agricultural crops growing, snow cover on the ground, and mud. The cost benefits to landowners nationwide are major, but cannot be estimated.

Map showing an example of a wetland area estimate generated from Agren's WetlandBuilder. Map provided by Agren.

Duquesne Light Company

Point of Contact: Bill Radomski, (412) 393–8118

Duquesne Light Company is a leader in the transmission and distribution of electric energy, serving more than half a million customers in southwestern Pennsylvania.

Although Duquesne serves a relatively small portion of the United States, it is one of the early users of lidar for transmission line vegetation management and other purposes within the electric power industry and is representative of nationwide requirements for other electric utility companies.

Duquesne identified the following major functional activity with mission-critical requirements for lidar data.

- Transmission Line Vegetation Clearance, under BU#21, Infrastructure and Construction Management

Transmission Line Vegetation Clearance

Mission-Critical Requirements:

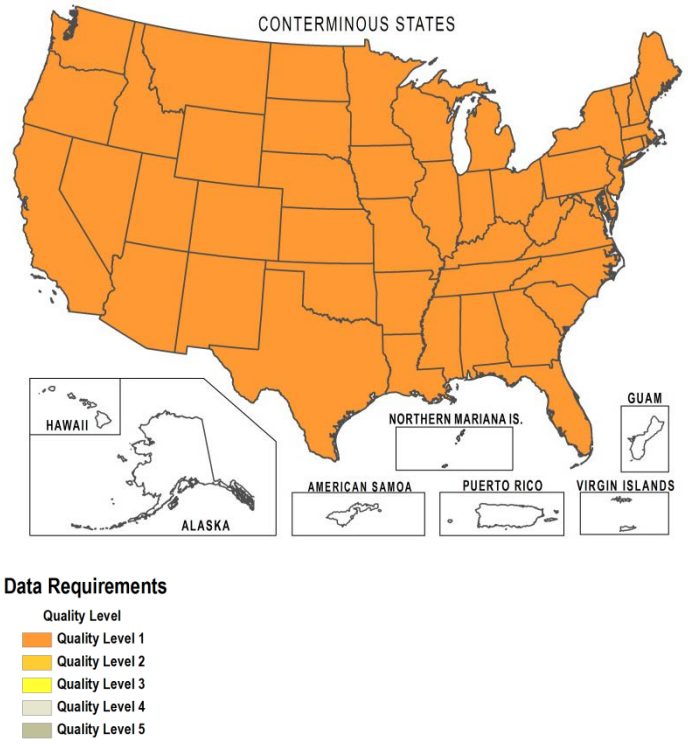
Duquesne Electric Light and other electric transmission line companies nationwide require QL1 lidar for transmission line vegetation clearance to satisfy NERC requirements, for ensuring that actual line sag equals the design sag, and for detection of encroachments on company rights-of-way.

Update Frequency: 4–5 years minimum; annually preferred

Business Use: Infrastructure and Construction Management, BU#21

Estimated Program Budget: Unknown

Quantifiable Benefits of Enhanced Elevation Data: Extrapolated nationwide to other companies, annual updates of QL1 lidar data will enable the electric utility companies to save up to $675 million per year[1] in not having to acquire their own lidar data to satisfy NERC requirements.



The North American Electric Reliability Corporation (NERC) regulates the bulk power system, which includes the facilities and control systems necessary for operating an interconnected electric energy supply and transmission network, including more than 450,000 miles of bulk transmission lines but excluding smaller lines used for local distribution of electricity. Without specifically requiring lidar, NERC standards are commonly interpreted to endorse the use of airborne lidar for line rating (based on actual field conditions that determine changes in power line catenaries due to thermal and mechanical loads) and transmission line vegetation management (based on monitoring of transmission line vegetation clearance to proactively prevent line-vegetation arcs and subsequent cascade system failures). NERC standard FAC–003–2 requirement 7 states: "Each Transmission Owner shall execute a flexible annual vegetation work plan to ensure no vegetation encroachments occur within the MVCD (Minimum Vegetation Clearance Distance)."

[1]For the benefit-to-cost analysis, because of uncertainties in the rate of implementation of lidar for transmission line vegetation clearance, 10 percent ($67.5 million per year) was used as the conservative benefit and the full 100 percent ($675 million per year) was used as the potential benefit.

For lidar surveys of bulk transmission lines, the acquisition date and time for each flight path must be available so that operators can reconstruct the ambient temperature and power line loading at the time the lidar was acquired because these factors affect the transmission line sag, which is compared with the designed sag.

Potential operational benefits to transmission line companies of lidar data for this functional activity:

Time and cost savings: Major	**Mission compliance: Major**	**$ Benefits: $675 million per year**

- Lewis Graham of GeoCue has determined that lidar provides the most cost-effective lidar approach, and estimates that lidar acquisition would cost $675 million per year for America's electric utility companies and their consumers. These costs would be greatly reduced whenever there is a new acquisition of nationwide lidar for individual areas. The Tennessee Valley Authority (TVA) alone estimated that it would save $600,000 per year from such lidar.

Customer service benefits from improved transmission line products and services:

Performance: Minor	**Timeliness: Minor**	**Experience: Minor**	**$ Benefits: Unknown**

- Reliable service benefits all customers; trees falling on power lines are the major cause of power outages.

Other benefits from the use of lidar data for this functional activity:

Public and Social: None	**Environmental: None**	**Strategic and Political: Major**

- There are major political benefits when electric service is reliable in the avoidance of major political issues when electric service is unreliable.

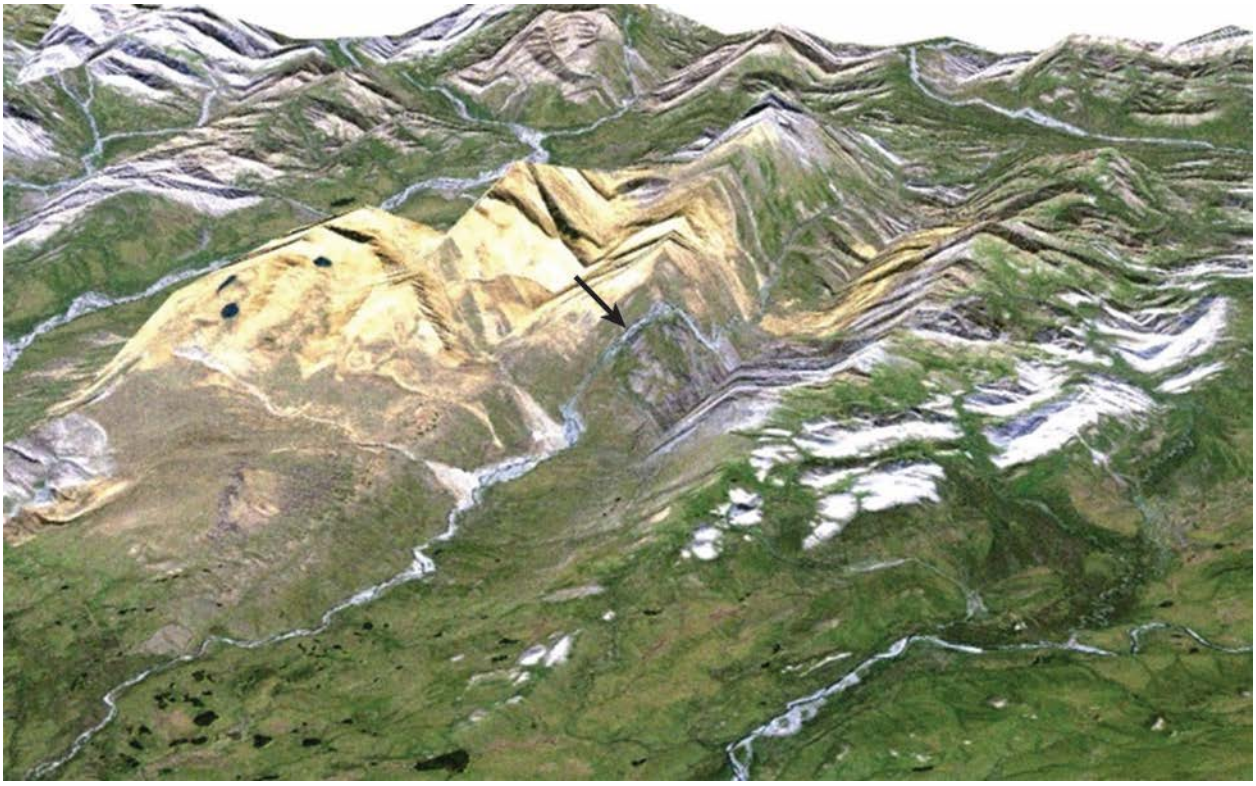
E–Terra LLC

Point of Contact: Steve Colligan, (907) 562–1500

E-Terra is a company dedicated to mapping and the development and support of GIS, computer-aided design, and database applications, specializing in the development of aviation safety solutions for Alaska

The Problem With Poor Mapping in Alaska

In nearly the 600,000-square-mile landmass of Alaska, there are less than 5,000 miles of roads and only 1 single-track railroad line. Of all the villages in Alaska, 82 percent have no connection to the national road system; all commerce and essential services and all personal transportation with these villages is done by airplane. These are mostly small, piston-engine airplanes that are not pressurized and cannot go into known icing conditions. With these and other factors, they cannot reasonably fly straight over the mountains (up to 20,000 feet high in some areas of Alaska); instead, the planes fly through mountain passes. These planes cannot use instrument flight rule (IFR) airways or line-of-sight (VOR) radio navigation, which are tools that work only for turbine aircraft, such as airliners flying high over the terrain.



Some data in the National Elevation Dataset (NED) are so inaccurate that some mountains in Alaska are shown miles away from their true location, and rivers appear to flow up and over hills, as shown near the arrow on the figure above. Satellite image provided by the University of Alaska Fairbanks.

Whereas all other States have been mapped at a scale where 1 inch equals 2,000 feet to National Map Accuracy Standards (NMAS), Alaska has only been mapped at a small scale of 1 inch equals 1 mile, and not to NMAS standards. Alaska is also the only State that does not have digital orthophotos, because the NED data for Alaska have mountains mapped miles away from their true locations in some places. Figure 3–2 shows how imagery draped over the NED results in rivers that appear to go up and over the mountains because the mountains are mapped in the wrong place in the NED. Such inaccuracies do not pertain everywhere. The NED is reasonably accurate for major areas of Alaska, leading to false assumptions that the NED data are accurate everywhere, when they are not. When U.S. Geological Survey (USGS) topographic quadrangle maps of Alaska (where 1 inch equals 1 mile) were produced in the 1950s, mapping inaccuracies occurred because of the vast expanse of areas to be mapped, the near-

total absence of survey control points, and the unavailability of any Global Positioning System (GPS) and statistical bundle-block aerotriangulation procedures, which were not developed until decades later.

Major Aviation Safety Issues

Alaska has not been mapped accurately enough in three dimensional (3D) view to use GPS in aircraft for terrain avoidance This is because the actual terrain may differ from the view that is presented by a 3D map that contains errors. With poor visibility common and with weather extremes (such as icing and clouds above the mountain passes), a flight through a mountain pass is similar to flying through a tunnel that has numerous dendritic dead-end junctions: one wrong turn can lead into a dead-end box canyon that is too narrow to turn around in and too steep to climb out of. As a result, Alaska has an extremely high incidence of controlled flight into terrain (CFIT) accidents. CFIT crashes occur when failures occur at all levels and backup safeguards are inadequate, resulting in the pilot flying a technically 100 percent operational aircraft into a situation in which he is not aware of his surroundings and thus flies into a mountain.

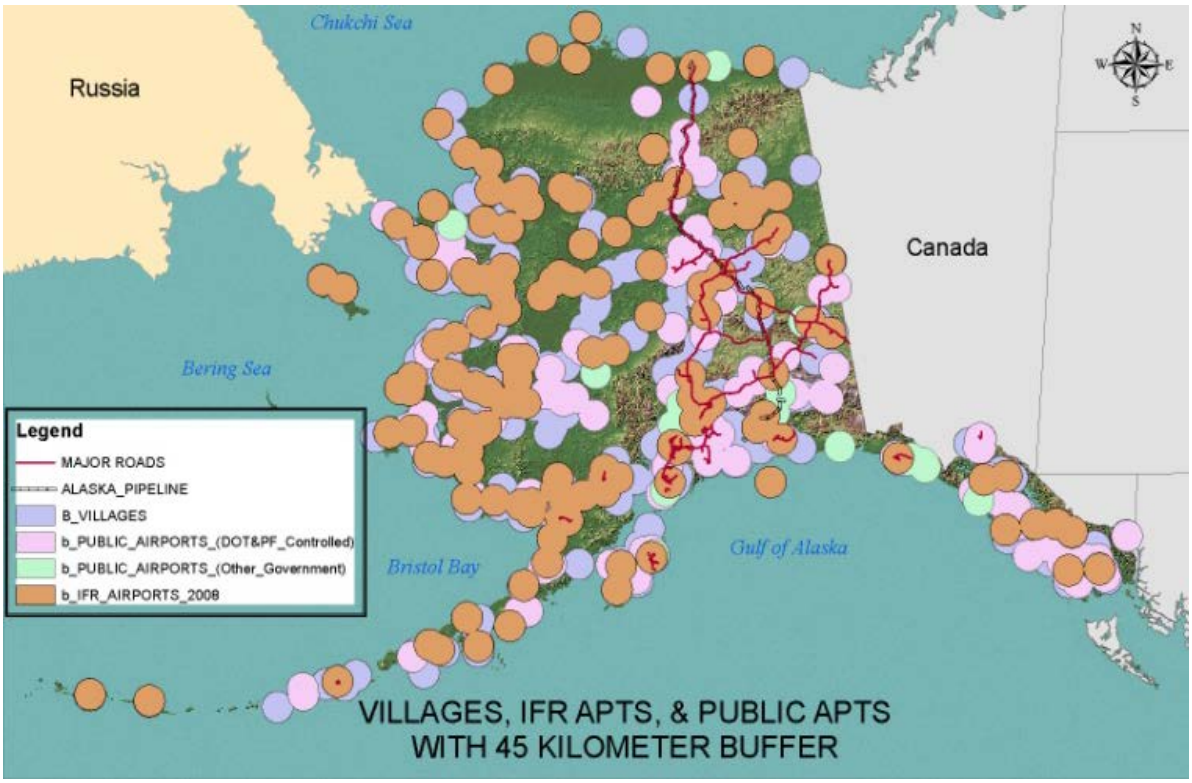
Alaska has approximately 10 percent of the Nation's air transport operators. Historically, this 10 percent generates approximately 35 percent of the Nation's air transport accidents. Between 1994 and 1996, there were 112 accidents in Alaska involving these kinds of operations. The flying challenges posed by Alaska's mountainous terrain and extreme winter climate together with the higher than average accident rate has made the quest for improved aviation safety in Alaska a major goal for the Federal Aviation Administration (FAA) and the Alaskan aviation community.

One of the goals of the FAA Flight Plan (the FAA's strategic plan) is to achieve the lowest possible accident rate and constantly improve safety. This plan specifically mentions Alaska eight times, while mentioning no other State by name. The plan mentions Alaska with reference to the satellite-based Capstone navigation and terrain awareness avionics as well as the Circle of Safety and the Alaska Flight Service Safety Programs. The Circle of Safety Program document refers to 100 occupational pilot deaths in Alaska between 1990 and 1998, stating, "Most CFIT crashes are attributed to pilot error."

Studies conducted in Alaska indicate that 38 percent of the 112 accidents from 1994 to 1996 might have been avoided by the availability of advanced avionics in the aircraft that track the aircraft's position relative to the terrain. However, aircraft positioning and navigation systems can lead to a false sense of security when the aircraft's position is precisely known but the terrain information may be in error by miles. A study by The MITRE Corporation and the University of Alaska at Anchorage in 2004 found that the rate of accidents for Capstone-equipped aircraft between 2000 and 2004 was reduced by 47 percent by improving aircraft positioning. Although Capstone avionics onboard an aircraft improve the pilot's knowledge of where the airplane is positioned at all times, the topographic data may be so inaccurate that the pilot does not know where the aircraft is positioned relative to the terrain. The number of accidents would likely be reduced if these aircraft also had accurate terrain information so pilots could track their aircraft's position relative to the actual terrain.

Alaska DEM Whitepaper

In 2008, the Alaska Geographic Data Committee (AGDC), which includes Alaska Mapped (representing the Statewide Digital Mapping Initiative (SDMI)), the Bureau of Land Management (BLM), the Geographic Information Network of Alaska (GINA) and the University of Alaska Fairbanks (UAF), sponsored a series of DEM workshops and a major study that resulted in the *Alaska DEM Whitepaper.* During this study, the FAA indicated that airborne interferometric synthetic aperture radar (IFSAR) with 20-ft contour accuracy is required for the areas indicated in figure 3–3 to satisfy requirements of the International Civil Aviation Organization (ICAO). The ICAO standards for the Electronic Terrain and Obstacle Database (eTOD) were developed to minimize the risk of CFIT crashes; Alaska remains the only State not compliant with these ICAO requirements.



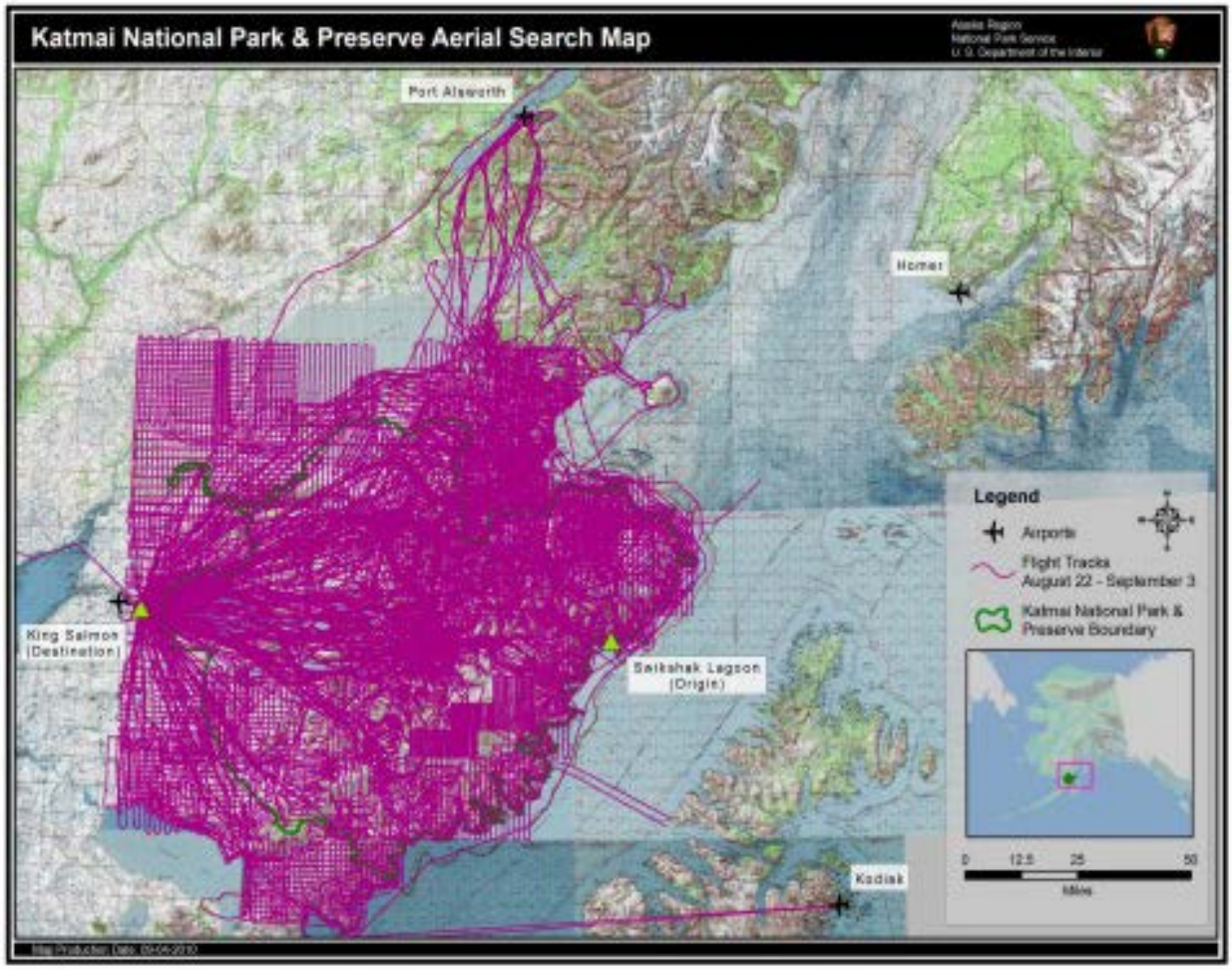
In 2008, the Federal Aviation Administration (FAA) identified the urgent need to acquire airborne interferometric synthetic aperture radar (IFSAR) of the more than 1,000 airfields in Alaska to satisfy area 2 requirements of the International Civil Aviation Organization (ICAO). This map was produced from shapefiles provided by the FAA and shows the sparse road network in Alaska.

Before completion of the *Alaska DEM Whitepaper*, the draft findings and conclusions of the study were presented to the National Digital Elevation Program (NDEP) members that met in Anchorage in autumn 2008. NDEP members from the BLM, the NRCS, the U.S. Forest Service (USFS), the USGS, the National Oceanic and Atmospheric Administration (NOAA), the National Geospatial-Intelligence Agency (NGA), the U.S. Army Corps of Engineers (USACE), the Federal Emergency Management Agency (FEMA), and the National States Geographic Information Council (NSGIC) unanimously agreed with the following consensus points:

- *Alaska has no time to waste.* ICAO area 2 requirements were scheduled to become effective on November 20, 2010. Other urgent statewide DEM user requirements included the immediate need for orthorectification of optical imagery for production of digital orthophotos. Representatives of diverse Federal and State government agencies had their own requirements for DEMs of the same accuracy level specified by the FAA.
- *All must remain true to Alaska's requirements.* Alaska needs elevation data with 20-ft-equivalent contour accuracy or better. Alaska needs digital surface models (DSMs) and digital terrain models (DTMs), especially of mountain peaks, ridgelines, and hydrology. Alaska needs to be mapped with technology that overcomes adverse weather conditions (maps through clouds and fog), that maps snow-capped mountains and glaciers, and that is cost-effective. Elevation data produced from satellite technology do not satisfy Alaska's requirements.
- *Alaska must find a timely, cost-effective solution.* Only airborne mapping options can satisfy Alaska's technical and accuracy requirements. Airborne IFSAR costs are significantly less than airborne lidar or photogrammetry. Multiple contracting options for airborne IFSAR are available to obtain the most cost-effective solution for timely delivery of quality products. Federal and State funding is required because the U.S. government owns nearly 75 percent of the land area of Alaska (primarily lands belonging to the BLM, the U.S. Fish and Wildlife Service (FWS), the National Park Service (NPS), and the USFS).

Aircraft Search, Rescue, and Recovery in Alaska

Aircraft crashes are more common in Alaska than anywhere else in the Nation. In autumn 2010, after 28 1-degree IFSAR cells had just been acquired but not yet processed, there were two tragic aircraft accidents in Alaska. In September 2010, an NPS aircraft disappeared with four people on board, while enroute to the Katmai National Park and Preserve. IFSAR of the search area was not available, so extensive searches were conducted without the benefit of accurate elevation data. Figure 3–4 shows the aerial search map with flight paths used in an attempt to locate the downed aircraft. The search was very expensive and ultimately unsuccessful. Portions of the aircraft have subsequently washed ashore.



Aerial search map of the area in which the National Park Service (NPS) aircraft was assumed to have gone down trying to reach Katmai National Park and Preserve during adverse weather conditions and the flight lines used for extensive search and recovery operations that never found the aircraft until parts washed ashore. Map provided by the NPS.

In November 2010, a $150-million F–22 Raptor from Elmendorf Air Force Base (AFB) crashed, killing the pilot. It crashed in rugged terrain 15 miles southwest of Denali Highway, on land managed by the BLM. The crash site is located adjacent to a creek. The incident was environmentally sensitive due to composite materials of the F–22, considered hazardous materials (HAZMAT) upon breakup. Winter snow and runoff would expose other hazardous parts that contained highly pressurized gasses or dangerous flammable components with toxic content.

The initial search and rescue operation became a recovery operation on November 20. The U.S. Air Force (USAF) 3d Wing, 673d Air Base Wing was involved, as was the Alaska 3d Maneuver Enhancement Brigade of the U.S. Army. The 6th Engineer Battalion provided logistical and mobility support for recovery operations, and the commander reported, “Weather and terrain were particularly challenging, and presented extreme mobility challenges for our vehicles and soldiers.” Heavy snow and snow storms in steep mountain terrain raised avalanche concerns,

especially with Blackhawk and Chinook helicopters with increased rotor wash and sound. The existing USGS NED was insufficient to aid in identification of ground safety hazards, establishment of landing zones, and slope analysis for potential avalanche zones. Errors of more than 90 m were identified in the NED. Current imagery was not available; sun elevations at this latitude limited commercial imagery collection until late February.

The USGS learned that the crash site was on one of the IFSAR cells recently collected by the USGS but not yet processed. The "as is" IFSAR, DTM, DSM, and orthorectified radar imagery (ORI) were shipped express to Elmendorf AFB where accurate base elevations were used for 3D modeling and visualization of the surrounding crash site. Using the new elevation datasets, analysts remapped potential landing zones and performed more detailed and reliable terrain analysis than was possible using NED as the elevation data input. Secondary products were created to establish avalanche safety zones and ingress and egress route planning. The IFSAR data were also vital for line-of-communication analysis and radio repeater deployment.

Although $60 million is a substantial amount for IFSAR mapping of Alaska statewide, this is significantly less than the $150 million value alone of the single aircraft that was lost; the IFSAR data were vital for the success of recovery operations. Most significantly, similar crashes of civil and military aircraft (as well as numerous accidents that do not involve aircraft) occur regularly throughout the vast State of Alaska, and search, rescue, and recovery operations do not normally have the benefit of IFSAR data.

FAA Nationwide Requirements

In 2011, in response to interviews for the National Enhanced Elevation Assessment, the FAA identified a requirement for QL5 IFSAR nationwide for enroute navigation and safety, thereby establishing a requirement for statewide IFSAR data in Alaska that supercedes the 2008 requirements shown in figure 3–3.

Alaska Flight Simulators

Due to all the complex factors described above, Alaska's pilots require different skill sets than pilots elsewhere. Most flight-training in the United States is done with common flight simulators made to simulate IFR conditions and aircraft system failures, rather than visual flight rule (VFR) procedures common in Alaska. Most common flight simulators are made to train the turbine-engine-airline-IFR environment (high above all terrain and weather). In harsh contrast, aircraft simulators for Alaska are made to simulate Alaska's unforgiving mountains and passes in photorealism and harsh weather conditions that too often lead to CFIT accidents. Simulators for training pilots to conditions in Alaska (fig. 3–5) require elevation data draped with imagery. In a sense of "look-before-you-fly," Alaska's pilots learn their way through the mountains in the simulator and gain experience necessary for flight safety.

Flight Simulator used by E-Terra in Alaska. Image courtesy of E-Terra.

E-Terra's Mission Critical Requirements

E-Terra identified the following major functional activity with mission-critical requirements for IFSAR data of Alaska:

- Alaska Aviation Safety Project, under BU#20, Aviation Navigation and Safety

IFSAR data for this project are also used for FAA Cue Based Training, wireless communications research, airspace training, U.S. Department of Defense site approach training, and integrated statewide strategic emergency communications management plan implementation.

Alaska Aviation Safety Project

Mission-Critical Requirements:

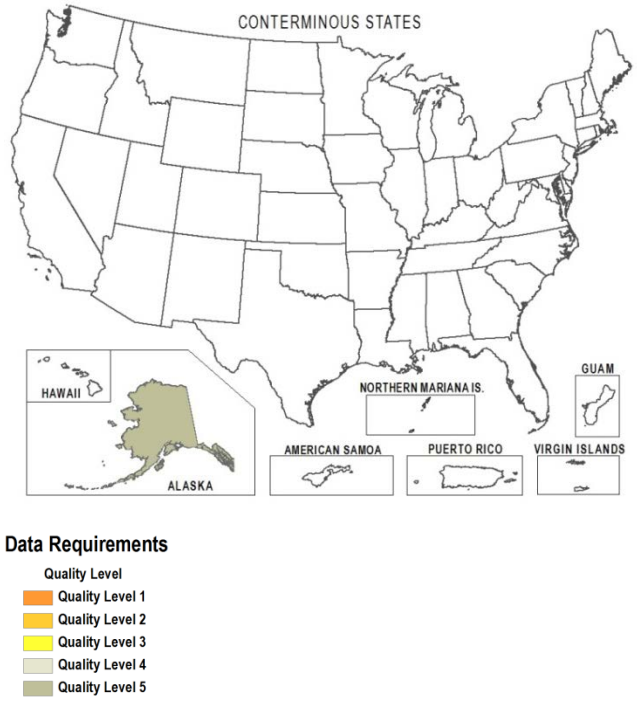
QL5 IFSAR is required for all of Alaska for: (1) enroute instrument procedures including Capstone navigation and terrain awareness avionics, (2) ICAO area 2 compliance for terminal safety approaching more than 1,000 (mostly very small) airfields in Alaska, (3) aircraft search, rescue, and recovery operations, and (4) realistic flight simulators for training pilots on the harsh realities of flight in Alaska

Update Frequency: >10 years

Business Use: Aviation Navigation and Safety, BU#20.

Estimated Program Budget: $1 million, Alaska State Department of Transportation (DOT), FAA Aviation Safety Team

Quantifiable Benefits of Enhanced Elevation Data: There is a direct dollar-for-dollar reduction in costs by having accurate terrain provided from other sources to build aviation products. With the lack of any accurate terrain, each project is a data collection project rather than a technology integration project. More abstract, as more of these types of products are available for training and navigation, each loss of life avoided equates to $1 million to $2 million per life. Accurate data in training and navigation correspond to direct cost avoidance, resulting in many millions of dollars per year in savings in injury, life, and property. Cost avoidance is between $3 million and $24 million per year[2].



The Alaska Aviation Safety Project (AASP) is a cooperative effort between E-Terra, the National Aeronautics and Space Administration (NASA), the State of Alaska, and many other stakeholders to build innovative remote-sensing-based aviation safety solutions. With technologies ranging from advanced terrain management solutions to 3D animations, interactive mapping products, and real-to-life aviation navigation training applications, the AASP has been able to offer extensive value to general aviation (GA) and scheduled flight operators around Alaska. The map portal segment of AASP research focuses on compiling aviation safety related textual, graphical, and spatial information, integrating these products with remote sensing data for context. These data are then published as an aggregate Web solution to offer an intuitive method for pilots to study and retain the information before attempting to fly a new path. IFSAR data are vital for the success of the AASP.

The cost benefits of receiving statewide IFSAR for the AASP are estimated to be as follows:

- *Direct:* Each dollar spent collecting accurate terrain data for general purpose within the State of Alaska is a dollar that will be alleviated from the AASP project to acquire data for training and navigation purposes. A large part of each navigation project is consumed collecting or buying data because they are currently not available. Sharing these costs for these base products (accurate terrain) allows the creation and proliferation of more and better training and navigation products at an accelerated rate compared with current plans and budgets. This would reduce product development costs by 25 to 30 percent while at the same time provide a high overall product quality and use by industry.
- *Abstract:* From a cost avoidance perspective alone, based on the value of a life saved (currently $2 million), the cost of terrain data can support the collection of high-resolution terrain data from AASP's own business model. Avoided costs of search and rescue can be multiple millions per incident. Any incident avoided, each life

[2]For the benefit-to-cost analysis, $3 million per year was used as the conservative benefit and $24 million per year was used as the potential benefit

protected, or injury avoided is a cost avoided. This avoided cost is conservatively estimated to be between $3 million and $24 million per year. This is supported in cost-of-life calculations, not including search and rescue and other costs as follows. There were 1,186 aviation accidents in Alaska between 2000 and 2009; 107 were fatal crashes that resulted in a total of 236 fatalities, on average 12 lives per year resulting in $2 million per year not including collateral damage.

The end goal is to change the culture through training, enhance navigation with usable accurate data, and avoiding costs by reducing incidence and mortality.

Cost benefits estimated by E-Terra were validated as reasonable by the project manager of the State of Alaska Department of Transportation, Aviation Division.

Insurance Services Organization

Point of Contact: Ralph Dorio, (201) 469-2463

The Insurance Services Organization (ISO) is a leading source of information about property and casualty insurance risk, providing data, analytics, and decision-support services for the property and casualty insurance industry.

The ISO currently has no known mission-critical requirement for enhanced elevation data, but uses the best available information to assess property and casualty insurance risk. In many cases, risk is assessed on the basis of historical insurance claims filed by zip code, rather than predicting where claims from various natural hazards may occur in the future.

In assessing four basic types of natural hazards, the ISO recognizes that lidar data could provide superior sources of information about property insurance risk:

- *Geophysical Hazards*: lidar is used by the USGS and others for determining risks from earthquakes, tsunamis, and volcanoes. The ISO accepts USGS requirements for lidar data for identification of seismic faults and other geophysical hazards without considering such data to be mission-critical at this time for the ISO or its insurance company clients.
- *Meteorological Hazards*: lidar is used by NOAA and FEMA for determining risks from hurricanes, and the ISO sees the potential for lidar to also be used in future modeling of risks from tornadoes. The ISO accepts NOAA and FEMA requirements for lidar data for such meteorological hazards without considering such data to be mission-critical at this time for the ISO or its insurance company clients.
- *Hydrological Hazards*: lidar data are already widely used by FEMA for determining risks from floods and by the USGS for determining risks from landslides often caused by saturated soils. The ISO accepts FEMA and USGS requirements for lidar data for such hydrological hazards without considering such data to be mission-critical for ISO or its insurance company clients.
- *Climatological Hazards*: lidar data are used by the National Interagency Fire Center (NIFC) and other Federal and State agencies for wildfire modeling. The ISO accepts NIFC requirements for lidar data for determining such climatological hazards without considering such data to be mission-critical at this time for the ISO or its insurance company clients.

Currently, only flood insurance premiums are assessed by FEMA actuaries as a function of elevation data for individual properties. Whereas lidar is a mature technology for assessment of flood risks, its value for assessment of other insurable risks is still evolving. The ISO may reconsider as improved computer models evolve.

J.R. Simplot Company

Point of Contact: Shawn Kasprick, (701) 352-0861

One of the largest privately held firms in the country, with annual sales of about $4.5 billion, J.R. Simplot Company's mission statement—*Bringing Earth's Resources to Life*—pertains to a large array of services that include agriculture, food products, land and livestock, turf, and horticulture. The company produces fertilizers and processes and packages food products. The company also provides assistance to small, medium, and large farms with production agriculture, including precision agriculture.

J.R. Simplot Company identified the following major functional activity with mission-critical requirements for enhanced elevation data.

- Precision Agriculture, under BU#8, Agriculture and Precision Farming.

Precision Agriculture

Mission-Critical Requirements:

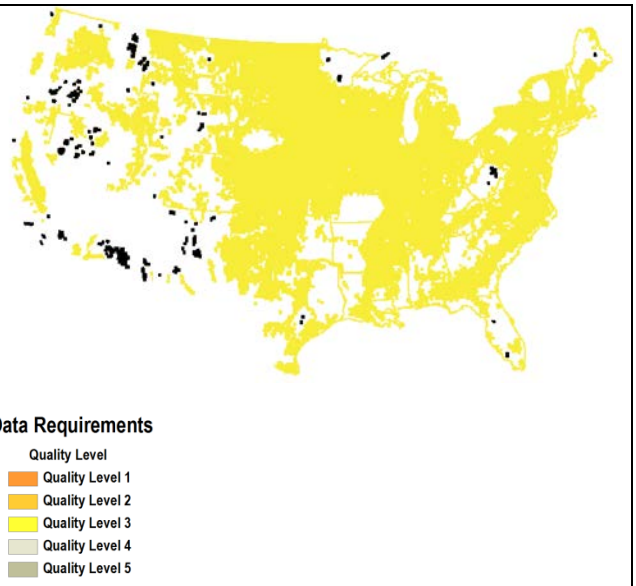
QL3 lidar is required for all agricultural land areas of the Nation for topographic analysis of slope, aspect, curvature, and soil wetness (surface and subsurface) and resultant site-specific application of seed, fertilizer, lime, pesticides, and water to optimize farm yields.

Update Frequency: 6–10 years

Business Use: Agriculture and Precision Farming, BU#8

Estimated Program Budget: Not available. In 2010, an estimated 262.3 million acres of farm lands was harvested in the United States at total product values of $356.2 billion.

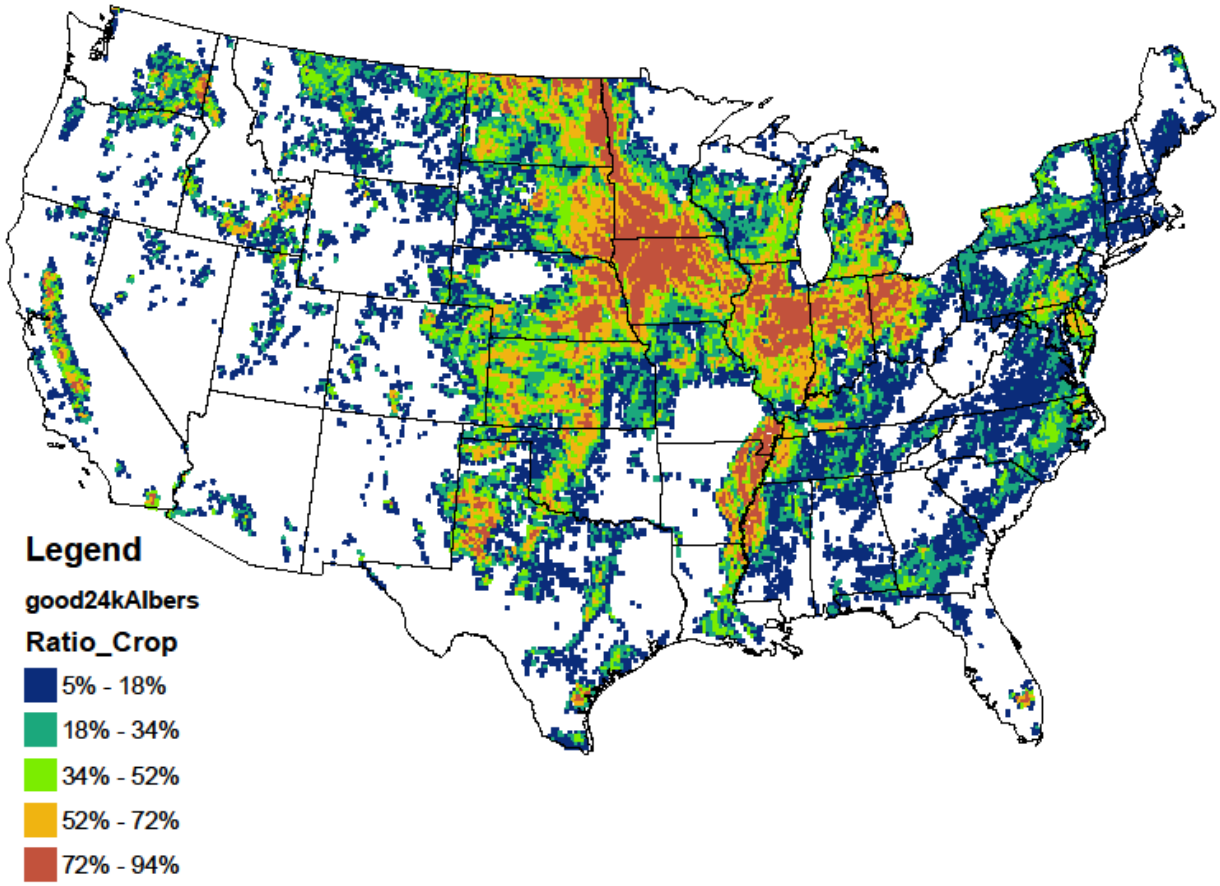
Quantifiable Benefits of Enhanced Elevation Data: With estimated savings of $50 million year in the Red River Valley (parts of North Dakota and Minnesota) for corn and wheat alone, the value to America's farmers of public domain lidar for all crops nationwide is believed to be as much as $2 billion per year[3] plus nearly $1.5 billion (one-time savings) with an assumed value for lidar of $5 per acre for not having to hire surveyors to solve common drainage problems.



The yellow areas represent requirements for QL3 Lidar

Simplot relies on lidar, where available (fig. 3–6), for precision agriculture applications—enabling small, medium, and large farms to benefit from improved knowledge of the terrain for site-specific application of seed, fertilizer, lime, pesticides, and water—resulting in increased farm yields. This includes knowledge of soil type, soil wetness, drainage, and topographic variations within farm fields (slope, aspect, and curvature) that can affect crop yield. Without site-specific methods, the uniform treatment of wheat, corn, soybean, and cotton fields, for example, is wasteful and uses an excess of costly resources in the form of fertilizers, pesticides, and herbicides with potentially excessive farm runoff. In wetter areas, lidar is largely used to identify areas that need surface ditching, tile drainage, or grass waterways to reduce saturated soils and crop damage. In dryer areas, lidar is used to design farm terraces to retain moisture and reduce runoff.

[3]For the benefit-to-cost analysis, because of uncertainty in the rate at which lidar will be used for precision agriculture and drainage, $116.7 million per year was used as the conservative benefit and $2 billion per year was used as the potential benefit. This was computed as the cost of lidar QL3 data ($252.67 per square mile) multiplied by 461,875 square miles of agricultural lands.



Map showing five broad bands of crop land density as a percent of total land area on U.S. Geological Survey (USGS) 7.5-minute quad maps. Quality level (QL) 3 light detection and ranging (lidar) is required of all agricultural lands, but the value of lidar varies as a function of crop land density compared with the entire area of each quadrangle map. Although this map shows crop percentages in large bands, actual benefits of lidar are computed per quadrangle map area as a percentage of crop lands for each map area.

Lidar derivative products are very important for precision agriculture because (1) slope data are used to minimize soil erosion; (2) aspect data are used to identify areas of solar heating where soils are more wet or dry; and (3) landscape position (curvature) data are used to identify areas of high or low soil moisture content.

Not accounting for topographic variations, soil wetness, nutrient availability, and other variables can result in needless costs for chemical treatments and major losses of productivity.

Referencing a Red River Valley drainage study (Edwardson and others, 1988), Simplot provided updated data for 2010 (table 3–1) that assess the effect of crop losses due to potentially avoidable drainage issues. The USDA National Agricultural Statistics Service (NASS) provides statistics on acres planted, by crop, along the Red River Basin in North Dakota and Minnesota (National Agricultural Statistics Service (2008). The numbers in the right column identify the value of these two crops alone that could potentially be saved with improved grading and modern treatment of drainage issues identified by lidar. Obviously, there are many other crops planted annually in the U.S. that also experience drainage issues that adversely affect farm yields.

Table 3–1. Estimated corn and wheat crop loss effect from farm drainage issues in Red River Valley

[Data are from Edwardson and others (1988) except for potential value of lost yields, which are from the National Agricultural Statistics Service (2008)]

Crop	Input costs, dollars per acre	Lost yield, bushels per acre	Lost value, dollars per acre	Acres planted in 2007	Potential value of lost yields, bushels
Corn	275–375	24.5	91.87	3,821,000	351,035,027
Wheat	150–250	11	52.25	4,129,800	215,782,050

Farm drainage issues cost American farmers hundreds of millions of dollars annually in crop production losses. Although lidar alone would not prevent such losses, Simplot has demonstrated that lidar data and precision agriculture dramatically reduce drown-outs and oversaturated soils while addressing the other benefits of precision agriculture. If nationwide lidar could solve just 10 percent of the farm drainage problems for these acres of corn and wheat in the Red River Valley alone, the value to American farmers would potentially be more than $50 million per year. Major cost reductions for chemical treatments and similar savings for other crops nationwide outside the Red River Valley could easily multiply these benefits to $2 billion per year. Furthermore, if lidar data were readily available nationwide, agricultural equipment manufacturers would likely develop lidar-specific applications similarly to variable-rate fertilizing, spraying, and other techniques. Because lidar data are currently available only for a small percentage of total farmlands in the United States, the full benefits of lidar for precision agriculture cannot be fully realized.

References Cited

Edwardson, Steven, Watt, David, and Disrud, Lowell, 1988, Laser-controlled land grading for farmland drainage in the Red River Valley—An economic evaluation: Journal of Soil and Water Conservation, v. 43, no. 6, p. 486-490.

National Agricultural Statistics Service, 2008, Agricultural statistics 2008: National Agricultural Statistics Service, [variously paginated].

Mendocino Redwood Company, LLC and Humboldt Redwood Company, LLC

Mendocino Redwood Company Point of Contact: Tom Bendure, (707) 463-5117
Humboldt Redwood Company Point of Contact: Eric Johnson, (707) 764-4198

Mendocino Redwood Company (MRC) and Humboldt Redwood Company (HRD) collectively own approximately 440,000 acres of redwood and douglas fir forestlands along the northern coast of California. From the beginning, the stated purpose of MRC and HRC has been to demonstrate that it is possible to manage productive forestlands with a high standard of environmental stewardship and also operate a successful business. The company names were chosen to reflect the nature of the business and to pay homage to the important role of the local community associated with a timber business.

MRC and HRC identified the following major functional activity with mission-critical requirements for lidar data.

- Sustainable Forestlands, under BU#5, Forest Resources Management

Sustainable Forestlands

Mission-Critical Requirements:

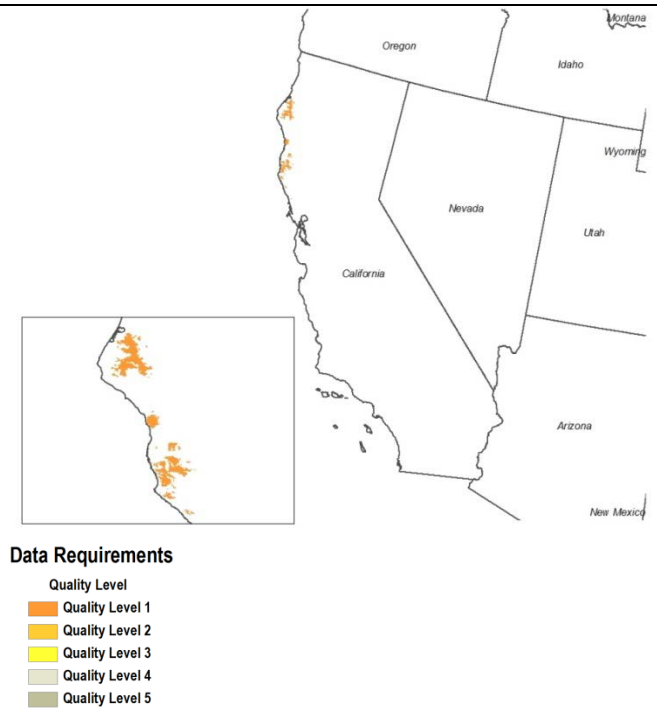
QL1 lidar is required of MRC and HRC land holdings for redwood and douglas fir timber inventory and assessment and harvest planning for sustainable forestlands.

Update Frequency: 6–10 years

Business Use: Forest Resources Management, BU#5

Estimated Program Budget: Unknown

Quantifiable Benefits of Enhanced Elevation Data: $139,454 per year ($71,967 for MRC; $67,487 for HRC)



Timber cruise evaluations enable timber companies to estimate the value of their standing timber. They are important when planning for a timber harvest or sale. Estimating future volumes or growth projections is an important part of evaluating timberlands and deciding whether to cut a stand of trees now or to let it continue to grow. MRC and HRC are very selective in identifying trees for harvesting so as to ensure sustainable forestlands and limit landslides that can occur when trees are harvested, weakening the root structure that limits soil erosion and landslides.

Operational benefits to MRC and HRC of lidar data for this functional activity:

Time and cost savings: Major	Mission Compliance: Moderate	$ Benefits: $139,454 per year

- Major time and cost savings for timber inventories, cruise reporting, mapping of ground elevations, and measurements of crown heights.
- Enables the development of annual growth models and identification of individual trees for harvesting.
- Maps the landscape and ground surfaces to determine where harvesting can occur without contributing to landslides.

Customer service benefits from improved MRC and HRC products and services:

Performance: Minor	Timeliness: Minor	Experience: Minor	$ Benefits: None

- Lidar data would enable MRC and HRC to do a better job of planning for sustainable harvesting and providing better planning data to contractors who perform the harvesting.

Other benefits from MRC and HRC use of lidar data for this functional activity:

Public and Social: Minor	Environmental: Minor	Strategic and Political: Minor

- Lidar data would help MRC and HRC to execute sustainable forest management, reduce environmental concerns, and foster public support for their environmental stewardship.

The Nature Conservancy

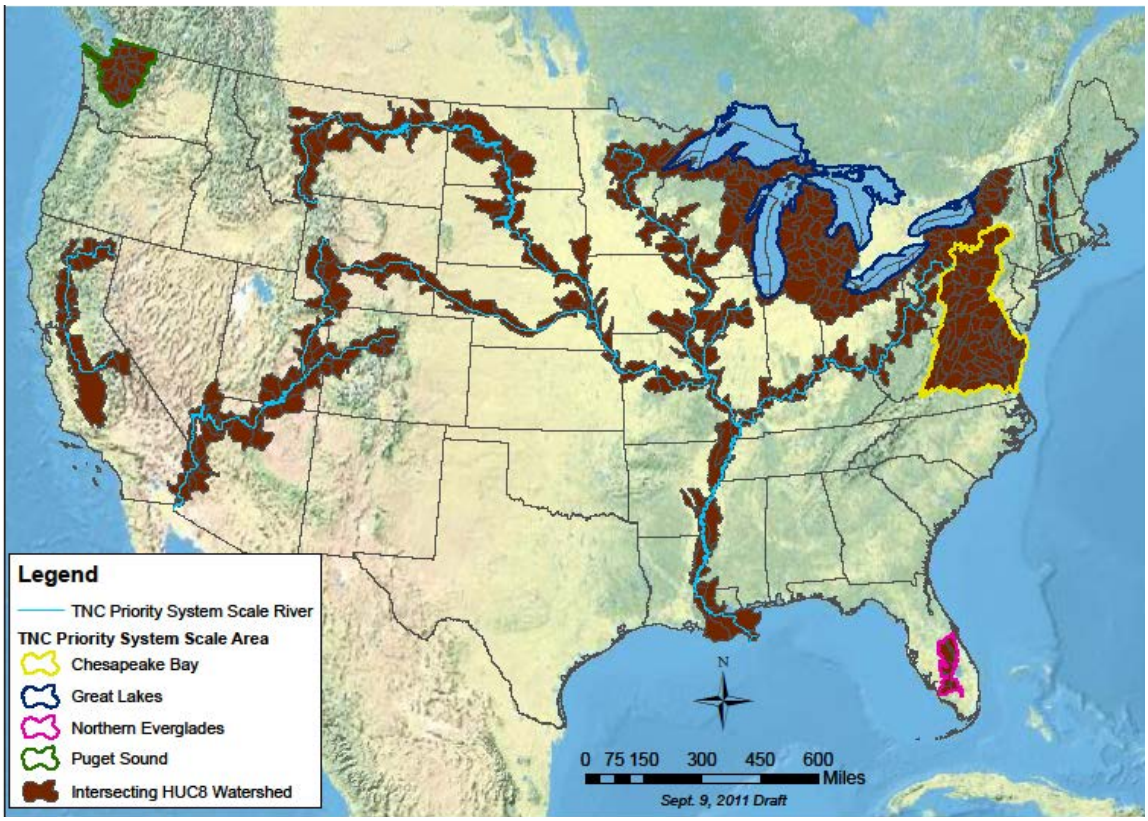
Point of Contact: Joe Fargione, (612) 331–0745

The mission of The Nature Conservancy (TNC) is to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.

TNC's POC identified the following major functional activities with mission-critical requirements for enhanced elevation data.

- Healthy Watersheds, under BU#1, Natural Resources Conservation, and BU#14, Flood Risk Management
- Coastal Stewardship and Resiliency, under BU#4, Coastal Zone Management, and BU#15, Sea Level Rise and Subsidence
- Forest Species Distribution Modeling, under BU#5, Forest Resources Management

Figure 3–7 shows TNC's priority freshwater systems and intersecting hydrologic unit code (HUC) 8 watersheds.



Map showing The Nature Conservancy's priority fresh water systems (colored outlines) and the intersecting (HUC) 8 watersheds (brown shading).

Healthy Watersheds

Mission-Critical Requirements:

QL2 lidar is required of buffer areas around selected streams and ecosystems for restoration of natural and beneficial functions of floodplains and restoration of wetlands.

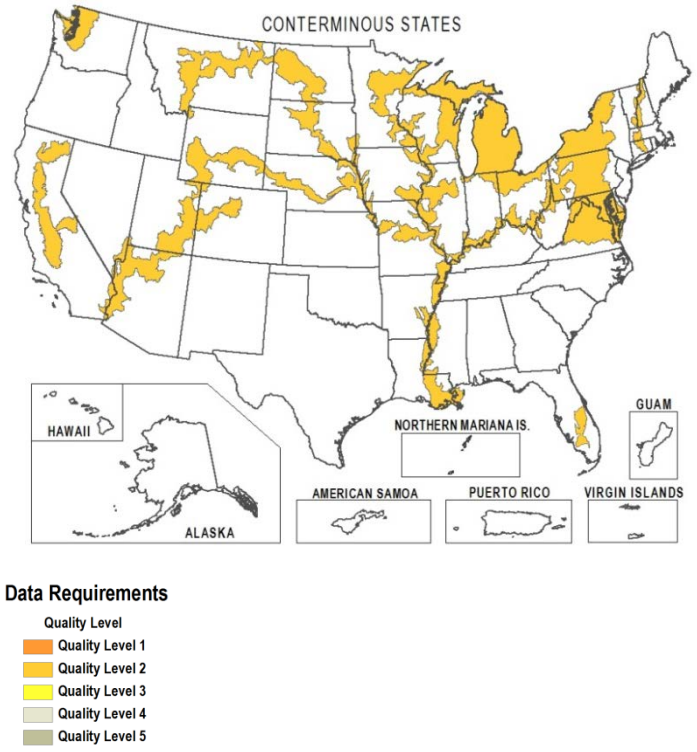
Update Frequency: 6–10 years

Business Use: Natural Resources Conservation, BU#1, and Flood Risk Management, BU#14

Estimated Program Budget: Not available

Quantifiable Benefits of Enhanced Elevation Data: Enable TNC to evaluate levee setbacks or removal to restore natural and beneficial functions of floodplains, reduce overall flood damages, restore biodiversity, allow soil enrichment in the Mississippi Delta and other riparian areas, restore lost land areas, recharge groundwater, and reduce salt water intrusion. Enable TNC to evaluate alternatives for restoring wetlands that filter out agricultural nutrients and animal waste that pollute our streams and key ecosystems like the Chesapeake Bay and the Gulf of Mexico.

Estimated Cost Benefits: $10.07 million per year



Amid significant alterations of our major waterways to optimize commercial benefits and in the name of flood control, TNC and the Association of State Floodplain Managers (ASFPM) realize that flood losses have continued to rise each year. At the same time, environmental degradation, particularly of water-related resources, has increased, and anticipated changes in climate bring the potential for significant alteration of fragile ecosystems. Consistent with the National Environmental Policy Act (NEPA), which laid a foundation for protecting the environment amidst human development, TNC and the ASFPM aim to improve the natural and beneficial functions of floodplains while mitigating damages and losses due to floods.

Flooding is a natural process that forms and maintains floodplains. Periodic flows of water that overtop the banks of a river are the lifeblood of riparian corridors. Periodic floods increase soil fertility, support riparian vegetation, create essential habitat for waterfowl and fish and other aquatic species, recharge groundwater, and create wetlands that filter impurities. Levees are designed to exclude floodwaters from floodplains, and often have unintended consequences for the loss of ecological functions, potential damages to downstream property owners, and the externalized costs of levee maintenance. Furthermore, floodplains have been viewed as suitable sites for human development where levees are expected to keep water out of natural floodplains and away from people. When levees fail, damages are often worse than if they had never been built.

It has long been known that farm chemicals and animal wastes are polluting our ecosystems. TNC is interested in promoting an environmental strategy to restore riparian buffer areas from farm lands subject to runoff from farm chemicals and animal waste, so that these buffer areas could be used for restoration of wetlands that would filter out nutrients and wastes that pollute our ecosystems.

TNC requires lidar to perform watershed analyses, to quantify flood water storage potential, to identify active river areas and prioritize them for restoration and conservation planning, and to take practical steps to restore the natural and beneficial functions of floodplains and restore wetlands. TNC seeks to use lidar to identify lands on which restoration of habitat and hydrological function would have the greatest benefit for people and nature. By removing nutrients and sediment from rivers, water supply and quality are improved (BU#2) as are river and stream resource management (BU#3).

At expected costs of 80 cents per acre for lidar, TNC estimated that it would save more than $302 million in not having to acquire lidar for this large project area. This total benefit would help TNC avoid a 30-year campaign to

obtain funding to pay for lidar acquisition (Association of State Floodplain Managers, 2008) would mean savings of $30.07 million per year. Even though TNC would have difficulty acquiring funds to pay for lidar data every 30 years, a 6- to 10-year update frequency is still needed, so an approach where agencies work together to acquire the data to satisfy common needs would be another benefit of a systematic program.

Note: For more information on issues raised by TNC's first two functional activities, readers are encouraged to read a position paper prepared by the Association of State Floodplain Managers (ASFPM); 2008.

Reference Cited

Association of State Floodplain Managers, 2008, Natural and beneficial floodplain functions—Floodplain management—More than flood loss reduction: Madison, Wisconsin, Association of State Floodplain Managers, 8 p., accessed May 2, 2012, at http://www.floods.org/PDF/WhitePaper/ASFPM_NBF%20White_Paper_%200908.pdf.

Coastal Stewardship and Resiliency

Mission-Critical Requirements:

QL2 lidar is required of coastal counties, including the Great Lakes (out to the 30-ft-contour line), for restoration of natural and beneficial functions of coastal wetlands, to mitigate the effects of sea level rise and subsidence, to mitigate the effects of human development that adversely affect our coastal zones, and to promote coastal resiliency.

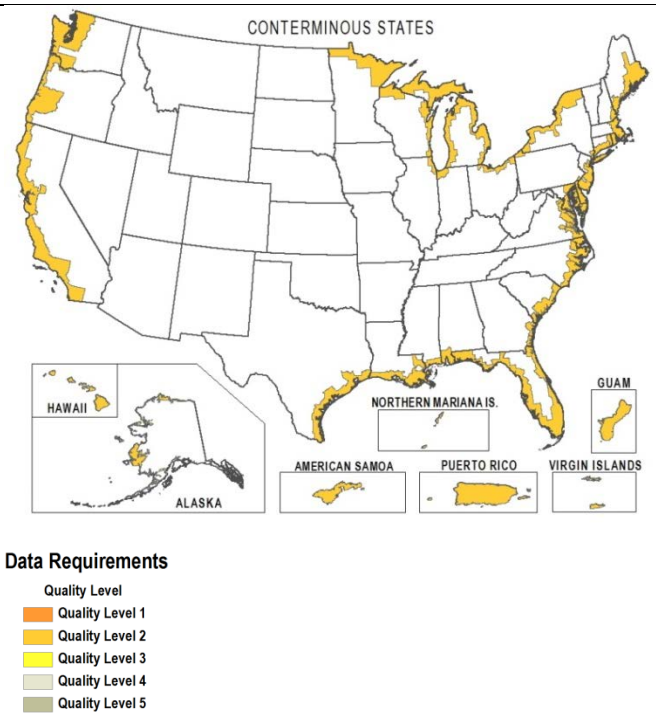
Update Frequency: 4–5 years

Business Use: Coastal Zone Management, BU#4 and Sea Level Rise and Subsidence, BU#15

Estimated Program Budget: Not available

Quantifiable Benefits of Enhanced Elevation Data: Periodic updates of lidar data will enable TNC to evaluate the changes in coastal wetlands, coastal erosion, loss of land due to sea level rise and subsidence, and develop plans for mitigating the effects of sea level rise, subsidence, and human development.

Estimated Cost Benefits: $5.83 million per year



America is losing coastal wetlands at the rate of 25 to 35 square miles per year, wetlands that are needed to buffer and protect the land from hurricanes and storm surge. Sea level rise and subsidence of several feet this century will affect millions of Americans in coastal lowlands whose livelihood will be threatened without mitigation. Levees, dams, and reservoirs cut off the supply of sediment to coastal wetlands, which then experience subsidence and intrusion of saltwater. The construction of navigation channels and canals in coastal areas also contribute to saltwater intrusion. These are all coastal issues for which TNC requires lidar data to analyze the problems, track changes, and develop potential solutions that promote coastal resiliency.

At expected costs of 80 cents per acre for lidar, TNC estimated that it would save $175 million in not having to acquire lidar for this large project area. This total benefit would help TNC avoid a 30-year campaign to obtain funding to pay for lidar acquisition would mean savings of $5.83 million per year. Even though TNC would have difficulty acquiring funds to pay for lidar data every 30 years, a 4- to 5-year update frequency is still needed, so an approach where agencies work together to acquire the data to satisfy common needs would be another benefit of a systematic program.

Forest Species Distribution Modeling

Mission-Critical Requirements:

QL3 lidar is required of forested areas of the United States for modeling of forest species and their distribution. Forest species distribution modeling is used for a wide variety of forest conservation applications.

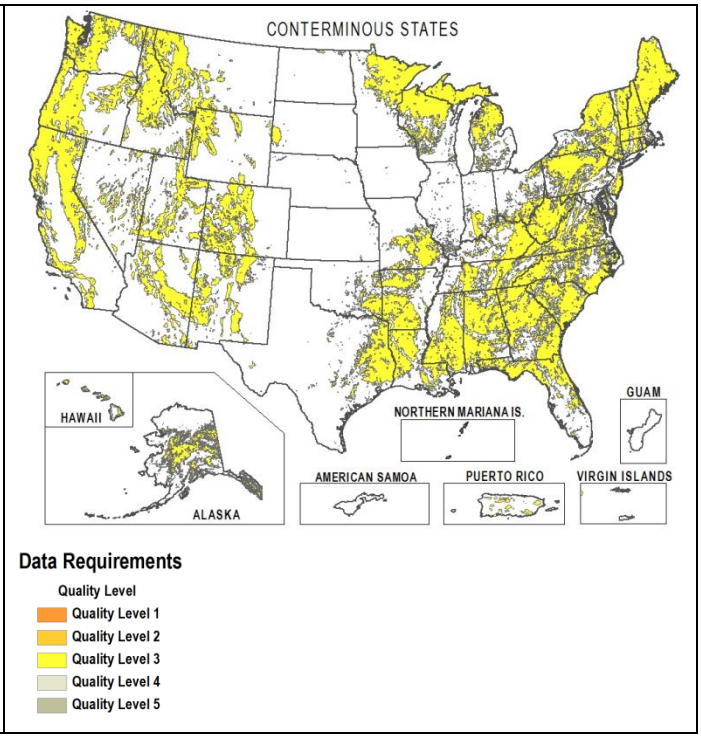
Update Frequency: 4–5 years

Business Use: Forest Resources Management, BU#5

Estimated Program Budget: Not available

Quantifiable Benefits of Enhanced Elevation Data: Periodic updates of lidar data will enable TNC to evaluate the changes in forest species and their distribution. Lidar enables the modeling of species for diseases such as the ongoing pine beetle outbreak; lidar enables the mapping of canopy height, understory, and biomass; estimates of standing carbon; and wildfire management and modeling.

Estimated Cost Benefits: $19.66 million per year



Lidar data enable TNC to analyze land use and land cover and perform predictive modeling; to compare current and historic canopy heights; to estimate standing carbon for different species; and to perform diverse forest inventories and analyses. Numerous studies have shown that the distribution of tree species is strongly affected by small changes in topography and associated microclimates; thus, lidar data are essential for accurate predictions of species distributions. Such species distribution models have a wide range of uses, such as identifying high-quality wildlife habitat and predicting responses to pest outbreaks, drought, and climate change. Lidar is also vital for wildfire modeling where terrain slope, fuel loading, and wind speed and direction are key parameters in predicting the spread of wildfires and development of fire-fighting strategies, especially vital in wildland and urban interface areas.

At expected costs of 80 cents per acre for lidar, TNC estimated that it would save $590 million in not having to acquire its own lidar for this large project area. This total benefit would help TNC avoid a 30-year campaign to obtain funding to pay for lidar acquisition would mean savings of $19.66 million per year. Even though TNC would have difficulty acquiring funds to pay for lidar data every 30 years, a 4- to 5-year update frequency is still needed, so an approach where agencies work together to acquire the data to satisfy common needs would be another benefit of a systematic program.

NextEra Energy Resources

Point of Contact: Michael Rose, (561) 304–5191

NextEra Energy Resources is the largest generator of renewable energy from the wind and sun in North America, operating 85 wind facilities in 17 States and Canada and producing more than 8.298 megawatts of electricity, or enough power for more than 2 million average homes. The company co-owns and operates the largest solar field in the world in California's Mojave Desert.

NextEra identified the following major functional activity with mission-critical requirements for enhanced elevation data.

- Wind Farm Siting and Design, under BU#11, Renewable Energy Resources

Wind Farm Siting and Design

Mission-Critical Requirements:

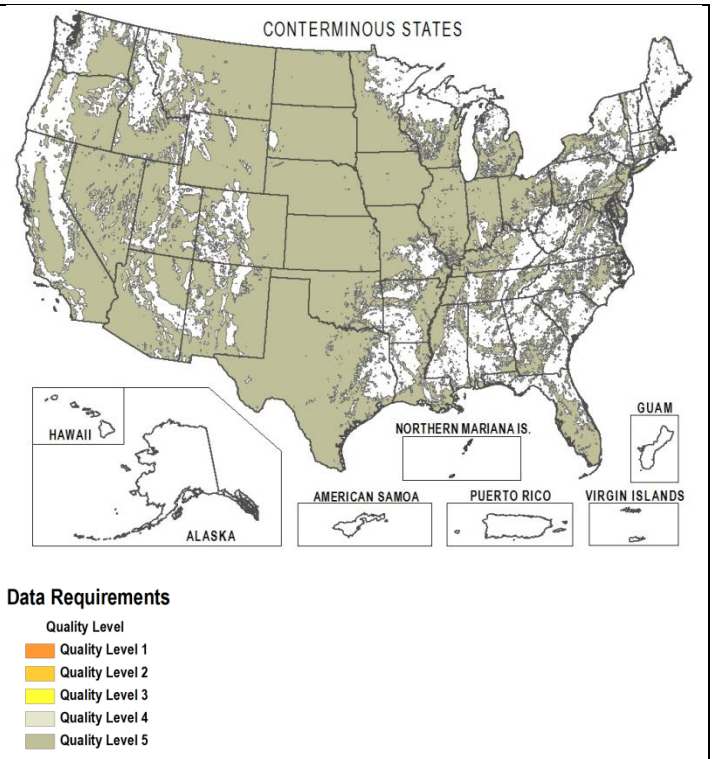
QL5 IFSAR is required (DTMs and DSMs) for nonforested areas of 48 States for siting and design of wind farms for which topography, slope, and surface roughness are important in computation flow dynamics (CFD) models and maximization of wind farm efficiency.

Update Frequency: 2 years, although NextEra could potentially study different areas of the country based on an established data acquisition cycle, knowing when new IFSAR data would become available.

Business Use: Renewable Energy Resources, BU#11

Estimated Program Budget: Unknown

Quantifiable Benefits of Enhanced Elevation Data: IFSAR data will enable NextEra to site and design wind farms for maximum efficiency. Wind farms planned for the coming decade could save up to $100 million per year[4] if IFSAR succeeds in achieving a 1 percent improvement in efficiency.



NextEra currently uses COTS GIS software and 10-m DEMs from the NED and ESRI raster data for wind farm site selection and wind farm designs, but NED data are deficient in terms of accuracy, resolution, and currency, and because NED DEMs map the bare-earth terrain rather than the top reflective surfaces (including trees and buildings) that effect wind speeds. NextEra needs higher accuracy and higher resolution DSMs to model wind regimes. Accurate estimations of wind speeds are of obvious importance in reducing the uncertainty in the predicted energy production of a potential wind energy project. To understand wind regimes, time series wind data are collected from local airports and NOAA, and wind flow models are built to produce a wind resource grid that takes topography, slope and surface roughness into account. Computation Flow Dynamics (CFD) models must be acceptable to gain site approvals.

[4]For the benefit-to-cost analysis, because of uncertainty in NextEra's ability to meet its goal of 1percent of improved efficiency from IFSAR, $10 million per year was used as the conservative benefit and $100 million per year was used as the potential benefit.

NextEra evaluates about 500 potential wind farm sites per year, with 8 to 32 potential layouts per site. Most sites are rejected, resulting in actual construction of about 20 wind farms per year by NextEra. A typical wind farm has about 100 turbines, each turbine requiring about 40 acres of land free of trees, buildings, and silos. Surface roughness data from DSMs must be current within the past 2 years to ensure that buildings have not been built or trees grown that would interfere with wind farm efficiency.

Many renewable energy projects funded and built in the last 20 years underperform projected estimates by as much as 10 percent. A 1 percent change in a renewable energy project's net capacity factor can mean $500,000 in annual net income for a typical 100 megawatt (MW) wind farm (or solar farm) project. Thus, if accurate, high-resolution elevation data used for wind farm site selection enable a 1 percent improvement in energy production performance per site, this could be worth $10 million per year for 20 new wind farms constructed annually, and the dollar benefits would continue to accrue in subsequent years of operation. At the rate of 20 new 100-MW wind farms constructed annually for a decade, the cumulative benefits over 10 years would be $550 million. After this first decade, those 200 100-MW wind farms would continue to save about $100 million per year, but only if enhanced elevation data succeeded in achieving a 1 percent improvement in wind farm performance. Although the true effect of elevation data is unknown, it is a fact that accurate and current high-resolution elevation data are critical in wind farm site selection and layout in hilly and mountainous terrain, but not on flat farmlands and prairielands where subtleties in topography are not an issue.

NextEra has evaluated IFSAR data from Intermap and found them superior to the NED in many respects, seeing key features in IFSAR data not seen in NED data. NextEra has also evaluated lidar data and found the point cloud data beneficial, but more data than necessary, requiring thinning and smoothing. IFSAR data with 5-m point spacing is ideal for preliminary site selecting, cut and fill estimating, and construction planning; but field surveys are still needed for taking ground photos of the terrain, evaluation of soil and ground conditions, verification of receptors, micrositing, and final engineering and construction.

Plum Creek Timber Company

Point of Contact: Alex Hinson, (706) 583-6747

Plum Creek is the largest and most geographically diverse private landowner in the Nation, with approximately 6.8 million acres of timberlands in 19 States. Plum Creek manages its forests for a sustainable harvest, today and into the future. Plum Creek also serves as a steward of natural resources (natural gas, oil, minerals, aggregates, and stone) that reside beneath the surface. Plum Creek follows sustainable forestry and environmental and conservation best practices that protect water quality and wildlife habitat and provide recreational opportunities.

Plum Creek identified the following major functional activity with mission-critical requirements for lidar data.

- Sustainable Timberlands, under BU#5, Forest Resources Management

Plum Creek has a policy that it does not share its shapefiles of land holdings and thereby could not provide specifics as to where the benefits apply. In asking for QL1 lidar with annual updates, Plum Creek asked that $1 million per year be applied to its total 6,771,000 acres of timber, but that the benefits be divided with one-fourth of its benefits ($250,000 per year) to each of its four geographic areas. Because exact areas within each State could not be valued, these benefits were spread out over the entire forested areas of the 19 States involved, yielding the averaged benefits for the entire forested areas of these States as follows:

- Southern States: For Plum Creek's 3,565,000 acres in Alabama, Arizona, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Texas, and West Virginia, $250,000 per year benefits were averaged to 0.15 cents per acre per year for the entire 167,561,957 acres of forested areas in those 11 States.
- Northwestern States: For Plum Creek's 1,422,000 acres in Montana, Oregon, and Washington, $250,000 per year benefits were averaged to 1.23 cents per acre per year for the entire 20,283,151 acres of forested areas in those three States.
- Great Lakes States: For Plum Creek's 785,000 acres in Michigan and Wisconsin, $250,000 per year benefits were averaged to 0.80 cents per acre per year for the entire 31,329,816 acres of forested areas in those two States.
- Northeastern States: For Plum Creek's 999,000 acres in Maine, New Hampshire, and Vermont, $250,000 per year benefits were averaged to 0.91 cents per acre per year for the entire 27,596,501 acres of forested areas in those three States.

Sustainable Timberlands

Mission-Critical Requirements:

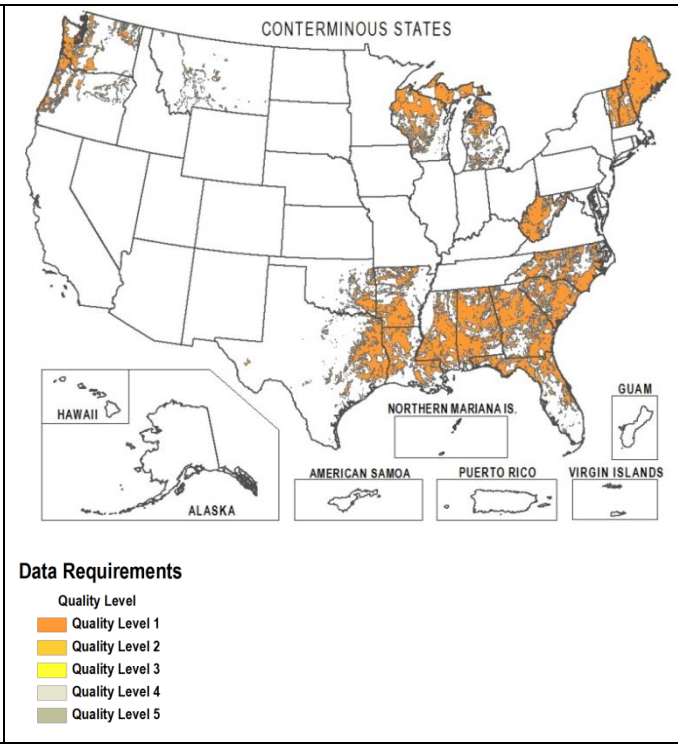
QL1 lidar is initially required of Plum Creek land holdings for forest inventory and assessment and planning for sustainable timberlands; thereafter, QL2 lidar is required annually to update canopy crowns.

Update Frequency: Annually

Business Use: Forest Resources Management, BU#5

Estimated Program Budget: Unknown

Quantifiable Benefits of Enhanced Elevation Data: Annual updates of lidar data will enable Plum Creek and other timber companies elsewhere to evaluate tree stand information, calculate forest metrics, assess forest health, plan for sustainable tree harvesting and regrowth, and perform wildfire modeling. Plum Creek estimates total benefits of $1million per year; lidar is actually worth $3 per acre for the much smaller number of specific acres (about 333,300) targeted each year for potential harvest.

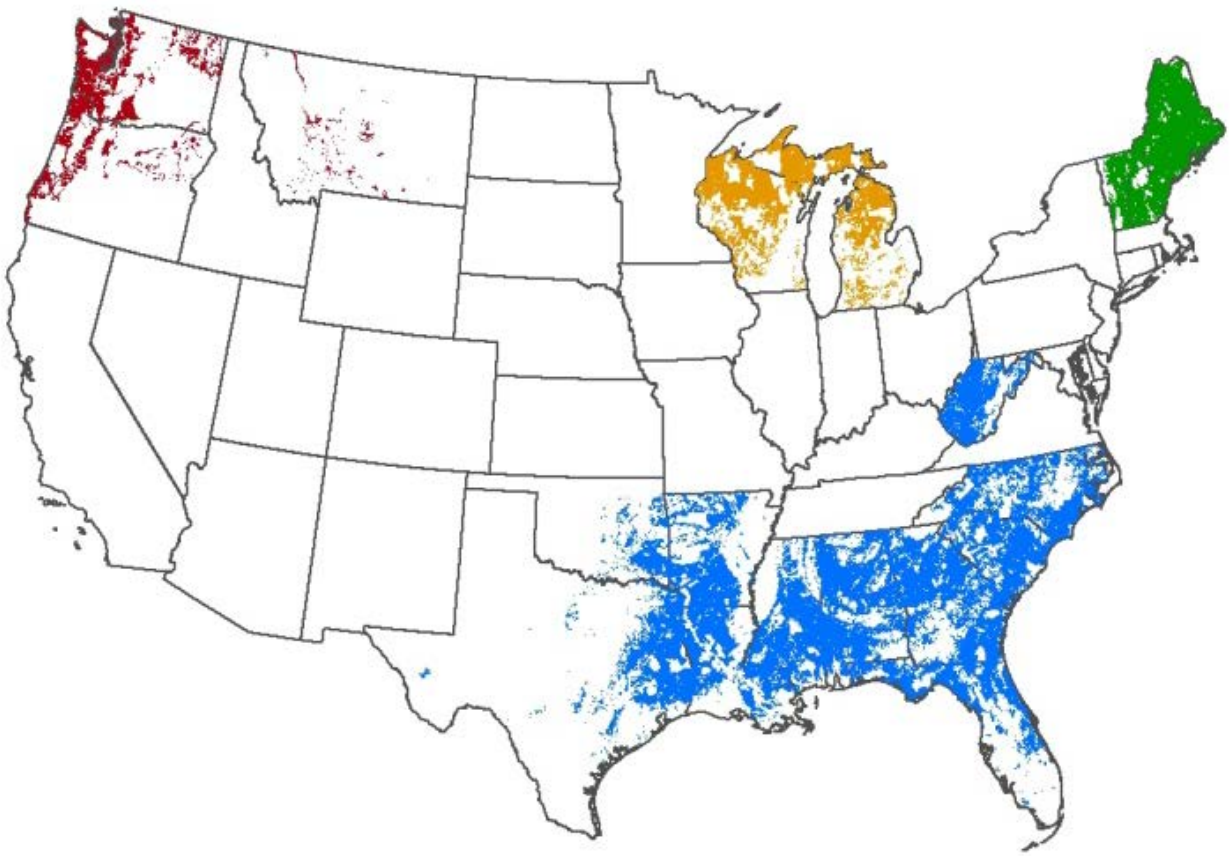


Plum Creek's current interests relate to the 6.771 million acres of timberlands in the 19 States listed in the previous part of this section. There are many other firms in the timber industry, with interests outside of geographic areas owned by Plum Creek, that require lidar for use by foresters, silviculturists, biometricians, and other specialists in the timber industry.

Operational benefits to Plum Creek of lidar data for this functional activity:

Time and cost savings: Major	Mission Compliance: Moderate	$ Benefits: $1 million per year

- Major time and cost savings would be realized by having much more efficient methods for forest inventories and for measurements of ground elevations, tree canopy heights, and tree dimensions.
  - The eleven southern States receive $250,000 per year benefits for the Plum Creek areas included within the broader forested areas shown in blue in figure 3–8.
  - The three northwestern States receive $250,000 per year benefits for the Plum Creek areas included within the broader forested areas shown in red in figure 3–8.
  - The two Great Lakes States receive $250,000 per year benefits for the Plum Creek areas included within the broader forested areas shown in yellow in figure 3–8.
  - The three northeastern States receive $250,000 per year benefits for the Plum Creek areas included within the broader forested areas shown in green in figure 3–8.



Map showing the regional benefits anticipated by Plum Creek Timber Company from acquisition of light detection and ranging (lidar) elevation.

Customer service benefits from improved Plum Creek products and services:

Performance: Minor	**Timeliness: Minor**	**Experience: Minor**	**$ Benefits: Unknown**

- Lidar data would enable Plum Creek to do a better job of planning for sustainable harvesting and providing better planning data to contractors who perform the harvesting.
- By being unable to share its shapefiles for Plum Creek areas, benefits per acre to its specific holdings are averaged; however, these averaged benefits are also applied to other forests within these 19 States where other timber track companies would also reap the benefits of lidar.

Other benefits from Plum Creek's use of lidar data for this functional activity:

Public and Social: None	**Environmental: None**	**Strategic and Political: None**

TomTom

Point of Contact: Maureen Williams, (603) 643-0330 ×13266

TomTom is the world's leading provider of in-car location and navigation products and services focused on providing all drivers with the world's best navigation experience. TomTom products include portable navigation devices, in-dash infotainment systems, fleet management solutions, maps, and real-time traffic solutions.

TomTom identified the following major functional activity with mission-critical requirements for enhanced elevation data:

- Location and Navigation Services, under BU#18, Land Navigation and Safety, and BU#26, Recreation

Location and Navigation Services

Mission-Critical Requirements:

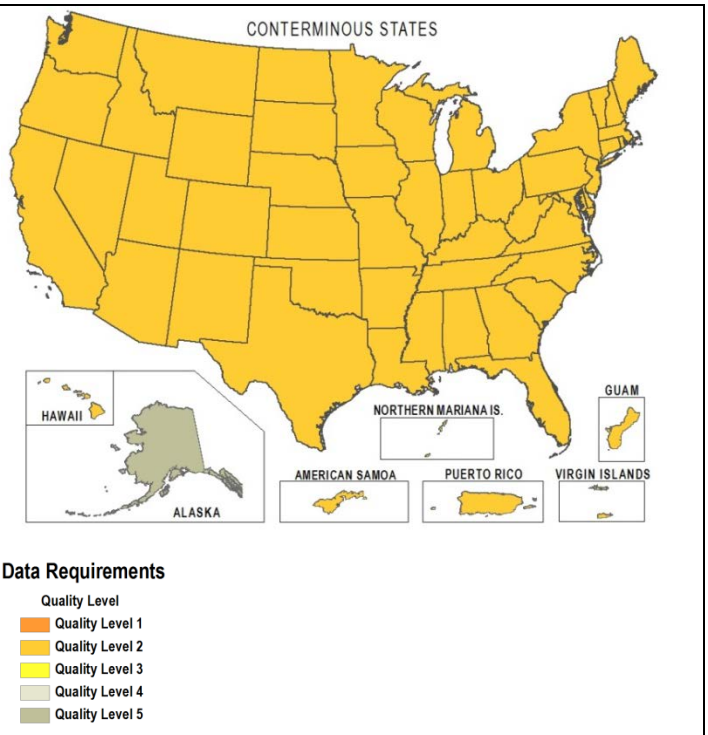
QL2 lidar nationwide (except QL5 IFSAR in Alaska) will enable cars and trucks, under development, to be safer and more fuel efficient; and enable new products and services for golfers, runners, bikers, rock climbers, skiers, and drivers of all-terrain vehicles and snowmobiles.

Update Frequency: 4–5 years

Business Use: Land Navigation and Safety, BU#18, and Recreation, BU#26

Estimated Program Budget: Not available

Quantifiable Benefits of Enhanced Elevation Data: Research programs and car manufacturers have estimated that road elevation and slope data, combined with transmission-control technology and in-vehicle location and navigation products, will enable fuel consumption to decrease by 4 to 12 percent, saving billions of dollars annually[5] for American drivers. Driver alertness tests, based on 3D road information, such as "steep curves ahead," could save many of the thousands of deaths caused annually by driver fatigue.



Fuel Efficiency

In anticipation of increased fuel efficiency standards, and based partly on research performed by engineers at the University of Berlin, car and truck manufacturers have determined that they can reduce fuel consumption between 4 and 12 percent by building vehicles that use elevation and slope data from lidar, combined with transmission-control technology and in-vehicle location and navigation products, to down-shift and up-shift transmissions in anticipation of gradients ahead. The trucking industry is apparently supportive of such advanced driver assistance technology. Americans currently drive approximately 3 trillion miles per year and consume 175 billion gallons of gasoline and diesel fuel per year; a 4 percent reduction in fuel consumption would save 7 billion gallons of fuel annually or $24.5

[5]For the benefit-to-cost analysis, because of uncertainty in the dates and rates of the automotive industry's introduction of intelligent transportation system (ITS) and advanced driver assistance system (ADAS) initiatives based on lidar for roadway geometry, $0 per year was used as the conservative benefit and $6.125 billion per year was used as the potential benefit based on 1 percent fuel savings of 1.75 billion gallons of gasoline and diesel fuel at $3.50 per gallon (see *http://www.fhwa.dot.gov/policyinformation/pubs/pl10023/fig5_2.cfm* for fuel consumption statistics). Even this 1 percent is a conservative estimate compared with the 4 to 12 percent savings estimated by TomTom.

billion for consumers at an average of $3.50 per gallon. Even if the reductions in fuel consumption are only 1 percent, the annual savings for American drivers would still be $6.125 billion per year.

Driver Safety

The National Highway Traffic Safety Administration conservatively estimates that 100,000 police-reported crashes are the direct result of driver fatigue each year. This results in an estimated 1,550 deaths, 71,000 injuries, and $12.5 billion in monetary losses. Even greater losses are attributable to drunk driving. TomTom is working with car and truck manufacturers to build vehicles that notify or warn drivers when there are steep curves or other dangerous conditions ahead. The same lidar datasets used to reduce fuel consumption would also be used to reduce accidents and deaths. With the fatigue testing feature, drivers would receive a message to push certain buttons when there is a dangerous road ahead; the amount of time taken to respond correctly would be an indicator of potential drowsiness so that warnings can be made that would alert drivers that respond poorly. Assuming this new technology succeeds in preventing a portion of such accidents, this could be an innovation worth hundreds of millions, if not billions, of dollars annually.

Sports and Recreation

TomTom is developing applications that combine GPS positioning with elevation data. Similar to a sports watch for runners, TomTom expects the introduction of lidar-based innovations to be incorporated in a variety of recreational tools so that users know the steepness of slopes, vertical feet of climb, and other relevant information.

WindLogics

Point of Contact: Stacy Fleenor, (651) 556-4204

WindLogics combines industry leading scientific analysis and deep expertise in planning, developing, and operating renewable energy projects. WindLogics is the lead wind and solar advisor to NextEra Energy Resources, which operates the largest solar field in the world in California's Mojave Desert.

WindLogics identified the following major functional activity with mission-critical requirements for enhanced elevation data:

- Solar Farm Siting and Design, under BU#11, Renewable Energy Resources

Solar Farm Siting and Design

Mission-Critical Requirements:

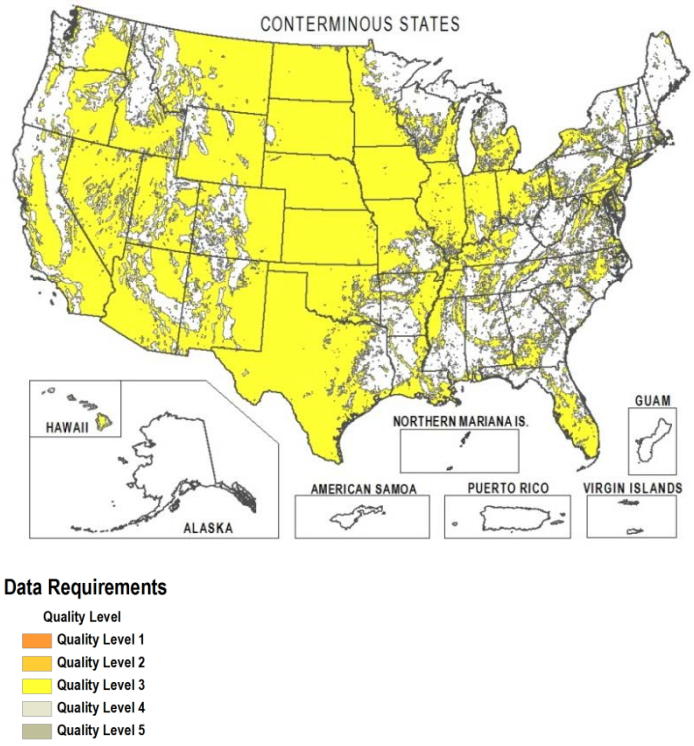
DSMs and DEM-derivative products from QL3 lidar are required for nonforested areas of 49 States for siting and design of solar farms for which topography, slope, and aspect as well as top surfaces of individual buildings and trees are important for identifying areas shaded from the sun.

Update Frequency: 2 years, though WindLogics could potentially study different areas of the country based on an established data acquisition cycle, knowing when new lidar data would become available.

Business Use: Renewable Energy Resources, BU#11

Estimated Program Budget: Unknown

Quantifiable Benefits of Enhanced Elevation Data: lidar data will enable WildLogics and NextEra to site and design solar farms for maximum efficiency. Estimated savings from the use of lidar for improved efficiency of solar farms cannot be estimated at this time.



WindLogics does not currently use lidar for planning of solar farms. However, it fully recognizes that lidar, where available, including derived slope and aspect data, would be ideal for identification of horizon profiles (shading profiles) vital for solar farm siting and design and maximization of solar farm efficiency.

Anonymous Oil and Gas Company

A small (when compared with global industry leaders) oil and gas company, which requested to remain anonymous, identified the following major functional activity with mission-critical requirements for enhanced elevation data:

- Oil and Gas Operations, under BU#12, Oil and Gas Resources

Oil and Gas Operations

Mission-Critical Requirements:

QL3 lidar plus QL5 IFSAR for Alaska and U.S. territories, is required for mapping, 3D visualizations, and geospatial analyses of slopes, hillshades, contours and viewsheds used for well site location suitability analyses, pipeline and road route selections, seismic program planning, hazard identification, and timber cut estimations.

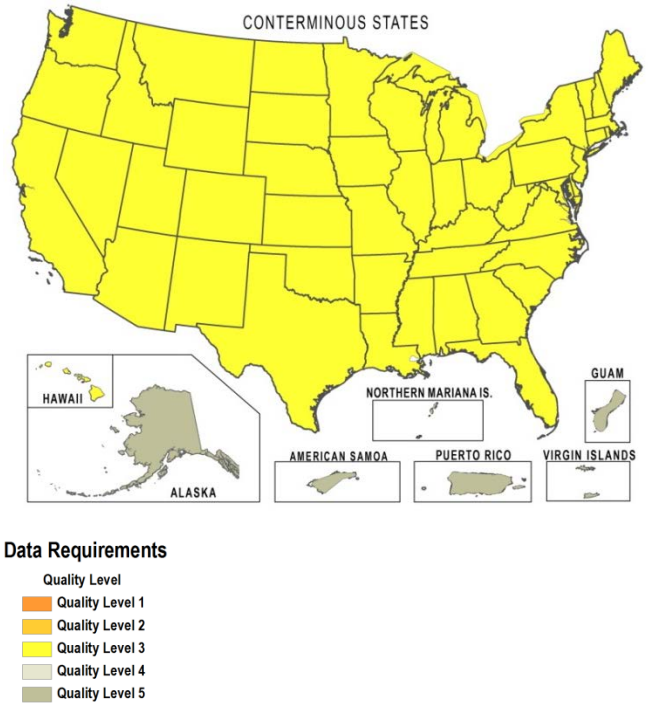
Update Frequency: 6–10 years.

Business Use: Oil and Gas Resources, BU#12

Estimated Program Budget: Not available

Quantifiable Benefits of Enhanced Elevation Data: Moves a significant amount of work from the field to the office. Allows a reduction in number of field staff required and the time required to gather data and perform analyses.

Potential savings for this relatively small company alone are estimated to be in the hundreds of thousands to millions of dollars annually, depending on number and size of projects the company undertakes. When considering other global industry corporations, benefits are easily $10 million per year.



Operational benefits of lidar data for this functional activity:

Time and cost savings: Major	$ Benefits: Not provided

- Higher accuracy data save significant amount of field visits and survey time; provide better results in shorter time and have a large effect on employee and contractor safety. Fewer requirements to visit the field, and when we do, we know exactly what to expect and where potential dangers exist.

Customer service benefits from improved products and services:

Performance: Potentially major	$ Benefits: Unknown

- Higher accuracy data provide higher confidence in analysis results and better mapping products and allow for more focused efforts by planning and engineering teams.

Other benefits from use of lidar data for this functional activity:

Public and Social: Moderate	Environmental: Moderate	Strategic and Political: Minor

- Public and social benefits: Less intrusion on members of the public; less trespassing on private lands; better selection of well, facility and pipeline locations to reduce effect on the public, including safety concerns.
- Environmental benefits: Reduced environmental "footprint" by conducting the work in the office rather than in the field.